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Investigating Educators' Perceptions of STEM Integration: A Semi-Structured Interview Approach

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by

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Abstract

Investigating Educators' Perceptions of STEM Integration:

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The study utilized a semi-structured interview approach to identify phenomena that are related to integrated STEM education by addressing the question, what are the critical components of an integrated STEM definition and what critical factors are necessary for an integrated STEM definition's implementation? Thirteen expert practitioners were identified and interviewed. The interviews were transcribed and analyzed for content in three different ways, by person, by interview question, and across all interviews using exploratory data analysis methods. Ten identified phenomena were grouped into two classes: structural implementation phenomena and interpersonal implementation phenomena. The structural implementation phenomena were: subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, and outside support (from businesses and industry). The interpersonal implementation phenomena include: leadership, collaboration, willingness, authentic/meaningful/relevant experiences for participants, and outside support (from people in business and industry). The analysis concluded that these phenomena could be considered both critical components and key implementation factors due to their interconnected nature. The data showed that the identified phenomena are necessary as part of an integrated STEM curriculum which makes them critical components, and that

the identified phenomena are necessary to create and implement an integrated STEM setting, making them implementation factors as well. Implications for further research include: the possibility of looking at the interconnectedness of the phenomena, examining how each phenomenon contributes to integrated STEM, and measuring current STEM implementations to see if they incorporate the identified phenomena. Additionally, inclusion of an absent phenomenon could be researched to see if integrated STEM education is improved.

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To the participants in this study, I know that you are not named, however, both you and I know who you are. Without you, this study would not have been possible. Thank you for giving me your time: time for interviews, time for clarifications, time for communication, and time to share your expertise. Time is one of the most precious things we have, and your gift was greatly appreciated.

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To all, my hope is that the results of the study will provide insights into integrated STEM education, which we can utilize to improve the process for our students. Once again, a very sincere thank you for all that you contributed to this journey.

Table of Contents

Tables

Figures

Chapter 1: Statement of the Problem

Introduction

Mathematics and science teachers at all levels of education have been issued a call for changes in science, technology, engineering, and mathematics (STEM) education by the Obama administration through the Educate to Innovate initiative. In the report from the President's Council of Advisors on Science and Technology Policy (*Prepare and Inspire: K-12*, 2010) four main priorities were identified: 1) ensuring a STEM-capable citizenry, 2) building a STEM-proficient workforce, 3) cultivating future STEM experts, and 4) closing the achievement and participation gap. In meeting this call, K - 12 schools are struggling with "what is STEM education?" Similarly, higher education struggles with preparing future practitioners on how to teach STEM education. Society needs and demands more STEM career minded people (Carnevale, Smith, & Strohl, 2010). STEM education is an important topic at all levels of education with virtually all involved parties being caught up in the movement. Many studies have suggested changes in the way schools teach science, technology, engineering, and mathematical concepts. To illustrate why the call for change in STEM education is happening and to explain why this study related to STEM education is important, this paper will present four main reasons for the suggestions to enhance STEM education.

Reasons for the call to change STEM education

Rapidly changing technology. First, it has been noted by Peter Diamandis and others that we are living in exponential times (Diamandis, 2010). By this statement, Diamandis implies that at no time in our past has information ever been generated at the pace of today. The video, *The Information Age – We Are Living in Exponential Times*, based on research concerning the progression of information technology states, “It is estimated that the amount of data created doubles every two years,” “Some of the most in-demand jobs did not exist five years ago,” and “What this means for education is that we are preparing students for jobs that don’t exist yet, using technologies that haven’t been invented to solve problems that we don’t even know are problems yet” (Fisch, McLeod, & Brenman, 2013). When looking at data from the U. S. Department of Labor, you can glean that upwards of 80% of jobs in the next decade will require a large degree of technical skills and most of the fastest growing occupations will require significant mathematical and/or science preparation (Fastest Growing Occupations, 2012). These occupations are in STEM fields.

If this continues to be reality, how can today’s schools better prepare students for these careers that do not yet exist? Will our current curriculum and methods work under this reality? Groups like the National Science Foundation (NSF) have been conducting research on alternate methods of teaching STEM content and looking at why some schools have better performance in STEM disciplines than others. Regardless of whether changes in how the STEM disciplines are currently taught occur or not, the fact remains that ultimately schools must produce students that can enter the workforce and face the challenges of rapidly changing information and technology.

Student performance in STEM curricular areas. Second, when comparing scores of students in the United States to students of other countries, the students from the United States lag behind many other nations in math and science. The Trends in International Mathematics and Science Study (TIMSS) 2011 ranks student performance in mathematics and science relative to other nations. The TIMSS 2011 International

Results in mathematics has students in the United States ranked 11th with an average scaled score of 541 in 4th grade math, and ranked 9th with an average scaled score of 544 in 8th grade math as compared to other nations (Mullis, Martin, Foy, & Arora, 2012). The TIMSS 2011 International Results in Science has students in the United States ranked 7th with an average scaled score of 544 in 4th grade science, and ranked 10th with an average scaled score of 525 in 8th grade science as compared to other nations (Martin, Mullis, Foy, & Stanco, 2012). With the rapidly changing pace of technology and information and performance level of U.S. students in math and science, change has been suggested for the American educational system. This has led to government oversight of education through laws like the No Child Left Behind Act (*NCLB Legislation*, 2010) and its constant call for greater school accountability with respect to student performance.

Changes in individual student motivation. A third cause for changes in STEM education is the difference in the way today's students are motivated. The millennial generation is different from any previous generation. Howe and Strauss (2007) have done research on the millennial generation and found that they are digital natives who value experiential and exploratory learning. Millennials tend to be impatient, are easily bored, and expect instant gratification. They believe that they can multitask often switching between homework, social media, and listening to music. Millennials tend to be team oriented and are comfortable working in groups (Howe & Strauss, 2007).

According to Daniel Pink, (2011) organizations need to focus on three things to improve motivation at work: autonomy, mastery, and purpose. Autonomy relates to when and how a task is performed, how a task is completed, and with whom a person works. Mastery allows people to become better at something that has relevance to them.

Pink states that you need to assign tasks that allow employees to extend themselves without being overly difficult while creating an environment where mastery is possible. By purpose, Pink means that work needs to fulfill a person's natural desire to contribute to a cause greater and more enduring than themselves. This means that the work needs to be relevant (Pink, 2011).

The employee that Pink is investigating relative to his theories of motivation will likely soon be an American school graduate and a member of the millennial generation. While it is recognized that schools are different from the workplace, Pink's theories on motivation do have implications for schools. Students of today are a product of the information age and the exponential times that have resulted. Students rapidly adapt to new technology. Today's students are able to master technology far better than most of the previous generations. However as stated above, U.S. students' performance compared to their peers is not favorable. As a result, schools are looking for different ways to motivate students and using the technology that students use has become more common in instructional practice. Some schools are implementing Pink's notions related to motivation in staff development. From this author's perspective as a veteran classroom teacher, students are not motivated by the same things and in the same way that students of the past were motivated. Ken O'Conner states that grades are not motivators of students and many of the ways we traditionally have attempted to motivate students do not work (O'Connor, 2011). If this is indeed true and research by O'Conner seems to prove this out, new ways of student motivation will need to be discovered. It seems logical to turn to the work of Pink for guidance, in motivating students, since they will be filling the jobs on which Pink's research focuses.

Changing STEM economic imperative. Data related to STEM careers and jobs is the final area of consideration which I will explore related to changes in STEM education. It can be shown that the United States is not producing enough STEM graduates to fill the growing need for STEM related jobs. According to the U. S. Department of Commerce, in 2010, there were 7.6 million STEM workers in the United States representing approximately 5.5% of the workforce. In addition, STEM occupations are projected to grow by 17% over the decade beginning in 2008, compared with about 9.8% growth for non-STEM occupations (Langdon, McKittrick, Beede, Khan, & Doms, 2011). The need for STEM jobs in our economy is widespread. Georgetown University's Center on Education and the Workforce found that the cluster of STEM occupations is forecast to provide 2.8 million jobs through 2018 and is made up of 1.2 million new jobs and 1.6 million replacement openings (Carnevale, Smith, & Strohl, 2010). In the Monthly Labor Review, it states that over the decade beginning in 2009 we will need to add one million more STEM professionals to the American workforce than the U.S. is producing at current rates (Lacey & Wright, 2009). In the report, *Rising above the gathering storm, revisited: Rapidly approaching category 5*, the National Academies *Gathering Storm* committee concluded that innovation will be largely driven from advances in science and engineering and the future economy will be dependent upon new innovation to create jobs. The report goes on to state that only 4 % of the workforce is made up of scientists and engineers, but they will create 96 % of future new jobs (Augustine et al., 2010). This means that STEM careers produce more jobs than other fields. These statistics show the demand for people that have STEM skills. It will fall to educational institutions of all levels to cultivate and develop students to fill these needed roles. STEM careers do have one advantage however; STEM careers generally pay better than other jobs. In the article, *STEM: Good jobs now and for the future*, it states that "STEM workers command higher wages, earning 26 % more than their non-STEM counterparts," in fact, "STEM degree holders enjoy higher earnings, regardless of whether they work in STEM or non-STEM occupations" (Langdon, McKittrick, Beede, Khan, & Doms, 2011). Thomasian (2011) reports:

> According to a recent analysis by the Bureau of Labor Statistics (BLS), the average annual wage for all STEM occupations was $77,880 in May 2009, and only four of 97 STEM occupations had mean wages below the U.S. average of $43,460. Moreover, the top 10 bachelor-degree majors with the highest payoff are all in STEM fields, according to the Georgetown University Center on Education and the Workforce (2011, p. 17).

The report by the Business Higher Education Forum, *Increasing the number of STEM graduates: Insights from the U.S. STEM education & modeling project*, states that 25.4 % of students who are math proficient have a low interest in STEM (*Increasing the Number of STEM*, 2010). Given the higher-paying nature and importance of STEM jobs to economic growth, the report argues education is needed at all levels to target these individuals and provide opportunities to experience STEM. One of the proposed ways to address this challenge is through STEM education in K – 12 schools.

Summary: Reasons to change STEM education. All four causes cited above, the rapid change in information and technology, poor performance in math and science by U.S. students, different motivation of employees (and possibly students), and the shortage of students going into STEM jobs, are related to the STEM education movement as seen in current educational practice. Schools have a desire to implement STEM curriculum in an effective manner and there is a push from groups like the National Science Foundation to create and implement STEM curriculum (National Research Council, 2011). Universities, like the University of Nebraska at Omaha, have campus-wide STEM initiatives and plans to address the shortage of students with STEM degrees and to fill STEM jobs in the future. STEM education is seen as a way to address these problems. First, STEM curriculum is seen as a possible motivator for students and anecdotal evidence bears this out. The University of Nebraska at Omaha has conducted a number of STEM projects over the past 16 years in which this author has been involved. When observing students engaged in STEM activities, there is a high level of engagement and an increased willingness to attempt to solve problems. The rationale for STEM as a possible student motivator is that STEM curriculum can be more engaging to students. It allows them to see and better understand critical connections between the disciplines of mathematics, science, engineering and technology. These connections should help provide: 1) the relevance (purpose) to student work, 2) autonomy in how a problem is solved, and 3) mastery of content while actually solving a problem. Second, if students are motivated, it is likely they will achieve at higher standards and be able to adapt to the rapidly changing world. Third, when those students exposed to STEM content have been successful and have seen the relevance of STEM, they will be more likely to pursue STEM-related career paths.

Given the national attention, economic imperative, and individual aspirations of students, STEM learning needs to be observed in a manageable context. The work of Pitt (2009) summarizes the challenges with STEM education in schools. Pitt argues that

STEM education is problematic and that there is little consensus about what constitutes STEM education. He found that some practitioners see STEM education as a way to make the subject boundaries blur where students can develop transferable knowledge. Others see STEM education as pre-vocational learning or training to encourage the pursuit of STEM careers. Still others believe STEM education links multiple discrete subject areas to create more than any single subject area can by itself (Pitt, 2009).

In order to study the phenomenon of STEM education, the framework for STEM education outlined by Kelley (2012) will be used. Kelley argues that three different educational movements; design-based education, project-based education, and subject integration; have combined in the form of today's STEM education. This framework was chosen because it fits the problematic nature of STEM education found by Pitt. Project-based learning aligns with the concept of transfer of knowledge. Design-based education addresses pre-vocational learning and training. Finally, subject integration crosses the boundaries between STEM subjects.

Statement of the Problem

The difficulty with answering the call for STEM education reform is that currently there is little consensus about what constitutes STEM education (Pitt, 2009). There is no concrete example of a practical STEM curriculum that had been implemented in public schools.

There is a gap in knowledge between conceptualizations of what integrated STEM curriculum is in a public high school and what factors the implementation of STEM curriculum should contain. In short, schools have struggled with how to implement a STEM curriculum. In a personal conversation with Dr. Nealy Grandgenett, Professor and Haddix Community Chair of STEM Education at the University of Nebraska at Omaha, he stated, “There are numerous schools in the area that are very interested in creating a STEM curriculum, but everyone is struggling with exactly how to do it” (N. Grandgenett, personal communication, September 30, 2013).

Using a semi-structured interview protocol, the study sought to learn what experts identified as critical elements of successful integrated STEM curriculum development in the context of design-based education, project-based education, and subject integration.

Purpose of the Study

While the optimal implementation of STEM in high schools is the long-range goal, there currently does not exist in literature, a thorough understanding of how STEM education is defined and how high schools are currently implementing integrated STEM curricula. In fact, a single definition of STEM education might be inappropriate. Rather to achieve long-range success, broad tactical definitions of STEM and STEM education might need to be constructed (Ostler, 2012). Ostler (2012) believes that, “If STEM education programs are to be successful, educators need to develop a long-range tactical understanding of STEM content and STEM education regardless of their own localized definition.”

Another theme that surfaced in the literature related to STEM education is the need for curricular support structures if a STEM curriculum is to function successfully in schools. Since the study focused on identifying critical elements of successful integrated STEM curriculum development, curricular support structures will likely need to be explored/identified as a part of the research.

As a result, to address these needs, the purpose of this exploratory study was to identify what STEM experts believe are the critical elements by which definitions of integrated STEM education are generated. Second, the study identified factors, based on expert opinion, that suggest how best to implement an integrated STEM curriculum in a public high school.

Conceptual Framework

The conceptual framework for this study was developed after themes related to integrated STEM education began to surface during the review of literature. Briefly, the conceptual framework for the study, which sought to identify critical elements by which definitions of integrated STEM education are generated, has three supporting legs. The first leg consists of three pedagogical methods identified in the literature: project-based learning, design-based education, and subject integration (Kelley, 2012). The second leg supporting integrated STEM education is the STEM curricular disciplines: science, technology, engineering, and mathematics. The third supporting leg is the curricular support structures found in schools and identified in the literature such as libraries (Tchangalova, 2009; Duff, 2012), counselors (Museus, Palmer, Davis, & Maramba, 2011; Schmidt, Hardinge, & Rokutani, 2012), administrators (National Academies of Engineering, 2014; National Research Council, 2011), professional development (Mason et al., 2012; Page, Lewis, Autenrieth, & Butler-Purry, 2013; Reynolds, Yazdani, & Manzur, 2013; Zollman, Tahernezhadi, & Billman, 2012), collaboration, (Schmidt, et al., 2012; Turner & Lapan, 2005), professional learning communities (Fulton & Britton, 2011), and the arts curriculum (Daugherty, 2013; Pink, 2005; Root-Bernstein, 2011). These three strands of the conceptual framework shape integrated STEM education and help determine how it functions. The conceptual framework utilized for the study is depicted below in Figure 1.

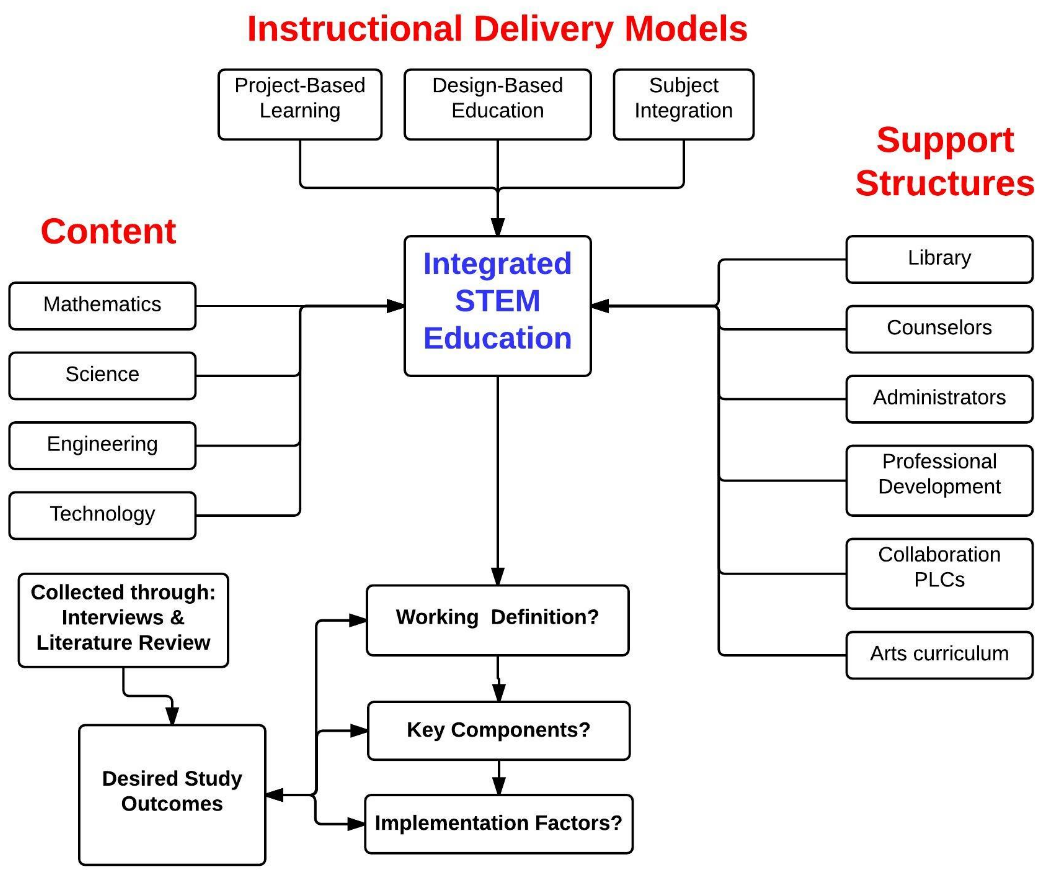

Figure 1. *Conceptual framework for integrated STEM education.*

Research Questions

The research questions for this study were broad and open ended in nature to facilitate discussion and idea generation related to integrated STEM education. The goal of this study was to describe the phenomenon of integrated STEM education and to develop integrated STEM education themes related to "expert" practitioner's experiences. These themes were used to identify what STEM experts believe to be the critical elements by which definitions of integrated STEM education are generated and identify critical factors that suggest how best to implement an integrated STEM curriculum in a public high school. The overarching research question was: What are the critical components of an integrated STEM definition and what critical factors are necessary for an integrated STEM definition's implementation? Below are four broader questions with different sub-questions for each that were addressed through the interview process.

1) What do you perceive as integrated STEM education?
    a) How would you define integrated STEM?
    b) What are the key components of integrated STEM?
    c) Other thoughts?
2) What does it take to create integrated STEM education?
    a) What resources will it take to implement integrated STEM education?
    b) What changes in staffing do you see being needed to implement integrated STEM education?
    c) Any thoughts on teacher certification considerations?
    d) What about facilities, equipment, software, etc.
    e) Are there teacher preparation/professional development needs to be addressed in order to implement integrated STEM education? If so, what are they?
    f) Other thoughts?
3) How does one implement integrated STEM education?
    a) Are changes in the structures of schools necessary for integrated STEM education to take place? If so, what?
    b) Whom do you see teaching integrated STEM education?

c) Where does it fit into the curricular structure of schools?

d) Other thoughts?

4) How would you assess integrated STEM education? What would be the ideal forms of assessment?

a) What assessment strategies would best fit integrated STEM curriculum? Why?

b) How can integrated STEM be assessed to match current standards?

c) How will an integrated STEM curriculum fit into the current standardized testing model found in education?

d) How would ideal assessment strategies relate to national standards for the STEM disciplines?

e) Other thoughts?

5) Other comments/thoughts that you feel I need to know about this topic?

Method

The approach of this qualitative study was a phenomenological research design. The method was a semi-structured interview approach of up to 15 “expert” STEM practitioners. The researcher asked STEM education practitioners identified as “experts” in the field by the University of Nebraska at Omaha STEM Leadership Team for names that can be possible interviewees. The names were compiled into lists which were analyzed and the most common or highly recommended names were solicited for interview. In addition, other STEM experts were included for diversity and special expertise to make the interview group as representative as possible. The interviews were conducted utilizing an interview protocol with the researcher following a script. The script was adhered to, as closely as possible, but due to the nature of qualitative interviews, strict adherence to the script was not always possible with the interview being allowed to go to its natural conclusion. As the interviews took place, the researcher took notes and developed further probing questions to really understand what the interviewee was saying. These further probing questions became data to consider during the data analysis process.

To analyze the data, the researcher read and coded all the interviews in order to develop concepts and themes that addressed the research questions. After initial data analysis, each interview participant was provided with a transcript of the interview and a compiled summary of the content that the analysis generated from their individual interview via electronic mail. The respondents were allowed to add, detract, or further clarify their thoughts. This was done to determine congruence in what they believe and what the analysis determined. If discrepancies were identified between their beliefs and the initial analysis for their interview, a follow-up was conducted via electronic mail. The data was analyzed three different ways: by person, by interview question, and across interviews. After the analysis, a synthesis of the data was completed to address the research questions put forth in the study.

Definition of Terms

The following definitions have been used throughout the study and are presented to the reader for clarification.

Qualitative Interview: A researcher asks one or more participants general, open-ended questions and records the answers (Creswell, 2015).

Phenomenology: A research approach that attempts to uncover what several participants who experience a phenomenon have in common (Creswell, 2007).

Integrated STEM education: An approach that explores teaching and learning between two or more of the STEM subject areas and/or between a STEM subject and one or more other school subjects (Sanders, 2009).

Project-based learning: A multidisciplinary approach combining design-oriented project-organized education and problem-oriented organized project-education (Dym, Agonino, Eris, Frey, & Leifer, 2005).

Design-oriented project-organized education: "Deals with know how: the practical problems of constructing and designing on the basis of a synthesis of knowledge from many disciplines" (Dym, et al., 2005, p. 109).

Problem-oriented project-organized education: "Deals with know why: the solution of theoretical problems through the use of any relevant knowledge, whatever discipline the knowledge derives from" (Dym, et al., 2005, p. 109).

Design-based education: Education in a full range of real-life activities and using a hands-on approach to teaching (Kelley, 2012).

Assumptions

The primary assumptions of the study centered around the design of the study. It was assumed that the experts who were interviewed had the information, knowledge, and opinions to answer the questions that were posed to them. The individuals surveyed all have experience in school settings, with STEM education professional development, and it was believed they hold a comprehensive view, therefore, talking to them was a logical way to identify critical elements of an integrated STEM education definition and to identify key factors related to the implementation of an integrated STEM curriculum.

Limitations

The limitations of the study were compatible with real-world research. The people who were interviewed limited the collection of information. The information that they provided was based on their experience and personal bias. However, the somewhat larger sample size of the qualitative study reduced this limitation.

Because of the semi-structured interview format, some data might have been missed as an interview follows one conceptual path instead of another. As part of the study methodology, an interview script was utilized to reduce this limitation.

Delimitations

One delimitation of the study was realizing that the collected data might yield all sorts of concepts and information; but due to the need to keep it focused, the study used the organization structure outlined by Kelley (2012). A further delimitation was the fact that STEM education has continued to evolve particularly with the advent of technology. The fact that participants had been selected based on their having been suggested several times and/or to provide diversity of the sample, is another delimitation.

Significance of the Study

The purpose of this study was to identify critical elements of an integrated STEM education definition and to identify key factors related to the implementation of an integrated STEM curriculum. Because of the nature of STEM education and its "newness" as a combined field, if you ask STEM practitioners it is likely you will get a wide range of key components of an integrated STEM definition and factors that influence implementation of an integrated STEM curriculum. By analyzing the collected data, the study results can be utilized, at least regionally, to begin conversations about if and what schools are currently doing is considered integrated STEM. By attempting to learn what resources, staffing, structure changes, etc. are necessary for a successful integrated STEM implementation, the study results can influence conversations about best practices in STEM education and whether STEM disciplines are integrated or not.

The study has the potential to change the direction of STEM education by providing a focus on the integration aspect of the STEM disciplines. Many authors (Merrill, 2009, Sanders, 2012) believe that STEM is more than each individual STEM discipline being taught one course at a time, and the study will at the very least provide talking points for future educational decisions related to STEM education. This researcher is interested in pursuing further research into STEM education after this study concludes, and it is believed that numerous follow-up studies can be conducted in the future related to current STEM programs based upon the findings from this qualitative research. STEM programs can be evaluated against the findings in this study to determine if necessary key components for integrated STEM education are present in current educational settings. This further research will allow school leaders to decide where and how to best allocate resources to foster integrated STEM environments. Ultimately, it is hoped that the study will play a role in helping bring cohesion to the profession through the structured process of inquiry to determine the key points related to STEM education.

Conclusion

STEM education is an important topic in today's educational discussions. Whether considering rapidly changing technology, student performance, motivation, or economic reasons, there is a national need to develop more people interested in STEM who will pursue STEM fields. The ambiguous nature of STEM education as it stands today confounds the problems associated with fulfilling this need. Numerous definitions of STEM have been put forth by different practitioners and there is little consensus among STEM professional, educators, or policy makers about how to improve STEM education to address the outlined need for more STEM career professionals.

This study has addressed this problem by identifying critical elements of an integrated STEM education definition and key factors related to the implementation of an integrated STEM curriculum. This has been accomplished through a qualitative interview approach based on a phenomenological research design. The following review of literature (Chapter 2) continues to point out the need for a study of this nature. The literature review is divided into five main sections including: 1) history related to STEM education; 2) conflicts, challenges, and rationale surrounding STEM education; 3) curricular support structures for STEM education; 4) STEM education projects; and 5) evidence in the literature supporting integrated STEM education. Chapter 3 describes the study methodology in greater detail. Chapter 4 details the results of the study. Chapter 5 contains outlines the synthesis of Data, and Chapter 6 addresses discussion and conclusions related to the study.

Chapter 2: Review of Literature

The purpose of this study was to identify critical elements of an integrated STEM education definition and to identify key factors related to the implementation of an integrated STEM curriculum. Very little literature exists about the definition and key components of an integrated high school STEM program and what makes it successful. The research that does exist tends to be anecdotal or to focus on just one particular program. In the following pages, the literature related to STEM educational programs has been grouped into the following areas: 1) history related to STEM education; 2) conflicts, challenges, and rationale surrounding STEM education; 3) curricular support structures for STEM education; 4) STEM education projects; and 5) evidence in the literature supporting integrated STEM education.

History of STEM Education

In many ways, STEM education has a long history in the United States dating back to almost the founding of our nation. The establishment of West Point Military Academy in 1802 had several purposes including the expectations that the institution's graduates would become the designers of the country's infrastructure like roads, bridges, and railroads (Jolly, 2009). The nation's stake in STEM education continued with the Morrill Act of 1862. The purpose of the Morrill Act was to improve agriculture and work skills through the creation of land grant universities, but it had the additional consequence of developing science and engineering programs in all states (Butz & Science and Technology Institute (Rand Corporation), 2004).

The next big change in education policy related to STEM education arrived in 1957 with the launch of Sputnik by the Russians. With the Cold War raging, the National

Defense Education Act of 1958 mandated specific educational courses and strengthening of instruction related to mathematics, science, and foreign language (Public Law 85-864, 1958). Education continued to be impacted through governmental action with the Elementary and Secondary Education Act of 1965 (Public Law 89-10) being passed by the Johnson administration. With data showing that students in upper grades did substantially less well in mathematics in 1970 than in 1963, the 1970's again presented a change in educational philosophy with the "back-to-basics" movement that was different from the "new math" movement of the 1960's (Kolata, 1977).

In 1983, the National Commission on Excellence in Education released the report, "A Nation at Risk". This report outlined a national crisis in American Schools related to mathematics and science. The report stated:

> Our nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world...If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might have viewed it as an act of war...We have, in effect, been committing an act of unthinking, unilateral educational disarmament (National Commission on Excellence in Education, 1983, p. 5).

This report again changed the educational landscape. It called for higher graduation requirements in core subjects including math and science. It recommended that K-12 and higher education adopt more "rigorous and measureable standards" and that expectations for student performance and conduct be raised (Graham, 2013). The standards movement stemmed from this report, and subsequently the National Council of

Teachers of Mathematics developed the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) and the National Research Council established Benchmarks for Science Literacy*, National Science Education Standards* (National Research Council, 1996).

Near the end of the last century, the U. S. Department of Education published a report that stated, "the rapid pace of change in both the increasingly interdependent global economy and in the American workplace demands widespread mathematics- and science-related knowledge and abilities" (Glenn, 2000, p. 7). This report further stressed the need for children to achieve competency in mathematics and science (Glenn, 2000).

The term "STEM" entered the common vernacular when Dr. Judith Ramaley, assistant director of the Education and Human Resources Directorate, first used it while at the National Science Foundation in 2001 (Chute, 2009). Previously, the acronym was "SMET" which did not have the positive connotations of the STEM acronym and it subtly implied that science and mathematics were better than technology and engineering (Chute, 2009). Since then, the term "STEM" has spread far beyond the NSF (Chute, 2009).

As the 21st century began, the references to STEM education increased. In 2002, the Bush administration passed the No Child Left Behind (NCLB) law. While there are no references in the law to STEM specifically, it does call for increased performance in the areas of mathematics and science for American students (*NCLB Legislation*, 2001). Numerous other reports issued by government education, and business groups have argued for the expansion of STEM education and the improvement of instruction in STEM (Carnegie Corporation, 2009; Council on Competitiveness, 2005; National

Governor's Association, 2007; National Science Board, 2007; National Research Council, 2007; President's Council of Advisors on Science and Technology, 2012).

One theme presented in these varied reports is that STEM education can lead an individual to employment that is valuable and important to the nation's ability to be innovative. Another conception is that people need to have a degree of technological literacy to be productive citizens whether they work in STEM fields or not (National Academies of Engineering [NAE], 2014). This report by the National Academies of Engineering illustrates why STEM education is seen as critical to the prosperity of the United States in the future.

> In today's science and technology-rich society, such literacy is important to being a smart consumer and thoughtful participant in democratic decision making and to making sense of the world more generally. Thus, STEM education serves to prepare a scientific and technical workforce, where integration is becoming increasingly common in cutting-edge research and development, as well as a scientifically and technologically literate and more informed society (NAE, 2014, p. 13).

History of the integrated STEM movement. The integrated STEM education initiative attempts to incorporate all STEM disciplines into one course or to incorporate extensive collaboration and interdisciplinary efforts between two or more STEM courses. In the article *Voices from the Past: Messages for a STEM Future,* author Todd Kelley (2012) argues that the history of technology education, engineering education and the current STEM education movement are very similar. Kelley (2012) outlines a three-pronged structure that provides a history of how the current STEM subject integration approach to education has occurred. His three prongs include: design–based education, project-based education, and subject integration.

Design-based education. Kelley (2012) argues that design-based education is one of the structures that lead to the current integrated STEM movement. Design-based education is based on the work of Heinrich Pestalozzi from the early 1800's who believed children should be educated in a wide range of real-life situations using a hands on approach (Kelley, 2012). Later in the 1800's, Fredrick Froebel, who was the father of modern day kindergarten (Kelley, 2012), built on Pestalozzi's work. Adelman (2000) argues that Pestalozzi greatly influenced and inspired Froebel's initial thoughts and practices. Froebel created a line of children's toys that were boxed sets of blocks designed to teach children about symmetry and beauty (Coleman, 2008). Frank Lloyd Wright played with Froebel blocks and recalled them as formative. Wright believed that the Froebel blocks were critical to helping develop his design abilities (Brosterman, 1997; Coleman, 2008). Design based education was further championed by Frederic Bonser and Lois Coffey Mossman in the early 1900's when both of them emphasized the need for students to design their own projects (Kelley, 2012).

Project-based education. The second prong in the history of the integrated STEM education movement was project-based education. Its roots can be discovered at the Van Rensselaer Polytechnic Institute where practical applications of science and mathematics led to the founding of a department of Mathematical Arts in 1835 "for the purpose of giving instruction in Engineering and Technology" (Mann, 1918, p. 12). Another American school of engineering that combined the theory and practice of engineering was the Worcester Technical Institute (now Worcester Polytechnic Institute) in Worcester, MA. It introduced the use of vocational skills to complete projects as part of the curriculum (Kelley, 2012). Project-based learning continued to grow during the 20th century with the work of Kilpatrick and Dewey. Their approaches to learning argue for meaningful task-like, case-based instruction and project-based learning (Dewey, 1938; Kilpatrick 1918). Project-based learning has continued to remain a focus in education with authors Dym, et al., (2005) studying the complexity of engineering design and how it is best taught. These authors deem project-based learning as the most favorable approach for teaching design in engineering education and further indicate that the best context for project-based learning is first year engineering education because it provides the opportunity for students to transfer learning from one experience to another (Dym, et al., 2005).

Subject integration. The third leg of the STEM integration platform is subject integration pioneered by Lois Coffey Mossman, who wrote that integration of school subjects could be accomplished through practical classroom activities (Kelley, 2012). Subject integration again came to the forefront in the Math/Science/Technology (MST) movement of the 1990's (LaPorte & Sanders, 1993). These authors state that the MST approach would improve the status of technology education by its incorporation into the core subjects (LaPorte & Sanders, 1993).

These three prongs, design based education, project-based education and subject integrated education, can all be seen in the current initiative of integrative STEM education as proposed by Mark Sanders (2012). His view of integrated STEM education refers to a designed based learning approach that integrates the concepts of mathematics and science education intentionally with the concepts and practices of technology and engineering education. He believes that STEM education can be further improved by integrating it even further with other subjects like language arts, art, and social studies (Sanders, 2012).

Kelley's three-pronged structure for the history of STEM education shows that the underlying concepts of STEM education have existed throughout the history of the American educational system. It may not be in exactly the same form as the current integrated STEM initiative; however, parts of the current movement have surfaced in the past in response to challenges that are not that unlike the challenges of today.

STEM Education: Conflicts, Challenges, and Rationale

Expanding on the organizational structure detailed in the history of STEM education section and outlined in the statement of the problem, the conflicts, challenges, and rationale for STEM education will be explored in more detail.

Conflicts. In the literature, there is little consensus among practitioners about what STEM education means, and sometimes conflicts exist between the STEM disciplines. In the article *Blurring the Boundaries – STEM Education and Education for Sustainable Development,* James Pitt (2009) argues that STEM in an educational context is problematic. For some, STEM education is seen as pre-vocational learning or training to encourage the pursuit of STEM careers. Others view STEM education as a different way to learn, where boundaries between subjects blur and students are encouraged to develop transferable knowledge and skills (Pitt, 2009). In the article, *STEM, STEM Education, STEMmania,* Mark Sanders (2009) notes he is skeptical when the term STEM is used to imply something new and exciting. He goes on to state that most current STEM practice appears to be basically status quo educational practices that have existed for a century (Sanders, 2009).

When discussing STEM education, Pitt (2009) states that:

> There is little consensus as to what it is, how it can be taught in schools, whether it needs to be taught as a discrete subject or whether it should be an approach to teaching the component subjects, what progression in STEM education is, and how STEM learning can be assessed. Some people define any activity that involves any of science, technology, engineering, or mathematics as a STEM activity; others argue that intrinsic to the concept is some linking of two or more of the component areas of learning, and that real STEM must be more than the sum of its parts (p. 41).

According to de la Paz & Cluff, (2009), the concept of STEM originated in the 1990's at the National Science Foundation (NSF) when it started funding the development of instruction that integrated mathematics, science, and technology. Bybee (2010) states that "STEM" has been used to label any policy, program or practice that involves any or all of the STEM disciplines. He goes on to say that a recent survey on the perceptions of STEM indicates that professionals in STEM fields often do not understand what is meant by the STEM acronym (Bybee, 2010).

STEM education is often viewed as dominated by the mathematics and science discipline considerations and with technology and engineering considerations playing a lesser role (Kelley, 2012). In fact, during the Mathematics/Science/Technology (MST) movement when math and science educators started to use the term MST in their vernacular, Foster (1994) claimed that MST looked less like a coordinated effort between mathematics, science, and technology and more like technology education wishing that it was a coordinated effort. Kelley (2012) goes on to state that many speculated that technology would become a stepchild to math and science. He warns that as engineering education struggles to enter the K–12 educational system, it must attempt to define itself so that engineering education will not face the unclear purpose and division within its practitioners that technology education faced in the past and currently still does. This is affirmed by in the article *The Time is Now: Are We Ready for Our Role?* where the authors argue that engineering education must form partnerships that allow all involved parties at all levels in the educational process to feel like they "win" (Haghihi, Smith, Olds, Fortenberry, & Bond, 2008). The need for an equal partnership between the STEM curricular areas is affirmed by authors de la Paz & Cluff (2009). They state, it is important "to seek to understand the importance of ensuring that the "T and E" are equal partners within STEM in order to adequately prepare the next generation workforce and produce valued contributors to our communities and society" (de la Paz & Cluff, 2009, p. 2).

Challenges. STEM education faces many challenges in its implementation. Katzenmeyer and Lawrenz (2006) performed research in the area of STEM program evaluation. They argue that there are not enough well qualified evaluators for STEM education projects and programs and that there is a severe lack of instruments with validity and reliability to measure the outcomes of STEM education interventions, teacher knowledge and skills, classroom practices, and student understanding of STEM content (Katzenmeyer & Lawrenz, 2006).

STEM Problem-Based Learning (PBL) has been defined as having a well-defined outcome with an ill-defined task within an interdisciplinary framework (Caparo, Caparo,

& Morgan, 2013). This is problematic, as ill-defined tasks can be complex and messy by nature and are challenging for students to initially accomplish at high level (Torp & Sage, 2002).

The article, *STEM Education: Proceed with Caution*, points out many challenges with STEM education including: (a) the unchallengeable curriculum (the rigidity and resilience of the school curriculum structure when proposing reform); (b) lack of clarity of the movement (there does not seem to be any clarity about what STEM education might look like in schools in terms of how the STEM subjects should relate to each other); (c) vocational vs. general education (explicit vocational approach in the STEM agenda, mainly related to science and engineering); and (d) dominance of mathematics and science over technology and engineering (Williams, 2011). Williams (2011) goes on to argue that when examining projects developed to help teachers implement STEM activities into their classrooms, the projects do not actually integrate science, technology, engineering and mathematics. Rather, these projects include parts of a few disciplines and primarily serve to advance the goals of mathematics and science.

Rationale. There is a large body of literature that provides rationale for an integrated STEM educational approach. Mark Sanders, a strong proponent of an integrated STEM education approach states, "there is sufficient evidence with regard to achievement, interest, and motivation benefits associated with new integrated STEM instructional approaches to warrant further implementation and investigation of those new approaches" (Sanders, 2009, p. 22). Sanders explains that veteran teachers understand the importance of creating classrooms that are interesting and motivating to improve learning for students. He states:

> It follows, therefore, that integrated STEM instruction, implemented throughout the P-12 curriculum, has potential for greatly increasing the percentage of students who become interested in STEM subjects and STEM fields. There is a distinct possibility that "STEM literacy for all" may pay greater dividends in the long run than "STEM preparedness for college entrance examinations" (Sanders, 2009, pp. 22-23).

Research shows students in STEM-focused high schools outperformed their peers at institutions where STEM disciplines were not integrated (Scott, 2012). Scott's research on the performance of STEM focused schools shows that high school students in STEM focused schools had much higher rates of passing mathematics and English than students that attended other schools. Additionally, Scott found that all of the STEM focused schools in the study that participated in state testing performed better than the state average in mathematics and English (Scott, 2012).

Proponents of integrated STEM education claim that the United States of America is not producing enough STEM graduates because there is a lack of social and economic incentives for pursuing STEM careers, and that increases in STEM courses taken in high school have not sparked interest in post-secondary STEM (Stearns, Morgan, Capraro, & Capraro, 2012). The authors argue that "improvement in the quality and integration of STEM education should be the focus of national attention because increasing high school students' STEM course load in high school has been shown to be insufficient" and "STEM courses should focus learning on creative exploration, projects, problem solving, and innovation rather than rote memorization of current curriculum" (Stearns et al., 2012, p. 1). This problem-based approach has shown that students learn better when they are authentically engaged in activities that are meaningful (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004). When students are engaged with real-world problems it makes knowledge more relevant to them and increases their ability to transfer skills and information from school to the world (Bransford, Brown, & Cockling, 2000).

Stephanie Pace Marshall (2010) states, "STEM education must engage students in understanding and experiencing the human consequences of innovation and its essential value in advancing the human condition" and suggests that to do this, we must immerse students in disciplinary and interdisciplinary thinking, creative problem solving, and innovative system and process design (p. 51). Building a stimulating curriculum that links across all STEM subjects is important to teachers and students alike (Pitt, 2009). Pitt believes that STEM learning has an intrinsic educational value and as such deserves a place in general education much the way that people agree that physical education is valuable in itself even though very few students become professional athletes (Pitt, 2009).

The concept of integrated STEM education faces many challenges. There is little consensus as to what integrated STEM looks like and how to implement it. School curricula and institutions can be inflexible and resistant to change for a multitude of reasons. The individual disciplines of STEM are often at odds, with one discipline attempting to have more influence than another discipline. However, with integrated STEM having the promise of more student engagement, higher student achievement, and possibly generating more individuals who show interest in and aptitude for STEM careers, it is important to try to meet the challenges and conflicts that hinder the successful integration of STEM education.

Curricular Support Structures for STEM Education

Curricular support structures will be necessary to facilitate the development of an integrated STEM curriculum. The literature identifies many curricular support structures that can improve STEM education when present, or hinder STEM education when not present. These curricular supports in schools are essential to support integrated STEM.

There are many areas within curriculum support and student services relevant to STEM enhancement. Engineering Librarian Nedelina Tchangalova (2009) from the University of Maryland believes that traditional library structures must change to fit 21st century needs. She suggests that the "graying" of the library profession with many librarians set to retire, is an opportunity to change the traditional library structure (Tchangalova, 2009). Many librarians do not have technical expertise in the STEM subject discipline areas. However, if new librarians are willing to learn in the STEM disciplines, they can use this opportunity to advance their training to support STEM learning and attain enough subject level expertise to create a library that meets the needs of STEM education (Duff, 2012; Tchangalova, 2009). STEM libraries more important characteristics include: (a) highlighting existing STEM resources; (b) emphasizing STEM in book orders; (c) providing placement and career training; (d) participating in career fairs; (e) keeping up with technology; (f) speaking to science clubs and student organizations; (g) increasing parent and community involvement; (h) inviting guest speakers; and (i) having book talks (Duff, 2012; Tchangalova, 2009). Tchangalova (2009) argues that a major professional competency that librarians should exhibit is supporting cooperation and collaboration. This is borne out in Duff's (2012) article, *10 Steps to Creating a Cutting-Edge STEM School Library,* where the author states that we must understand that for students to enter STEM career fields they must first become proficient in STEM classrooms. She argues that access to a STEM library is important to make this happen and that librarians must share STEM content and STEM information with their patrons.

Counseling is another area of traditional student support that can be modified to support STEM education. Schmidt, et al., (2010) state that counselors affect the career choices that students make and are the gatekeepers for STEM coursework. The Museus, et al., report (2011) shows that minority students are underrepresented and often do not believe that STEM courses are relevant to their backgrounds, and that counselors and other educators need to ensure minority students are exposed to STEM opportunities early in the educational process. Counseling can be an effective support for STEM education as practitioners discuss class choices and career options with students (Museus et al., 2011; Schmidt et al., 2010).

Professional development and collaboration for counselors is essential and counselors must improve their willingness/ability to counsel students toward STEM fields for STEM to grow. Counselors must broaden their STEM knowledge base by reviewing theory related to age appropriate student career development, exploring specific career fields of study, and sharing relevant STEM information with students and parents (Schmidt et al., 2012). Turner and Lapan (2005) argue that in middle school, students develop the skills that will influence STEM related course selection in high school and whether they take a STEM focused program of study. Therefore, since counselors have the power to persuade/dissuade student from STEM fields, professional development is important to inform counselors about STEM fields and curriculum.

Strategies to improve counseling for STEM education through professional development include: (a) ensuring that counselors have access to current career facts and skills requirements for STEM careers; (b) devoting time toward self evaluation of a counselor's partiality toward one career area over another; and (c) promoting career linking opportunities (Schmidt, et al., 2012).

School leadership has also been identified as an element of school culture that supports stem learning. School leadership is responsible for change and consequently must support the implementation of integrated STEM education (National Academies of Engineering, 2014). "Principals must be strategic, focused on instruction and inclusive of others in the leadership work" (National Research Council, 2011, p. 24). Administrators must provide instructional guidance for an integrated STEM curriculum and need to understand the challenges that an integrated STEM curriculum poses as well as understand the tools teachers will use to advance instruction (National Academies of Engineering, 2014). It is also believed that for integrated STEM education to be successful, the administration and other school leaders must understand integrated STEM education and what strategies (pedagogical and other) that can be utilized to ensure a successful program implementation (National Academies of Engineering, 2014; National Research Council, 2011).

The theme of professional development as a mechanism to support STEM education continues throughout the literature. Many authors call for STEM teachers to develop professionally in order to support and improve STEM education (Mason et al, 2012; Page, Lewis, Autenrieth, & Butler-Purry, 2013; Reynolds, et al., 2013; Zollman, et al., 2012). The Research Experience for Teachers (RET) project funded by the National

Science Foundation supports the active involvement of K-12 teachers in STEM areas including incorporating computer and information science in research projects to bring knowledge of engineering, computer science, and technological innovation into their classrooms. One of the goals of RET is professional development of teachers to build collaborative partnerships that help them translate their research experiences and new knowledge into classroom activities ("Research Experience for Teachers," 2010).

Two RET projects that have strong STEM teacher professional development components are *Enrichment Experiences in Engineering (E^3) for Teachers Summer Research Program: An Examination of Mixed-Method Evaluation Findings on High School Teacher Implementation of Engineering Content in High School STEM Classrooms* (Page et al., 2013) from Texas A & M university, and from the University of Texas at Arlington: *STEM High School Teaching Enhancement Through Collaborative Engineering Research on Extreme Winds* (Reynolds et al., 2013). Both of these projects have an emphasis on teachers having a hands-on research experience where they develop inquiry based engineering projects for their classrooms. Teachers learn about engineering career opportunities for students and develop an overall engineering career awareness. They are encouraged to participate in active sharing of the knowledge gained in the professional development experience. These programs and others like them support high quality professional development for teachers interested in STEM education with the overall goal of making them better teachers in the STEM disciplines.

The theme of collaboration as part of STEM teacher professional development is important in Fulton and Britton's (2011) assessment of STEM teachers in Professional Learning Communities (PLCs). This study which was completed in the fall of 2010 was a two year analysis funded by the National Science Foundation. There were five types of research included in the synthesis that were identified using variations of the search string "professional learning community". The research synthesized included: empirical research studies published since 1995 in peer journals and dissertations, research-based articles in other journals and conference proceedings, published expert knowledge and advice from periodicals, published description of models of STEM teaching in professional learning communities (PLCs), and a panel of practitioner experts responding to three rounds of questions with written responses and follow-up on-line discussions.

The researchers found that participating in learning teams allows STEM teachers to successfully engage in discussion about the subjects that they teach. The authors found that teachers in STEM PLCs understood mathematics and science better and felt more prepared to teach their subjects. STEM PLCs cause instruction to change because teachers use more research-based methods for teaching; teachers pay more attention to students' reasoning and understanding, and use more diverse modes of engaging students in problem solving (Fulton & Britton, 2011).

Another area of curriculum support for STEM education is the arts. In the article, *The Prospect of an A in STEM Education,* Michael Daugherty (2013) argues that art is essential to STEM education. Daugherty (2013) believes that by inserting an "A" for "Arts" in STEM education and making it "STEAM" education, educators can energize creativity and innovation in STEM education.

In his blog, Dr. Robert Root-Bernstein of Michigan State University (2011) points out that the arts do not make science or technology more aesthetic, rather they often make it possible. Instances where the arts directly led to the technology that Root-Bernstein cites include: (a) electronic display screens consisting of red, green, and blue pixels which originated from the innovation and collaboration of post-impressionist painters like Seurat; (b) computer chips that are made using the classic art process of etching, silk screen painting and photolithography; and (c) in medicine where the stitches that permit a surgeon to correct an aneurysm or carry out a heart transplant were invented by American Nobel laureate Alexis Carrel, who took his knowledge of lace making into the operating room (2011).

In a personal interview with Dr. Nealy Grandgenett, Professor and Haddix Community Chair of STEM Education at the University of Nebraska at Omaha, he stated as part of the Nebraska Robotics Expo there is now a creative visual arts competition. This allows the participants to participate in the creative and aesthetic parts of the engineering design process (N. Grandgenett, personal communication, January 23, 2014). Daugherty (2013) argues that it may be in the interest of the STEM movement to consider additional learning goals specifically related to creativity as it pertains to innovation. Both Daniel Pink (2005), who sees our society changing from the Information Age to a "Conceptual Age" of inventiveness, innovation, and creativity, and Robert Root-Bernstein (2011), who states that successful innovators in science and technology are artistic, would agree. In summation, as society changes to a more conceptual age, we are encouraged and urged to strengthen creativity because successful innovators in science and technology tend to be artistic people (Daugherty, 2013; Pink, 2005; Root-Bernstein, 2011).

There are many student service and curricular areas that can support the successful integration of STEM education in the school setting. Counselors and librarians play a vital role in students choosing STEM classes and providing them the resources to be successful. Curricular areas including the arts can be vital support structures of students in STEM classes by allowing them to develop the creativity to solve the complex problems integrated STEM education presents.

STEM education projects

Following the curricular supports that are important for successful integrated STEM education, various STEM education projects that highlight integrated STEM and how those integrated STEM education projects serve students will now be discussed.

In literature, there are two categories of STEM education projects: Curricular and Extra-curricular. Curricular in terms of this review means directly tied to a regular school curriculum during the regular school day. To align with the conceptual framework of the study, the selected curricular projects highlighted in the literature review were explicitly selected for their subject integrative nature. Extra-curricular means a project that is outside of the regular school curriculum. Again, to align with the conceptual framework of the study, the extra-curricular projects cited in the review of literature were chosen specifically for their relationship to design-based education. Extra-curricular projects can be sponsored by a formal school structure or another club or organization. One commonality of nearly all STEM education projects whether they are curricular or extra-curricular, is that there is a hands-on, inquiry based approach to students learning the STEM content. Often the engineering design process (or similar) is used as the overarching structure for the educational process (Berkeihiser & Ray, 2013; MacEwan, 2013; Riechert & Post, 2010; Taylor & Hutton, 2013; Teo, 2012; Worker & Mahacek, 2013; Zhe, Doverspike, Zhao, Lam, & Menzemer, 2010).

Curricular. The project *Think 3d! Training Spatial Thinking Fundamental to STEM Education,* correlates spatial learning with STEM learning success. The study consisted of 52 fourth grade students from three classrooms in a rural New Hampshire elementary school. The method was an experimental design with two experimental classrooms receiving the intervention of completing spatial assessments while participating in the program, and a third classroom serving as the control group. The third classroom took part in the program after completing the spatial assessment. The authors claim that spatial learning is lacking in elementary school (Taylor & Hutton, 2013). In this STEM implementation, students use origami and pop-up paper engineering to strengthen visuospatial thinking. Results show that the program shows promise for improving spatial thinking and engagement in the content (Taylor & Hutton, 2013).

Interdisciplinary approaches to STEM projects inspire both students and teachers (Berkeihiser & Ray, 2013). In Berkeihiser's and Ray's project which connected calculus students to engineering Computer Aided Design (CAD) students, students use experience from both disciplines to explore the same problem from different perspectives. Each group of students learns a little about how the other discipline functions and the benefits of a multidisciplinary approach to a problem (Berkeihiser & Ray, 2013).

In *Skeletons to Bridges & Other STEM Enrichment Exercises for High School Biology*, the authors connect STEM concepts to biology, which is done less often than with other sciences (Riechert & Post, 2010). In this project, three different examples of connecting engineering to biology were identified. First, "From Skeletons as Bridges" had students compare mammal skeletons to bridges in a hands-on activity. Students were introduced to the principles of bridge construction by investigating tension, compression, and bending as they apply to bridges and other engineering structures as well as to animal bones and spinal columns. Second, in "Sound Communication, Animal & Engineered Speakers," students discuss sound and how it is formed and then compare that to how animals communicate compared to human and mechanical means of producing sound (computers, speakers, etc.). Third, in "Aerodynamics and Dispersal," students explore drag with respect to mass and cross sectional area of objects. Students make a helicopter out of paper and try to build one that will stay aloft the longest. Their final design is compared to seed and flight dispersal characteristics of the propeller-like seeds produced by maple, ash, and sycamore trees (Riechert & Post, 2010). The authors report that these unorthodox STEM projects engaged students, encouraged them to think about the world from multidisciplinary perspectives, and made STEM learning more interesting (Berkeihiser & Ray, 2013; Riechert & Post, 2010; Taylor & Hutton, 2013).

Extra-curricular. Similar to curricular-based STEM projects, extra-curricular STEM projects are numerous and important to the learning process. Falk & Dierking (2010) argue that 95% of all learning takes place outside of formal school settings through venues such as places like museums, organized programs, hobbies, television, and other sources. According to the National Research Council (NRC, 2009), the strengths of programs outside of the school day are evident in technology and engineering education, where students solve engineering design challenges using their hands and minds. In the same way that the numerous curricular STEM projects were handled, this author chose to focus on extra-curricular STEM projects that were related to design-based education which is one of the prongs of the study's conceptual framework.

In *Getting Intentional about STEM Learning,* MacEwan (2013) outlines an afterschool project where students in elementary school worked in enrichment clubs with each having its own STEM theme. The goal of these clubs was for students to use critical thinking and problem solving skills to understand broad STEM concepts. MacEwan (2013) spends much time discussing the nature of professional development for the instructors, which utilizes the same hands-on, inquiry-based activities as those used with the students. Ultimately, the project wanted students and staff to recognize STEM as a common factor in many activities that they already enjoy and to realize that STEM does not have to be intimidating (MacEwan, 2013).

The 4-H Youth Development Program has been engaging youth outside of the formal school setting to reach their fullest potential since 1902 (Worker & Mahacek, 2013). One project that 4-H sees, as part of its STEM mission mandate, is “4-H Junk Drawer Robotics”. In this project, students are given a drawer of parts and tools to utilize in solving a problem. There are three levels that students progress through (To Learn, To Do, and To Make) which mimic the engineering design process. The author suggests that by infusing science into engineering and technology a synergy exists in situations where students are engaged and have fun learning (Worker & Mahacek, 2013).

The EUREKA STEM project at the University of Nebraska at Omaha (UNO) has been providing STEM education opportunities in the summer for minority girls beginning in grade seven for the last three years with grant funding by Girls, Inc. of Omaha, NE. This extra-curricular project focuses on underrepresented segments of the population related to STEM careers, namely minorities and women (National Research Council, 2007). The girls were on the UNO campus all day for approximately three weeks and engaged in career talks with local women in STEM fields and STEM curriculum led by

UNO faculty/staff and other certified teachers. The participants were divided into two groups, “Rookies” and “Vets”, that received STEM content including: hands-on STEM kits, robotics, rocketry, mathematics, chemistry, life sciences, engineering, high altitude Ballooning for the Rookies; and robotic programming, e-Portfolios, physics, math logic, advanced chemistry, advanced life science, biomechanics, and neurology for the Vets (Squires & Mitchell, 2015).

A EUREKA participant stays in the program for 5 years. The first and second year they attend the UNO EUREKA STEM camp. Following the first two years, participants are given an internship and paired with businesses and community partners, who serve as mentors. The goal then is that these girls major in a STEM field in college, and hopefully then work for one of the STEM businesses in our community, thus fortifying the STEM pipeline in Omaha. Amelia Squires, UNO STEM Outreach Coordinator, reports the following:

> STEM is contagious. Everyday there would be a girl or two who were very disengaged in the beginning of the lesson, but became increasingly more interested as the session continued and they saw their friends creating, building, experimenting, etc. By the end of a STEM activity, the girls were all participating and far exceeding the expectations they had built for themselves in the beginning of the lesson (Squires & Mitchell, 2015).

These design-based (extra-curricular) STEM projects serve the same goals as the subject integrative (curricular) STEM projects; that is, to engage students in thinking about the world from a multidisciplinary perspective, and to make STEM learning more interesting (MacEwan, 2013; Worker & Mahacek, 2013). The diverse nature of STEM projects, whether they are curricular or extracurricular, shows that integrated STEM education has the potential to address many of the issues related to STEM education and careers in our society today. The cited STEM projects, as well as many others, give researchers glimpses into what seems to work and what further research needs to be conducted to continue improvements to the implementation of integrated STEM education.

Evidence to Support Integrated STEM Education

After discussing what characteristics integrated STEM appears to exhibit, evidentiary support for integrated STEM education in the existing literature will be reported and analyzed.

Continued need for STEM careers. The need for STEM workers is well documented in the literature. Langdon, et al.' (2011) report that over the decade prior to 2011, growth in STEM jobs was three times faster than non-STEM jobs. They go on to say that STEM occupations are projected to grow by 17% from 2008 to 2018 compared to 9.8% growth for non-STEM occupations. In the *Report of the Academic Competitiveness Council* by the U.S. Department of Education (2007), it states that there is a rising concern about U.S. economic competitiveness and the ability of the nation's schools to produce citizens who are literate in STEM concepts to produce future engineers, scientists, technologists, and mathematicians. The report further states that these types of experts are critically needed to maintain the U.S. as a world leader in science, technology, engineering, and mathematics (U.S. Department of Education, 2007).

Stearns et al. (2012) found factors that show why America is not producing STEM-seeking graduates. These factors include: 1) a lack of social and economic incentives for pursing STEM careers, 2) increases in STEM courses taken in high school have not improved post secondary interest in STEM, and 3) STEM courses should focus on creative exploration of content, projects, problem solving and innovation rather than the rote memorization of current curriculums. The authors conclude that improvements in the quality of curriculum and integration of STEM education should be the focus of the nation (Stearns et al., 2012).

Benefit to students. In the National Academy of Engineering report, *STEM integration in K-12 education: Status, prospects, and an agenda for research* (2014), Margaret Honey chair of the committee that produced the report, stated that the committee does not produce an unequivocal endorsement for integrated STEM, but notes that there is a very exciting potential for using the connections that come naturally between the STEM disciplines to help students.

Hurley (2001) conducted a meta-analysis of 31 studies, which compared integrated science and mathematics instruction to non-integrated student performance. The mixed methodology study covering research from the entire 20^{th} century found qualitative evidence revealing the existence of five forms of integration: 1) sequenced - where science and mathematics are planned and taught sequentially, 2) parallel – where science and mathematics are planned and taught simultaneously through parallel concepts, 3) partial - science and mathematics are taught partially together and partially as separate disciplines, 4) enhanced - either science or mathematics is the major discipline of instruction, with the other discipline apparent throughout the instruction, and 5) total - science and mathematics are taught together in intended equality. In this meta-analysis, it was determined that there was a positive effect for integration in both mathematics and science (Hurley, 2001).

Scott (2012) performed a comparative case study method to create a holistic description for each of 10 selected STEM schools. The schools were chosen using a criterion-based selection method with the primary criteria for selection being: 1) the school was specifically intended as a STEM school, and 2) the school was designed to improve all students' understanding of the STEM disciplines rather than be focused only on advanced or gifted students. The results of this comparative case study found that students in STEM schools they researched outperformed their peers at other high schools on end of course finals and achieved higher proficiency on state tests (Scott, 2012).

Becker and Park (2011) conducted a meta-analysis to see if the integration of STEM subjects is beneficial to student achievement. In the report, 28 studies were selected and 33 individual effect sizes were calculated to examine the effects of integrative approaches among STEM subjects. Their findings revealed positive effects for student achievement when using integrated approaches for STEM learning. However, the authors noted a limitation of the study is that the number of studies included in the meta-analysis is relatively small since few studies that present quantitative evidence were available for selection, and indicated they felt that the small number of studies could lead to inflation of the results and a tendency to overreach the conclusions (Becker & Park, 2011).

Increased knowledge/conceptual learning. Evidence in the literature shows that integrated STEM has the potential to increase knowledge and conceptual learning. The National Academy Report, *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research* (2014), found that the integration of STEM concepts and methods has the ability to lead to increased conceptual learning in the STEM disciplines. Some caution is advised because of the small number of studies with small sample sizes, but the authors of the report see potentially promising findings.

Pfeiffer, Overstreet, and Park (2010) argue that well orchestrated Problem-Based Learning (PBL) activities improve learning. Pfeiffer et al. (2010) further argue that when school curriculum is focused on STEM PBLs, PBL projects improve student understanding by helping students to make the connections between content taught in other classes.

Sherrod, Dwyer, and Narayan (2009) claim that integrating mathematics into the science curriculum will not only improve student's understanding of mathematics, but demonstrates how math can be used. Wilhelm and Walters (2006) found that when mathematics is integrated into science, the curriculum is complementary, causing student learning in both mathematics and science to be enhanced.

Increased interest/motivation. Reviewing literature found that integrated STEM increases student interest, including minority student interest. Alpaslan Sahin (2013) looked at STEM clubs from a multi-school charter system in Texas. The study employed a survey design that was administered to a multi-charter school system with 36 campuses to investigate after-school programs where all fourth through twelfth graders were expected to complete a science fair project and were encouraged to participate STEM-related clubs. Sahin (2013) found that students who participated in STEM clubs chose STEM majors at a higher rate than those that did not participate in STEM clubs. The findings also showed that students in STEM clubs performed better and went on to post-secondary education at a higher rate than the students that did not participate in STEM clubs.

Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt (2011) reported on an iQUEST program that serves seventh and eighth-grade science classrooms with high percentages of Hispanic students. The project is geared toward girls and minorities who are underrepresented in STEM fields. The iQuest project found that its summer camps at California State University San Marcos which included integrated STEM content increased student interest and improved student attitudes toward science and technology.

The report by the National Academy of Engineering, *Engineering in K-12 education: Understanding the status and improving the prospects,* (2009) recommended that STEM disciplines should not be treated as “silos” rather they should be integrated and that engineering could serve as a motivating context to integrate the STEM disciplines. One of the believed benefits of integrated STEM education is that students can solve real-world problems and make connections to STEM fields that can increase interest in STEM fields (Brown, Brown, Reardon, & Merrill, 2011).

Rockland, et al., (2010) see robotics as an area that encompasses the areas of technology, computer science, engineering, and the sciences. Their project at the New Jersey Institute of Technology created the Medibotics curriculum, which used LEGO ® MINDSTORMS ® for Schools with ROBOLAB programming software kits to solve biomedical engineering problems. Because of the integrated nature of robotics, robots can be used in the classroom as a tool to increase motivation and student learning.

DeJarnette (2012) looked at literature related to current initiatives and research regarding early exposure for students to STEM initiatives in the elementary grades and concluded that the interactive Problem-Based Learning activities found within an integrated STEM curriculum are innovative and exciting for students. She believes integrated STEM will create motivation for students to take advanced mathematics and science courses as well as consider STEM careers.

The EUREKA! project at the University of Nebraska Omaha also showed evidence that integrated STEM content can increase motivation. Anecdotal evidence from this project showed that the minority female participants of the project had increased interest and motivation to learn STEM concepts (Squires & Mitchell, 2015). Survey data for the project bore this out when students were asked if they liked doing science, mathematic, engineering, and technology activities. Responses to these questions largely showed positive gains for both the "Rookies" and "Vets" from pre-test to post-test. However, the Rookies showed no change toward mathematics motivation and the Vets showed no change toward technology motivation. Overall, no categories showed a negative influence on motivation related to STEM activities (Squires & Mitchell, 2015).

Curriculum goals for schools. The National Academy of Engineering report, *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research* (2014) has outlined several goals for students that integrated STEM education should address. The first goal is STEM literacy, which includes awareness of the roles of STEM fields in society, familiarity with the basic principles of each STEM area, and a basic level of understanding of how to apply each discipline. The report sets other goals as: (a) developing 21st century competencies, (b) preparing a STEM ready workforce, (c) increasing interest and engagement in STEM fields, and (d) the ability to demonstrate connections between STEM disciplines (National Academy of Engineering, (2014). This report advocates more integration of STEM curricular areas in the K–12 education system by teaching STEM using real world problems and issues, which can enhance motivation for learning and improving student achievement. Mark Sanders (2009) argues that there is enough evidence relating to student achievement, interest and motivation associated with integrated STEM to encourage more implementation and research into integrated STEM education.

There is much evidence to support the concept of integrated STEM education. The need for increased interest in and need for more individuals entering STEM careers, the benefits to students in terms of improving motivation, interest, and conceptual knowledge, and the goals of integrated STEM education for students have been well documented. The evidence shows that integrated STEM can address some of the issues facing the American education system today. Yet, the need for further research to specifically look at student achievement and how to best implement integrated STEM education remains.

Conclusion

The literature related to STEM education is diverse and it contains a wide variety of researcher perceptions. It can be argued that STEM education has a long history and has its roots in the past as seen by the three prongs that Kelley (2012) outlines. In literature, there are many conflicting ideas about what STEM education really looks like and how to actually successfully create/implement it (Brown et al., 2011; Householder & Hailey, 2012; NAE, 2014). Sanders (2012) and others point out many challenges to the implementation of integrated STEM. There are many different ways that the existing curriculum and departments can support integrated STEM education, but it must be intentional (Daugherty, 2013; Duff, 2012; Fulton & Britton, 2011; Museus, Palmer, Davis, & Maramba, 2011; Schmidt, Harding, & Rokutani, 2010; Schmidt et al., 2012; Tchangalova, 2009). Numerous STEM projects that serve both the curricular and extra curricular realms are present in the literature. However, these projects report results for their particular project that may have little or no generalization to other STEM education implementations. Most research identified in the literature related to integrated STEM education has not been conducted in a typical high school setting. Rather, the research identified was related to some form of specialty school including: 1) STEM schools which focus on one or more of the STEM curricular areas and have selective admission requirements, 2) inclusive STEM schools that emphasize one or more of the STEM curricular areas but do not have selective admission requirements, and 3) schools with STEM-focused career and technical education (CTE). These schools are different from typical public high schools due to a STEM discipline focus area or admission criteria. However, there does appear to be enough support in the literature for integrated STEM education to make it worthy of further research.

Brown, et al., (2011) argue that there is little evidence that integrated STEM education actually exists in the schools. The authors state that even though many teachers understand and value STEM education, very few implement it. The implication from Brown, et al. (2011) in the article *Understanding STEM: Current perceptions,* is that in order for STEM education to become a reality, those who understand and value STEM education must find like minded colleagues with whom to collaborate in order to truly implement STEM education. The next chapter elaborates on the specific methodology that was used in this dissertation study including a conceptual framework, sampling techniques, data collection methods, and data analysis procedures.

Chapter 3: Method

Overview and Design

The area of STEM education is a growing field of interest and importance to K – 12 schools, higher education, groups like the National Science Foundation, National Academy of Engineering, etc., as well as the public and private sectors. As a society, it is critically important that more people enter STEM career pathways and STEM careers than is currently the case (Augustine et al., 2010; Carnevale, Smith, & Strohl, 2010; Lacey & Wright, 2009). When looking at what STEM education means, there are many definitions (Brown, 2012; Merrill, 2009; Sanders, 2012; United States Department of Education, 2007) and implementation of STEM education is different depending on the definition applied.

The purpose of this qualitative study was to explore the concept of integrated STEM education and how it is perceived by educational leaders in the field. As a consequence of this exploration, it was hoped that critical elements by which definitions of integrated STEM education were identified and factors which suggest how best to implement an integrated STEM curriculum were determined. This information would be helpful to continue research, curriculum development, teacher training, and implementation.

The study was conducted using a "descriptive survey" research design that was grounded in the techniques of phenomenological research. Phenomenological research is based upon descriptions of the experiences as they occur in everyday life by the participants in the phenomenon (Giorgi, 1995). Creswell (2007) believes phenomenology is a research approach that attempts to uncover what multiple participants who experience a phenomenon have in common. Other researchers identify the phenomenological research method as attempting to get at the perceptions of the people being studied (Lester, 1999; Willis, et al., 2007). Groenewald (2004) posits that the goal of a phenomenological researcher is to describe the phenomenon being studied, while refraining from any pre-given framework. Phenomenology is concerned with the lived experiences of the people involved with the issue being researched (Kvale, 1996).

From the perspective of the researcher, the goal of phenomenological research is to 'describe' a phenomenon. The use of the phenomenological method creates descriptions of the phenomenon through qualitative methods like interviews, discussions, and participant observations (Creswell, 1998; Lester, 1999). In the case of this research study, a modified phenomenological design was used to describe the phenomenon of integrated STEM. The rationale for the "modified" design is that phenomenology in its purest sense will not necessarily fit the study and the collected data. It is likely that some of the data will be quantitative in nature. The exploratory data methods outlined by John Tukey (1977) were used to analyze data both qualitatively and quantitatively. The desired result was a conceptual understanding of integrated STEM education; its critical components and requirements for implementation. Data was collected in a semi-structured interview format followed by content analysis.

Conceptual Framework

Based on the problem addressed in this study, the review of literature, and desired outcomes of the study, a conceptual framework for the exploration of integrated STEM education was created. The conceptual framework outlined ideas related to integrated STEM education content, methodologies, and supporting structures forming three legs that support the concept of integrated STEM education. Historically, integrated STEM seems to originate from three different educational movements whose aspects have been combined. Project-based learning is a pedagogical method focused on engaging students in the investigation of problems. In project-based learning, students pursue solutions to nontrivial problems through refining questions, making predictions, debating ideas, designing a plan, collecting data, analyzing data, and communicating results to others (Blumenfeld, et al., 1991). Design-based education consists of educating students through use of a variety of real-life activities and a hands-on approach (Kelley, 2012). Subject integration means exactly what it says, the combining of more than one academic subject to create an integrated, multidisciplinary approach to education. These three strands made up the historical/theoretical support for integrated STEM education. The STEM disciplines of science, technology, engineering, and mathematics created the second supporting leg for integrated STEM education in the study's conceptual framework. The final supporting leg consisted of the curricular support structures that exist in schools and were identified in the literature. These curricular support structures included, but are not limited to: libraries, counselors, administrators, teacher professional development, collaboration/professional learning communities, and the arts curriculum. The figure below represents how the three supporting legs flow into the concept of integrated STEM education and that the intended outcomes of this study were a working definition of integrated STEM education, identification of critical components of integrated STEM, and necessary factors for implementation of integrated STEM education.

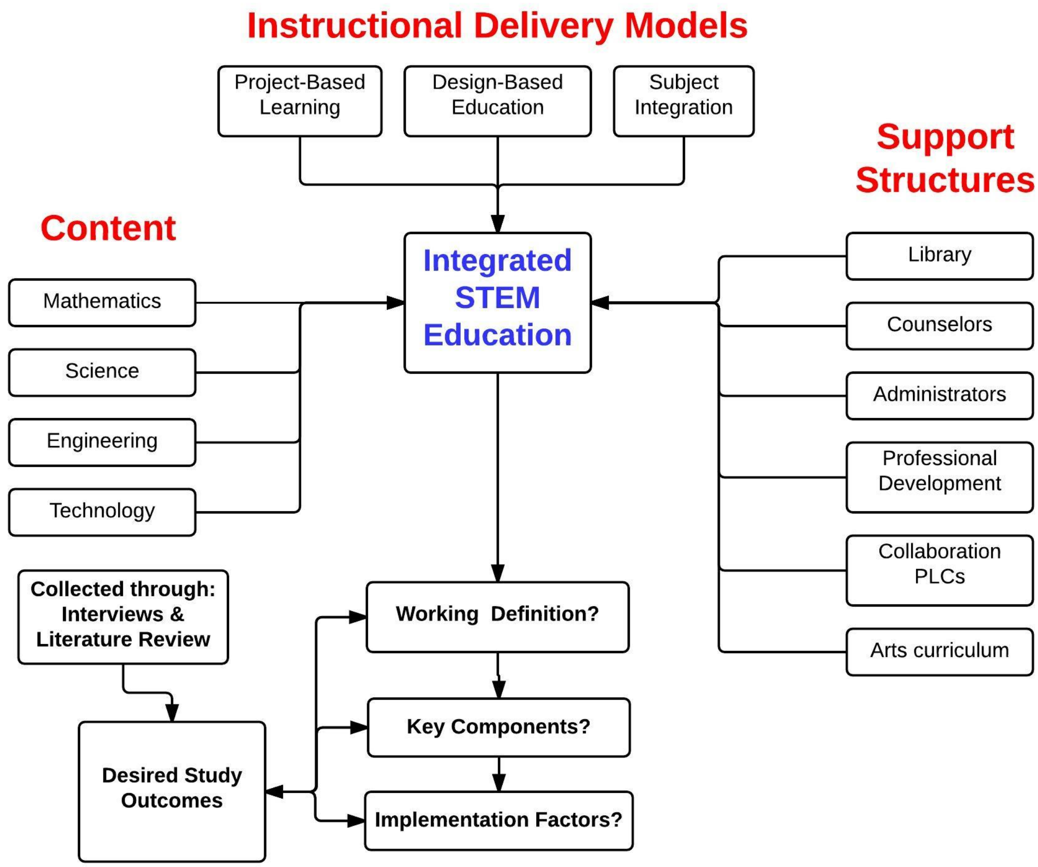

Figure 2. Conceptual framework for integrated STEM education.

Sampling

The area of integrated STEM education was explored by talking to dedicated educational practitioners/experts who were selected using the theory of concept sampling techniques outlined by Creswell (2015) where the researcher "samples individuals or sites because they could help the researcher generate or discover a theory or specific concepts within the theory" (p. 207). In this study, the researcher looked for participants who were actively engaged in STEM education. The study was designed to include interviews with up to 15 current STEM education practitioners who were identified as "experts" in the field, by the University of Nebraska at Omaha STEM Leadership Team.

The University of Nebraska at Omaha STEM leadership team consists of two members from the College of Arts & Sciences representing the disciplines of science and mathematics, one member from the College of Information Science & Technology representing computer science education, and one member from the College of Education.

To develop this list, the four University of Nebraska at Omaha STEM Community Chairs, who co-chair this leadership team, were asked to list possible interviewees for the study. Compiling these lists led to selecting the interviewees with consideration given to frequently mentioned names, diversity, and expertise. The individuals that were selected to be interviewed appeared on more than one list or have some special reason for selection (diversity, special recognitions, special skills, etc.) In keeping with qualitative research, the researcher did not attribute specific quotes to specific people; these comments remained anonymous. However, to lend credibility to the study and show the diversity and range of expertise, a summary of anonymous job titles of the Interviewees was presented in Chapter 4: Analysis of Data.

Data Collection Methods and Research Questions

A pilot for the study was conducted using a Graduate Research and Creative Activity (GRACA) grant. The pilot consisted of four interviews utilizing the research questions outlined in Chapters 1 and 3. It was determined that the interviews would last about one half hour. It was also determined that the pilot interviews would solicit responses which could be logically expanded in the dissertation study. The data provided by the interviewees in the GRACA pilot also appeared to generate an overlap in responses that would address the desired outcomes of the dissertation study. The data for the GRACA grant was analyzed and used to steer further data analysis. Since the research questions did not change from the pilot GRACA study to the actual dissertation study, the information identified in the GRACA pilot was presented in the dissertation as part of the interview pool and was not specifically identified separately as being part of the pilot.

Interviews were conducted using a semi-structured approach with up to 15 STEM education experts (determined through sampling methods outlined above) using an interview protocol both in person and over the telephone. Interviews were conducted from September 2015 through October 2015 (GRACA interviews were conducted in June 2015) with data analysis being carried out both during and following the completion of the interviews. The interviews were recorded using a digital recorder or Google Voice and computer for redundancy, and the recordings were transcribed. In addition to the recordings, the researcher took personal notes about the interview and begin to perform analysis as the interview proceeded in order to develop further questions and areas to address in the scope of the interview (Creswell, 2015). Generally speaking, the interviews were designed to gain an understanding of the research question: What were the critical components of an integrated STEM definition and what critical factors were necessary for an integrated STEM definition's implementation? Below are four general questions with different sub-questions for each main question that were asked as part of the interview process.

1) What do you perceive as integrated STEM education?

    a) How would you define integrated STEM?

    b) What are the key components of integrated STEM?

c) Other thoughts?

2) What does it take to create integrated STEM education?

a) What resources will it take to implement integrated STEM education?

b) What changes in staffing do you see being needed to implement integrated STEM education?

c) Any thoughts on teacher certification considerations?

d) What about facilities, equipment, software, etc.

e) Are there teacher preparation/professional development needs to be addressed in order to implement integrated STEM education? If so, what are they?

f) Other thoughts?

3) How does one implement integrated STEM education?

a) Are changes in the structures of schools necessary for integrated STEM education to take place? If so, what?

b) Whom do you see teaching integrated STEM education?

c) Where does it fit into the curricular structure of schools?

d) Other thoughts?

4) How would you assess integrated STEM education? What would be the ideal forms of assessment?

a) What assessment strategies would best fit integrated STEM curriculum? Why?

b) How can integrated STEM be assessed to match current standards?

c) How will an integrated STEM curriculum fit into the current standardized testing model found in education?

d) How would ideal assessment strategies relate to national standards for the STEM disciplines?

e) Other thoughts?

5) Other comments/thoughts that you feel I need to know about this topic?

The interviews conducted by the researcher attempted to follow a "script" while remaining flexible enough to follow the conversation of the interview (Creswell, 2015). The script included the same introduction and open-ended questions together with follow-up questions being asked. This allowed the interview to flow freely to its natural conclusion. The qualitative research process is emergent (Creswell, 2013) which means that the initial research plan put forth by the researcher "cannot be tightly prescribed, and that all phases of the process may change or shift after the researchers enter the field and begin to collect data" (p. 47). The questions can change, data collection methods can change, and the people interviewed can be modified during the study (Creswell, 2013). Using this methodology, if additional insights are gained about a particular area related to integrated STEM education during the interview, additional questions off script were asked of the participants to gain further understanding of what they are trying to convey. These further probing questions became data to consider during the data analysis process.

In addition to recording the interviews, the interviewer took copious notes to attempt to focus in on key concepts and gain further understanding. An effort to triangulate data was implemented as other interviews take place. The researcher attempted to not lead the interview in any way, but brought up points other Interviewees mentioned using the principle of Creswell's (2013) emergent design. For example, additional questions were asked around what other participants have said previously in an attempt to develop and strengthen themes and commonalities.

Data Analysis

Data analysis in qualitative research involves breaking data down into meaningful parts for the purpose of examining them. Analysis allows the researcher to make sense out of the data with the purpose to answer specific research questions (Savin-Baden & Major, 2013). Hatch (2002) sees data analysis as a systematic search for meaning. He sees the analysis of data in qualitative research as looking for patterns, identifying phenomenons, developing explanations, creating interpretations, or generating theories with the processes of synthesis, evaluation, interpretation, categorization, hypothesizing, comparison, and pattern finding all being present. Data analysis begins soon after the project starts and continues until the final report. It is usually inductive moving from smaller ideas to discover the larger phenomenons (Savin-Baden & Major, 2013).

Savin-Baden & Major (2013) recommend using more than one method of data analysis in order to create plausibility. They argue that if the researcher does several different kinds of data analysis on the same data, the results will complement each other thus lending plausibility to the findings. To that end, the researcher utilized Exploratory Data Analysis methods pioneered by John Tukey (1977), which considers qualitative and quantitative data as parallel structures when being analyzed. Tukey believes that qualitative data can be analyzed quantitatively and quantitative data can be analyzed qualitatively. With that in mind, the researcher considered several different qualitative data analysis methods for the study including: keyword analysis, constant comparison, and thematic analysis. Descriptive statistical analyses were conducted for a quantitative approach depending on the nominal data determined in the interviews. Keyword analysis involves searching the data of frequently repeated terms, unusual usage of terms, and words used in context (Savin-Baden & Major, 2013). Constant comparison involves the idea of continually comparing identified categories and codes from previous data to newly collected data to find consistencies and differences (Savin-Baden & Major, 2013). Thematic analysis is "the process of recovering the theme or themes that are embodied and dramatized in the evolving meanings and imagery of the work (Van Manen, 1990, p. 78). Braun & Clarke (2006) believe that thematic analysis can identify, analyze and report themes (patterns) within data. They outline the following steps to perform a thematic data analysis.

Table 1

Phases of thematic analysis

Phase	Description of the process
1. Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Note. Braun and Clarke's thematic analysis procedure.

It was believed by combining these primary methods of data analysis cited by Savin-Baden & Major (2013), themes and related information would surface that would address this study's research questions.

Data organization. The data was collected through semi-structured interviews, which were recorded and transcribed by hand. Ultimately, the data was organized into a series of word processing documents that were then used for data coding procedures.

Data coding procedures. The collected data was analyzed using the qualitative process of data analysis outlined by Creswell (2015, p. 236) (see diagram below). This process is inductive in nature going from general to more detail as it progresses and involves the simultaneous processes of analysis while collecting data. It is iterative in that it involves cycling back and forth between data collection and analysis (Creswell, 2015).

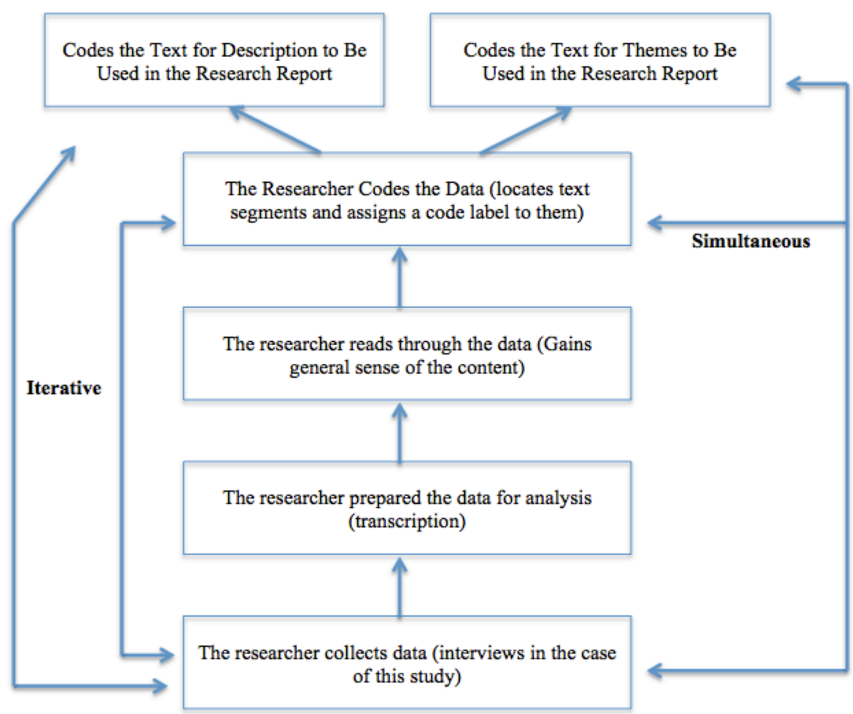

Figure 3. Creswell's qualitative data analysis procedure.

During this study, analysis of the data occurred as part of the interview process in order to identify themes and to be able to probe for further details and information. The researcher considered this to be the beginning of the data coding process. Later, more advanced data coding occurred after the interviews were completed. As data was introduced, general codes were applied to that data to help organize it. Those codes, later refined after the interviews, were condensed to determine themes and descriptions for the research report.

To code data, this researcher carefully read the interview transcriptions and wrote notes in the margins. To begin final coding, this researcher selected the shortest transcript to start and tried to distill what the interviewee said in answer to a question into just a few key words. Blocks of text, which the researcher labeled with just a few representative words, represented the actual coding of the interview. As the researcher read the document, the idea of lean coding (Creswell, 2015) was applied so that there were a manageable number of codes for each research question.

Using the coding process outlined by Creswell (2015), an initial read-through of text data led to the transcribed text being divided into segments of information. These segments were labeled with codes. The number of codes at this stage was further reduced by eliminating overlapping and redundant codes. Finally, the remaining codes were distilled into the overarching themes that were reported in the discussion and results section.

After initial data analysis, each interview participant was provided with a complete interview transcript and a compiled summary of the content that the analysis generated for their individual interview via electronic mail. This was done to determine congruence in what they believe and what the analysis determined. The interviewee had the opportunity to add, modify or retract statements based on their review of the initial analysis. The initial analysis that was returned by the Interviewee was utilized moving forward with the more detailed analysis to follow.

Plans for interpretation/representing the findings. The overall goal of the study was to identify the critical components for definitions of integrated STEM education and factors related to best implementation of an integrated STEM curriculum. To address the goals of the study, the interview data was analyzed (as outlined above) for patterns and themes in attempt to answer the broad questions posed in the interview. The researcher then took the themes from the interview data and attempted to merge them with information found in the literature. Grounding the findings of the study in the literature, provided reliability to the study. In the conclusion of the discussion section, recommendations about the findings related to integrated STEM education were presented. In addition, suggestions for further research based on the results of the study were posited for this researcher or others to consider in the future.

Resources need to conduct the study. The study required some resources to be completed. Some of the resources that were provided the University of Nebraska at Omaha College of Education, included computers for transcription of data, analysis of data, and presenting the findings. In addition, the College of Education was used in some cases for a quiet interview space in which to conduct the interviews. Other resources that the study required were microphones for recording the interviews, a transcription recorder (to be used for redundant recording of the interview and later transcription editing), a method for recording phone conversations (provided by Google Voice), and a human transcriptionist (for transcription checking and editing). In the case of this study, that person was the researcher.

Potential Researcher Bias

My role as a researcher was to guide and analyze the overall data collection and analysis processes. To minimize researcher bias, I conducted the interviews using a protocol that attempted to not lead the interviewees. While analyzing and coding data, I knew I had a vested interest in the study and needed to be aware of the possible bias that could occur because I am a STEM education professional practitioner. Reasons for potential research bias include: I have taught middle school and high school mathematics for 19 years. In addition, I have taken classes in engineering and biology and have experience tutoring students in the areas of chemistry and physics. Secondly, I have been involved in many different STEM educational projects at the University of Nebraska at Omaha as a participant, facilitator, designer, and a lead curriculum editor, and have attended STEM conferences and workshops both as presenter and attendee. Third, as a doctoral candidate, I believed the outcome of this qualitative research had the potential to shape future research into integrated STEM education in profound ways. I was actively involved in the study by putting forth names of potential interviewees, conducting the interviews, analyzing the collected data, and viewing all these tasks through my personal experiential lens that could bias results. At the same time, I expected that my experiences with STEM education would bring knowledge to the process that proved helpful in answering the questions presented in the study.

Summary. This study utilized a qualitative interview approach based in a modified phenomenological research design. The four University of Nebraska at Omaha

STEM community chairs suggested possible interviewees. These lists were combined and 13 people deemed to be STEM education "experts" were interviewed. The interviews were recorded, transcribed, and analyzed. The themes resulting from the data analysis are presented in Chapter 4: Analysis of Data and Chapter 5: Synthesis of Data. In addition, the plan was that strategies for refining a tactical definition of integrated STEM education would emerge along with recommendations for integrated STEM curriculum development and assessment.

Chapter 4: Analysis of Data

Introduction

During the course of the research study, 13 participants were interviewed either in person or over the phone. The interviews were transcribed in their entirety. Initial data analysis of the interviews began in three different stages. First, the big ideas from the raw interview data were compiled and sent to the Interviewee for feedback along with the entire interview transcription. Next, Interviewees were allowed to add, detract, and clarify information from the interview. The big ideas from the interviews along with the feedback were then summarized into the executive summaries. These follow later in Chapter 4 in the section titled, Executive Summaries of Each Interview.

Second, each question was analyzed using the raw data to generate initial codes related to integrated STEM education. These codes were grouped together to identify themes that emerged from each question. The identified themes and summary of each interview question also follow later in Chapter 4 within the Summary of Interview Questions section.

Third, the data was analyzed to remove all names and questions from within the raw interviews and to generate coding of the raw text. The coding generated from the raw text was grouped together into themes, which are later represented in Chapter 4 within the Identified Themes across Interviews section.

Further comparisons were made between these three data sets with the analysis following later in Chapter 5: Synthesis of Data.

Demographics of Interviewees

The study attempted to select participants for interviews that were diverse in many different aspects. The educational level attained by the participants was well above average with eight of the subjects having a Master's Degree and five of the participants having a Doctoral Degree. Nine of the Interviewees were male, while four were female. Most participants (12 out of 13) had experience in the classroom within one of the STEM disciplines. Eight of the Interviewees had their primary teaching experiences in high school settings, three had their primary teaching experiences in middle school settings, while one had their primary teaching experiences in the elementary setting.

Not all the participants of the study are currently in the classroom. This was intentional to garner responses from different stakeholders that influence and shape STEM education. The current positions of the interview participants in no particular order are as follows:

Table 2

Current Job Descriptions of Interview Participants.

Computer Science Teacher – Large urban high school
Computer Science Education Support Staff – Large urban university
Director STEM Education Center – Small East coast university
STEM teacher – Large urban high school
Senior Administrator - State education agency
Profession STEM Education – Large urban university
Physics and Computer Science Teacher – Parochial high school in large Midwestern city
Instructional Technology Design / Training Specialist – Large urban university

Education Director – Large metropolitan zoo
Engineering Education Professor – Large urban university
Educational Leadership Professor - Large urban university
Administrator Math Education – State education agency
Administrator – Not-for-profit corporation dedicated to encouraging K – 12 students to investigate and follow technical career paths

Executive Summaries of Each Interview

Each interview was analyzed in its raw transcribed state and key ideas in the form of phrases and sentences, representative of the content, were extracted and pasted into a new document. The document with the extracted content and the original interview transcript was electronically delivered to the participant who then had the opportunity to add, delete, or otherwise modify the content. Typically, the changes that the participants made were in the form of semantics like changing “kids” to “students”. In some cases, content was added to increase clarity of their ideas. Very little if any content was removed by any participant.

Interview 1. Interviewee 1 has a B.A. in Secondary Education with endorsements in Mathematics and Computer Science and an M.A.T. in Mathematics with an emphasis in Computer Science. Currently, he teaches Computer Science at a Magnet High School in a large metropolitan area. He has participated in a RET (Research Experience for Teachers) related to integrating Computer Science research and practices into the high school curriculum. Interviewee 1 was a NCWIT (National Center for Women & Information Technology) Teacher of the year and has been a CSTA (Computer Science Teachers Association) chapter president, as well as a member and presenter at NETA (Nebraska Educational Technology Association). He brings a wide variety of integrated STEM experiences into the classroom.

Perceptions of integrated STEM education. Interviewee 1 sees integrated STEM education as more than just the individual disciplines. Teachers must go beyond their content. Integrated STEM is about students working on projects that require more than a single STEM discipline to complete. The projects are often open ended and do not necessarily have nice answers. In an integrated STEM environment, collaboration between teachers and curricular areas is necessary with each teacher being aware of what other teachers are doing so that relevant connections between content can be exploited. School leaders must trust teachers as well as teachers trusting students. Finally, technology classes are not integrated STEM classes. It takes input from all the STEM disciplines to become integrated STEM.

Creation of integrated STEM. It takes willing teachers working as a cohort with an administration that supports and allows integrated STEM. Students need time to explore content in an open-ended nature as well as access to the Internet with fewer restrictions. Interviewee 1 believes that anyone can teach integrated STEM, but for it to be successful you need "buy in" from the entire staff. In addition, some specialists (computer science or engineering teachers) might be needed. Certification of integrated STEM is a challenge, because STEM classes will not necessarily fit into one certification. It should be noted that a lack of certification should not preclude a teacher from teaching an integrated STEM class, because there are capable teachers in other areas who can teach integrated STEM. Most facilities will work as an environment for integrated STEM, but you will need a flexible space. Teacher preparation is essential but it must be focused. Current and pre-service teachers can use extra training to gain experience with integrated STEM education, and teacher preparation methods need to adapt for integrated STEM to be successful.

Implementation of integrated STEM. Integrated STEM takes cohorts of teachers across disciplines, who are willing to try new things and are committed to integrated STEM education. These cohorts need to collaborate to create ideas for problems that students can attempt using STEM content. During this collaboration, teachers need a dedicated block of time. In addition, changes related to scheduling of the school day need to be considered. Educational stakeholders need to consider the possibility that not all current curricular objects will be covered every year as projects, students, and solutions change. Interviewee 1 believes that integrated STEM is a core concept that works best in an elective setting since teachers of elective courses have the freedom to explore ideas rather than teach specific topics.

Integrated STEM assessment. Assessments of integrated STEM need to be project-based or portfolio-based, where students have to define and solve real world problems. Assessment strategies could include interviews and rubrics. Many standards are vague enough to be matched to an integrated STEM curriculum. However, standardized testing is not ideal for the assessment of integrated STEM. These types of tests need to change to ask more problem solving questions. Assessment is the hardest part of integrated STEM because assessments will not be neat or tidy. To conclude, Integrated STEM is just good education and we must be careful not to exclude areas like the arts, English and history. Ultimately, integrated STEM should make students critical thinkers and problem solvers.

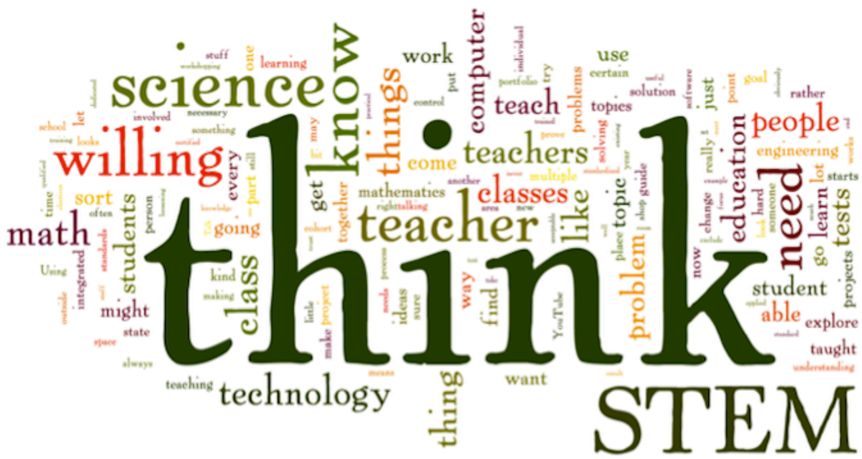

Figure 4. Wordle for interview 1 summary.

Interview 2. Interviewee 2 has a B.S. and M.S. in Biology. He went through a Teacher Academy Project to gain the necessary educational pedagogy and become certified to teach. Interviewee 2 is pursuing a Masters degree in Computer Science. Currently he is the Computer Science education support staff at an urban university. Before this position, he taught at a suburban high school and sponsored STEM activities including rocketry and computing. Interviewee 2 was a NCWIT (National Center for Women & Information Technology) Regional Educator of the Year, and has participated in a RET (Research Experience for Teachers) related to integrating research and practices into the high school curriculum. He has received grants from a state Educational Technology Association, the Omaha Armed Forces Communications Electronics Association, and a local school foundation.

Perceptions of integrated STEM education. Integrated STEM is solving larger problems by taking concepts from different areas and it requires the activation of prior knowledge to design a solution to a problem. Students are given a chance to work on a larger scope using multiple pathways to solve a problem. The projects that students are engaged in require concepts from multiple areas to be completed.

Creation of integrated STEM. Integrated STEM is a real world, rich educational experience for students. It requires cooperation on the part of all participants to complete an open-ended project with a larger goal. Time and resources are necessary for integrated STEM to take place, with local businesses being a possible resource for integrated STEM. Teachers need to be comfortable with a lot of different material to teach integrated STEM and training needs to be available for those teachers. That training should be conducted in project-based learning with time for teachers to think about and to design these types of activities. Workshops and practicum experiences are valuable for training. Teachers need time to collaborate and share ideas. Teachers also need to be flexible and be willing to investigate content that might not be part of their core area. Integrated STEM needs to have smaller classes to function optimally. Certification to teach integrated STEM is not necessary at this time. The classroom space for integrated STEM needs to be in a shop-like setting.

Implementation of integrated STEM. To implement integrated STEM, you need to find an idea driven by the content or identify areas where integrated STEM activities could fit into the scope of the curriculum. Integrated STEM teachers need to focus on a single aspect of the curriculum at first and go from there. When developing a class, make sure that objectives can be met by all learners by adapting projects for different levels. Next, develop a framework, try it out, fix mistakes, learn from it, and be willing to change. This means that implementation of integrated STEM is iterative in nature. Integrated STEM is an attitude rather than what is taught, so anyone can do it. It best fits as an elective in the upper levels, but could be incorporated into every class through targeted implementation. It should not replace science and math and can fit anywhere engineering design projects are appropriate. The time, finances, space, and resources being set aside by schools are currently lacking.

Integrated STEM assessment. Assessments should be project-based, use teacher developed rubrics, and have a student evaluation component. Traditional quizzes and tests will not work since they tend to focus on factual knowledge. Assessments must reach higher levels of thinking such as application and synthesis. Standards might be mapped to integrated STEM, with projects being designed to capture content related to standards within the assignments. In addition, evaluation can be formatted to draw attention to the standards within the project. Integrated STEM could be detrimental to standardized testing unless it is carefully crafted, because STEM assessments look at the big picture rather than specific content. National standards can be addressed through rubrics or student reflections guided toward those standards. When considering assessment, it is critical that students be asked to reflect on what they are doing/have done. To conclude, integrated STEM is time consuming and must push students to higher levels of thought to be successful.

Figure 5. Wordle for interview 2 summary.

Interview 3. Interviewee 3 has a B.S. in Mechanical Engineering, a M.S. in Mechanical Engineering and a Ph.D. in Mechanical Engineering. Currently, she is the Executive Director for a STEM education center at a small East coast institute as well as an adjunct faculty member of a post-secondary mechanical engineering department. Interviewee 3 has numerous awards including being elected an American Society for Engineering Education Fellow. She received a Distinguished Service Award from the Women in Engineering Programs and Advocates Network, a Special Recognition and Outstanding Teaching Awards from an East coast private research university, and a Tech Alumni Achievement Award from an East coast public research university. Interviewee 3 is in the leadership of the American Society of Engineering Education and is a member of ITEEA, Tau Beta Pi, WEPAN, NSTA, and NCTM.

Perceptions of integrated STEM education. Integrated STEM uses science and math knowledge while following the engineering design process to complete a project and create an artifact in the process. Students do not learn subjects independently. Rather, the knowledge that the students are learning is all related and directed toward an end goal. Integrated STEM is the application of knowledge where students must see connections of the subject areas to solve problems. Integrated STEM is project or activity based and is active rather than passive. It requires the use of math and science along with technology to gather or test solutions. Finally, it is important that students understand and buy into whatever activity or project that is being created.

Creation of integrated STEM. To create integrated STEM it takes educators who are willing to give up their areas of expertise and collaborate with others. In addition, core concepts need to be taught in different ways. Students need access to tools (technological and mechanical) and instruments for making measurements. The classroom is non-traditional with a large project space. It needs to contain a good technology/engineering facility, and the science classrooms need to be adequately equipped. Teaching staff does not need to change, but teachers do need to be willing to work together. STEM certification is not required, but teachers need a depth of knowledge about one discipline and need to be willing to work with other experts. Professional development for teachers needs to occur. To help facilitate professional development, great teachers who are already implementing integrated STEM need to be identified and then used as resources for professional development. Professional development needs to include integrated experiences for teachers where they can see and feel what it is like. Teachers in professional development should play the role of the student while going through the integrated design process to complete an integrated STEM project. Finally, administrators must buy in to integrated STEM and give multi-disciplinary teams of teachers shared planning time to talk about content and the students that they are teaching.

Implementation of integrated STEM. Implementation can be done by a single teacher or by teams of teachers. It will have to consist of project-based activities that tie relevant content from the subjects together. Implementation will need to be strategic and longer blocks of time would be beneficial for an integrated STEM curriculum. The teachers would primarily be math, science, and technology shop teachers (possibly engineering teachers) who get students to think through problems, ask questions, and gather and test data to come up with solutions that are usable. Integrated STEM is a core class with the separate core classes working together for a common goal. The depth of knowledge in each individual course brings strength and validity to integrated STEM. Implementation of integrated STEM would be enhanced if teachers had the opportunity to have a truly rich experience doing an integrated STEM project. This will help with both teacher and student buy in; without buy in integrated STEM will not happen.

Integrated STEM assessment. Integrated STEM assessments needs to focus on the practices. Assessments need to include a way to determine the depth of knowledge in each STEM area that students used when they were working on their projects. This can be done by having conversations with students and providing interactive experiences where students are manipulating things and explaining why they are doing what they are doing. Students should be able to argue from evidence and use mathematical, physical, and software modeling to demonstrate knowledge, and the assessments should reflect that. Integrated STEM curriculums will not fit the current standardized testing model. However, there is a chance if integrated STEM is done well with the teacher highlighting the concepts that are tested, students will perform well on standardized tests. Ultimately, a lack of good assessments is what will hinder the implementation of integrated STEM, because if you cannot assess it properly you cannot prove that it improves student performance. To conclude, integrated STEM is a great thing for the learner because it finally gives relevance to content, and is an engaging way to learn. It could lead to more people opting into STEM fields or being more informed, literate citizens about technical subjects.

Figure 6. Wordle for interview 3 summary.

Interview 4. Interviewee 4 has a B.A. in elementary education, a secondary mathematics endorsement and a M.A.T. in mathematics. She currently serves as a STEM teacher in a large metropolitan school district. Interviewee 4 is also a member of a state Teachers of Mathematics organization.

Perceptions of integrated STEM education. Integrated STEM connects different content areas that students are studying and might find interesting as careers. It provides an opportunity for students to see mathematics in a useful setting other than direct instruction. Integrated STEM brings different content areas together where they were previously separated. Components of integrated STEM include: meaningful student experiences, student driven data collection, opportunities for students to get involved with outside experts from business and industry, performing investigative tasks, and giving students a chance to try things in a safe environment. Integrated STEM must focus on learning goals. It is a method of teaching rather than what schools are teaching which requires an application of content using a problem solving approach. Finally, it is important for students to "buy in" to integrated STEM and know why schools are doing this.

Creation of integrated STEM. To create integrated STEM, it takes time to collaborate and plan, as well as creativity on the part of teachers. Teachers must have the same STEM skill set that we are asking of STEM students. It takes commitment from teachers to try new things. Teachers must be willing to spend time collaborating to find the meaningful connections between content that can be exploited. It takes commitment from school districts to support the initiative by providing teachers the necessary professional development, time and resources, as well as commitment from the community in terms of providing support and resources (personal, physical, and financial). To create integrated STEM, it takes an individual decision to attempt STEM education with a push to go ahead and start. You must have clearly defined goals of what integrated STEM education is and what you want to accomplish. School structures might need to be changed to allow longer blocks of time for students and teachers. If teachers are team teaching, class sizes might be larger with multiple instructors present in the class at the same time. Integrated STEM is core content in the school that replaces algebra and physics for freshman, and geometry and computer science for sophomores. As juniors and seniors, students can take STEM electives. Certification in STEM education is the next logical step for teachers to gain the experiences necessary to teach integrated STEM. Integrated STEM is expensive to accomplish but it is worth it. To create integrated

STEM, you need to seek outside funds from the community and through grant writing. Passionate leaders are important to support the cause of integrated STEM education. As you continue, you need to be consistently revisiting your curriculum and be in constant collaboration with the community. Teachers need training in pedagogical methods for instructing integrated STEM. Ultimately, you must get teachers and administrators onboard and as part of the process you must create a goal and take a risk.

Implementation of integrated STEM. To implement integrated STEM, it takes all stakeholders supporting it, school leaders, teachers, parents, and community members. As teachers, you need to constantly educate and talk about why and how to do integrated STEM. Invite parents into the classroom. Take pictures. Post blogs. Start by writing a goal, getting people onboard, and stick to your clear-cut goals for what you want your outcomes to be for your students. Then, constantly revisit the curriculum and structures to make sure that they are geared toward your goal. Flexibility in student scheduling is important in order to allow students opportunities to take STEM courses. Teachers have to be willing to try teaching integrated STEM but need to understand that there is less structure in these types of classes. Teachers must know their outcomes and essential learnings and be constantly checking to see if they are on target. Ideally, integrated STEM would be an elective but that is much more expensive. Teachers must be trained, be willing to collaborate, and be creative as they work with businesses and industry. In an integrated STEM course, students should be working on projects that they design and implement. Ultimately, a capstone project for a course should be completed by students.

Integrated STEM assessment. Assessments should be a mix of traditional and non-traditional activities which would be project-based. The “soft skills” students are developing need to be assessed in some way. The projects students complete should be a large part of the grade. Things like professionalism while working with community members should be assessed and graded. Assessments need to be hands-on projects that demonstrate applications through real world experiences. Standards can be matched by tracking student progress, through testing related to those standards, and how STEM students' skills compare to their non-STEM peers. Integrated STEM curriculums must align with standards in order for STEM students to do well on standardized tests. Because of standardized testing, when replacing a core class with a STEM class, you must make sure that STEM classes reach the same outcomes as the core class that it replaced. If it is an elective, these restrictions are eased. Anecdotal evidence at my school shows that students taking integrated STEM courses are better problem solvers and more persistent related to problem solving than non-STEM peers. STEM is a way of thinking or teaching rather than content, and it is not just for "honors" students. It must include a problem solving approach, a team building approach, and a willingness to step outside of your comfort zone to try something new.

Figure 7. Wordle for interview 4 summary.

Interview 5. Interviewee 5 has a B.S. in secondary education, a M.S. in secondary education, and a Ph. D. in teaching and learning. Interviewee 5 is currently a senior administrator within a state education agency who oversees all content areas.

Perceptions of integrated STEM education. Integrated STEM is not a content. Rather, it is an approach to teaching and the application of content beyond the classroom. Integrated STEM is how all the content areas interact in an authentic manner and how they are applied in non-classroom settings. Integrated STEM includes: integrated STEM pedagogy, authenticity, relevancy, and broad applications of scientific principles. Authentic experiences must be created for students similar to those that could be actually utilized in a real life setting. We must learn to teach all content through the context of other subjects. There is disagreement on what integrated STEM is and it is challenging to articulate exactly what it is without understanding the context. A debate is on-going about whether it is a set of knowledge or a pedagogical approach to teaching.

Creation of integrated STEM. To create integrated STEM it takes authenticity, collaboration, and opportunities for teachers from different content areas to work together to create relevant experiences for students, as well as teachers who understand multiple content areas. All teachers need to see themselves as STEM teachers. Schools need to reach out to the community for expertise while looking to form partnerships with business and industry. Teachers need professional development and time to collaborate. The professional development should provide teachers with a pedagogical approach to teaching the integrated STEM content and instruction as to how it can be applied in the classroom. With these types of experiences, teachers will begin to think of themselves as STEM teachers and see how they can use STEM concepts to help students become

STEM capable. Since integrated STEM is an approach to teaching rather than content, instructional coaches are needed to help facilitate understanding of pedagogical approaches of integrated STEM. STEM certification and STEM standards are not needed. Facilities that are required for integrated STEM vary depending on the content being taught or project being worked on by students. Finally, integrated STEM needs marketing to teachers and students.

Implementation of integrated STEM. Integrated STEM is an approach to teaching that needs to show how content areas are connected by showing applications beyond the classroom. Schools need to provide teachers with the opportunity to view and participate in team teaching experiences with common plan time and collaboration built into the schedule. Integrated STEM can fit anywhere in the curriculum but it must be intentional.

Integrated STEM assessment. Assessments must move to competency-based models that use authentic assessments. Assessments need to access the problem solving and critical thinking skills of students. A possible assessment technique for students would be for them to create a portfolio with artifacts that demonstrate innovation and creativity, as well as the STEM skills and capabilities they have learned. Matching integrated STEM to current standards is tough because a standard focuses on learning outcomes, and Interviewee 5 thinks of it as a process that is used to reach a content standard. If integrated STEM is a content, then it does not fit into a standardized testing model. If we are going to call integrated STEM a content, suitable standards and standardized tests will need to be developed. However, this is undesirable. To conclude, we need to discuss what integrated STEM really is and how to integrate STEM capabilities and skill sets throughout all content standards. Teachers need help recognizing that all teachers are STEM teachers. Finally, integrated STEM must be project-based.

Figure 8. Wordle for interview 5 summary.

Interview 6. Interviewee 6 has a B.S. in mathematics education, a M. S. in mathematics and science education, and a Ph.D. in education with an emphasis in curriculum. Currently, Interviewee 6 is a Professor of mathematics education at a large urban University. He has authored over 130 STEM-related publications and is an active grant director. Interviewee 6 has received various awards for his work, including a Chancellor's Medal, the Alumni Teaching Award, the Distinguished Research and Creativity Award, a state Technology Professor of the Year, and the NASA Mission Home Award.

Perceptions of integrated STEM education. Integrated STEM is where the STEM disciplines are truly taught in an interdisciplinary way. It breaks down the artificial barriers between subjects, with deeper mathematical connections and understanding being achieved through the use of science or engineering. Technology enhances the problem solving and/or engineering design process. Integrated STEM needs to be more focused on inquiry and problem solving within the context application. It is interdisciplinary, hands-on, and flexible. The integrated STEM approach is starting to break down discipline barriers.

Creation of integrated STEM. To create integrated STEM, school leaders and teachers must be willing to give up “turf”. It also requires a variety of shared experiences. Integrated STEM will require faculty interdisciplinary specialists and STEM-oriented curriculum directors with a vision for integrated STEM. These leaders need to bring down artificial barriers and keep the faculty and students informed on the bigger picture. Teachers and subject level departments need to help initiate innovation. Integrated STEM will require flexibility in how it is taught and how it is credited to student transcripts. STEM classes like computer science and engineering need to be offered for core content graduation credit. Computer science and engineering certifications need to be created since these areas are an area of national need. Professional development needs to focus on what teachers can use in their classroom and how they can use it. Curricula need to become less dense. Schools need to stop covering so many topics superficially and cover fewer topics in a much deeper way. Finally, it appears that momentum is changing toward STEM education, as conversations are dynamically shifting in high schools and universities.

Implementation of integrated STEM. The implementation of integrated STEM takes a STEM presence and advocacy. It also requires a STEM leader and an interdisciplinary committee. Schools need to have better department structures so that each department does not defend “turf”. Instruction needs to be inquiry or problem-based in nature and include the engineering design process. Technology can be used to handle rote tasks. Instructors of integrated STEM need to have an expertise in a STEM discipline but must also think of themselves as STEM teachers. The curricular structure of schools must evolve to include joint planning time for teachers. It also must consist of super units (big projects) for students that include high energy/excitement environments. Integrated STEM should be a core class or a set of interconnected classes. Everyone worries about implementation of integrated STEM and what that implementation looks like. Regardless, that implementation needs to be more flexible and incorporate an interdisciplinary environment.

Integrated STEM assessment. Integrated STEM assessments need to be project-based and/or problem solving based in nature and it must include higher-level inquiry. Part of the projects need to include student presentations of their work. The projects need to demonstrate connections and understanding of content with less emphasis on multiple choice testing. Standards are changing to fit integrated STEM with more problem solving and multiple representations being present. If you look at the standards narrative, it says standards can be taught in larger environments like integrated STEM. Integrated STEM will help rather than hinder standardized testing since these tests are increasingly about higher level thinking skills. Integrated STEM with problem solving and engaging content will help develop these higher level-thinking skills. Integrated STEM is about how you teach content for a deeper understanding. This means that curricula need to change to be integrated and interdisciplinary. When considering national standards, higher order thoughtful questions and rubrics can be used to relate student learning to those standards. We need to move away from arbitrary homework, quizzes, and tests. As a result, a standardized STEM assessment is worth considering. Finally, the politics seem to be shifting toward integrated STEM. Integrated STEM is a more dynamic engaging way to learn and students and parents are beginning to see the relevance of integrated STEM.

Figure 9. Wordle for interview 6 summary.

Interview 7. It should be noted that Interviewee 7 did not respond to the opportunity to add, detract, or retract any of the interview initial analysis. The researcher is considering this non- response, as meaning no changes were needed. Interviewee 7 has a B.S. and a M.S. in education with specialization areas of mathematics, physics, and computer science. He also holds a certification in network management from Cisco System. Currently, he teaches science and technology and is the technology director at a parochial high school in a large metropolitan area. Interviewee 7 has taught on-campus and on-line courses in mathematics, science, education, and computer technology for several metropolitan universities and community colleges. He has served on many advisory boards and writing teams including a State Association of Teachers of Mathematics, a State Mathematics and Science Frameworks, a State Mathematics and Science Coalition, and the Education Council of a State Technology Commission.

Perceptions of integrated STEM education. Integrated STEM is bringing math, science, engineering, and technology into all classes where they apply. It gives students the opportunity to investigate a broader topic, which has STEM components. Classroom activities are focused on a particular topic and are longer-term with a project-based nature. Integrated STEM needs to be student centered, student driven, project-based, and designed to demonstrate the application of skills. It can be set in an extracurricular club or competitive contest. Integrated STEM is actually looking at content in a very careful way while expanding the content and skill base.

Creation of integrated STEM. To create integrated STEM, it takes leadership from the administration, teachers, and students. In addition, the administration must see the importance of STEM experiences for students. Time will need to be provided for coordination and planning for teachers. Teachers must be dedicated and able to motivate students to take STEM classes and to engage students in STEM classes. Integrated STEM can be created with minimal physical resources, but time is critical for the teacher and students to engage in the activity. Other resources may vary widely depending on the project and the students' interests. To create integrated STEM, we need to think about it as if we were thinking about athletic programs, where it is just assumed that people will be working after school. This means that we will need to staff integrated STEM outside of the school day. We also need to hire people or train people with the needed background to teach integrated STEM. A general STEM certification might be possible, but an integrated STEM certification will be difficult in terms of the required comprehensive content knowledge. In the classroom, there needs to be an engineering space for project-based work and a place where groups can meet. Teachers and pre-service teachers need professional development related to the experience of completing an integrated application based project. Teachers need to develop a passion by deciding what they really enjoy doing, and developing that for their classrooms.

Implementation of integrated STEM. The implementation of integrated STEM takes a real desire and motivation from the adult leader to want to make integrated STEM happen. Integrated STEM can be implemented through after school programs, extra-curricular activities, and competition teams. During the school day, STEM topics can be integrated into existing STEM courses; for instance integrating engineering into computer science topics or integrating computer science into biology. It might also be possible to create an integrated STEM course over time that has meaning, but the challenge is - will colleges and employers know what it is? Schools do not have to change structurally because integrated STEM can be done within the school through after school programs. However, more integration and open-ended opportunities for students in the curriculum would be beneficial. It helps teachers of integrated STEM to have a particular skill set in STEM areas, but all kinds of people teach, moderate, and lead good STEM programs. One consideration for implementation is that integrated STEM might not be content based. Rather, it could be process based instead.

Integrated STEM assessment. To assess integrated STEM, we can look at where students end up five years after program completion. More immediate assessments can be conducted through student resumes, student portfolios, amount of shared work, and community presence and engagement. Other assessment strategies need to be project-based, portfolio-based, or competition based activities. Ultimately, assessments need to model the career field that students will enter. Standards might be able to be matched by integrated STEM if we look at the process standards. In integrated STEM, the only thing that you can really assess is the process, because you do not really know the content in all cases. Integrated STEM will not fit into the current standardized testing model. Finally, one concern is student motivation. Student motivation is difficult in all classes and integrated STEM might help address the motivation issue.

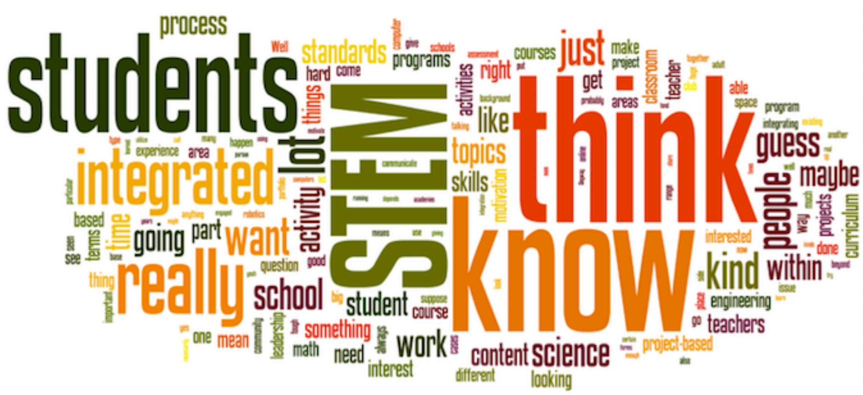

Figure 10. Wordle for interview 7 summary.

Interview 8. Interviewee 8 has a B.A. in elementary education and special education and a M.A. in curriculum and instruction. He was a career teacher at the elementary level in a large metropolitan school district. Currently, Interviewee 8 is an instructional technology design / training specialist at an urban university. He has received numerous teaching awards including a Kiewit Teaching Award, a US West Technology Application Award, a School District Foundation Award and an Addy Public Service Announcement Award. Interviewee 8 is a member of the Nebraska Educational Technology Association and the International Society of Technology Education.

Perceptions of integrated STEM education. Integrated STEM education takes place in an open-ended classroom where the STEM disciplines are integrated within the school day. It involves solving real world problems and working collaboratively in groups where students utilize their knowledge of STEM content. Students must think critically and creatively using technology and research to solve real world problems. Large blocks of time are required for students to work and learn. Teachers need time to write, test, and examine the curriculum. No assessments that we have today are geared toward a student integrating and understanding STEM content.

Creation of integrated STEM. To create integrated STEM, it takes creative people who are willing to collaborate. School leaders are needed to support and guide the process. Curricula and attitudes of stakeholders need to change. Integrated STEM must come from a grassroots push, so that it can be embraced by the school and community. It will require intangible money spent on teachers, thinking, creating, writing, developing curriculum, as well as buying different technology and educational materials. To lead the creation of integrated STEM requires practical visionaries who can demonstrate what integrated STEM looks like in the classroom. Administrators must find a gain in student achievement for them to support integrated STEM and governmental policy will need to change. Certification could be a specialty area but STEM certification is not necessary. We need a dedication to the philosophy of integrated STEM rather than certification. Integrated STEM can be thought of as a business model, but it does not have to be expensive. Students need to communicate and collaborate to develop STEM knowledge. Teacher preparation needs to demonstrate tangible examples of what integrated STEM looks like and needs to draw on others' experiences to understand integrated STEM. To truly create integrated STEM, we must find examples of it being done in a classroom and learn from those experiences. By looking at student test scores, data to support the adoption of integrated STEM can be found.

Implementation of integrated STEM. To implement integrated STEM we must find the research that says integrated STEM is a good educational practice. The concept must be sold to all stakeholders to change the minds of school leaders and teachers. School days need to be restructured so that large blocks of time are available and they become less rigid and segmented. Teachers need to have a deep understanding of curricular areas and they need to have enthusiasm for integrated STEM. The secondary level is the most difficult level to implement integrated STEM, because of the structure of the school day. Teachers of integrated STEM need to be dynamic educators who think creatively. The lessons that they develop need to be project-based and outcome-based real world projects. Integrated STEM is a track for students to follow rather than a core or elective class.

Integrated STEM assessment. Current assessment techniques need to be reworked, and the emphasis on the types of assessments we currently use should be less. Integrated STEM assessments should consist of project-based, product-based, or outcome-based experiences and include student demonstrations of what they know by building, creating, changing, or adapting something as part of that assessment. Integrated STEM needs to arm students with more than content knowledge. Students need to become critical thinkers and collaborative workers; assessments should exemplify those skills. With careful thought, current standards can be matched to course outcomes and activities that address the skills required within the standards. There is a need for standardized testing to assess content knowledge, but also there is a need for project-based assessments that address those STEM skills not easily tested using standardized testing. If a curriculum is written correctly and it weaves critical learning outcomes into an integrated STEM environment, integrated STEM content can be created that addresses national standards.

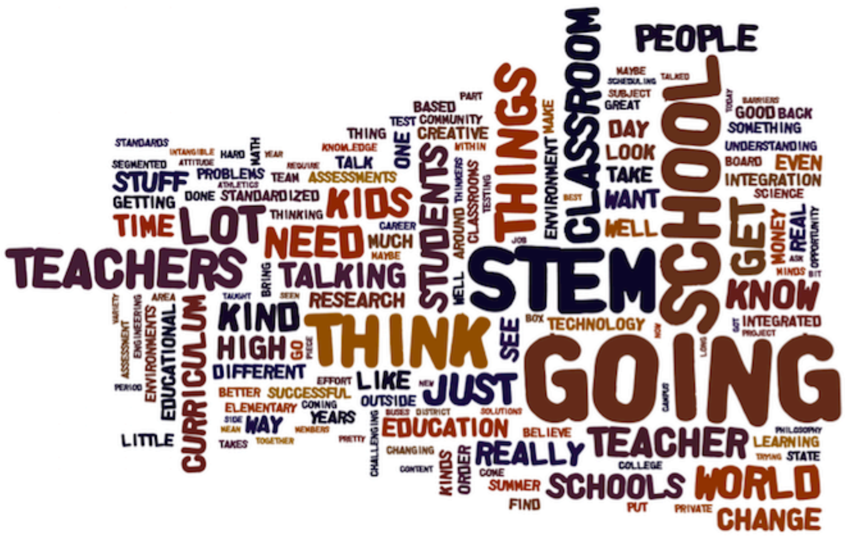

Figure 11. Wordle for interview 8 summary.

Interview 9. Interviewee 9 has a B.S. in education with a biology endorsement, a M.S. and Ed.D. in educational administration. Currently, she serves as a director of education at a large metropolitan zoo. Previously, Interviewee 9 taught high school biology for six years at a large metropolitan high school. Interviewee 9 has served as the director of the informal science division on the Board of National Science Teachers Association (NSTA) and has been elected to leadership position with the National Science Education Leadership Association (NSELA). Interviewee 9 has received numerous honors and awards including a Distinguishing Alumni Promising Professional Award from a large urban University, a state Academy of Science Friends of Science Award, a state Association of Teachers of Science Business Partner "Catalyst" award, and a Phi Delta Kappan "Outstanding Service to Education" Award.

Perceptions of integrated STEM education. Integrated STEM education integrates all the core areas of the curriculum while bringing in literacy. It combines all the knowledge that students are learning and builds upon what they have learned through their experiences to be able to apply knowledge and solve real-world problems. Integrated STEM needs to include problem solving, application of knowledge, and literacy (reading and writing). It cannot be centered in the formal education setting. Many STEM experts are in businesses, universities, or informal science organizations that need to be included in integrated STEM education. In addition, current research related to integrated STEM education must be incorporated.

Creation of integrated STEM. To create integrated STEM, it begins with the educator. It is a totally different mindset and paradigm shift in the way of teaching. Integrated STEM is experiential learning either in project-based or problem-based settings. The creation of integrated STEM takes a cast of different people who are open minded to developing new ways and techniques for teaching students. Outside experts can be brought into the classroom to help facilitate integrated STEM. Partnerships need to be built and utilized between schools and business and industry leaders. Educators from the traditional classroom often lack the skills needed to facilitate the educational process in integrated STEM environments and to be able to create problem-based, relevant application problems and lessons. This means that professional development needs to occur to provide teachers experience with problem based learning, project-based learning, or experiential learning. Real world experiences can help teachers build the activities and lessons that are needed for the integrated STEM environment. Non-traditional teachers are often able to fill the role of integrated STEM facilitator because of their real world experience. To teach successfully in an integrated STEM environment, you need to have some skills, abilities, knowledge, and background in all the STEM areas. Certification for integrated STEM would be great, but be sure not to discount people who do not have a STEM background. Schools in integrated STEM environments need to replicate what is happening in the business and industry world. It should look like business and industry with the school providing students experiences that model a STEM business. Software and hardware can become quickly outdated, so sustainability plans need to be in place with the business and industry partners helping with training on new equipment. Professional development is constant and ongoing and needs to replicate real-world experiences for teachers, so they gain a better understanding and can teach from experience. Collaboration is critical.

Implementation of integrated STEM. The implementation of integrated STEM takes many years of work. You must get the stakeholders together and develop a vision and goal. Staff needs to be selected or trained to implement that vision and goal. Staff must know how to use and locate the resources necessary to implement an integrated STEM curriculum and outside experts can be a part of that. After starting, yearly reflections can let you see where you have been, where you are, and where you need to go. Implementation takes flexibility, different teaching pedagogy, co-teaching, and team teaching. An eight period bell schedule does not tend to work for integrated STEM. Primarily the teachers will be math, science, and CTE or industrial technology teachers but all teachers can play a role. Integrated STEM is an elective that is a career exploration pathway for students. To implement integrated STEM, it takes money, time, effort, and the right combination of people. Integrated STEM can be an amazing thing.

Integrated STEM assessment. Assessment of integrated STEM will look very different from current assessments. Assessments can be part of a certification process or an associate's degree. Assessments would be project-based or problem-based activities where students are exploring, asking questions, and solving a problem that will culminate in a capstone project. Possible assessments include a student portfolio of work, using rubrics, student presentations, or students actually doing and applying knowledge. The next generation science standards would align nicely with integrated STEM but state standards could be tricky. Standardized testing would be difficult to match with integrated STEM, but it is possible that standardized questions could be written that look at application of knowledge that would better assess integrated STEM. Integrated STEM needs performance expectations aligned to what is going on in the real world workforce, which the integrated STEM classroom is trying to replicate and model. To assess integrated STEM well, we need to get creative with what we consider assessments.

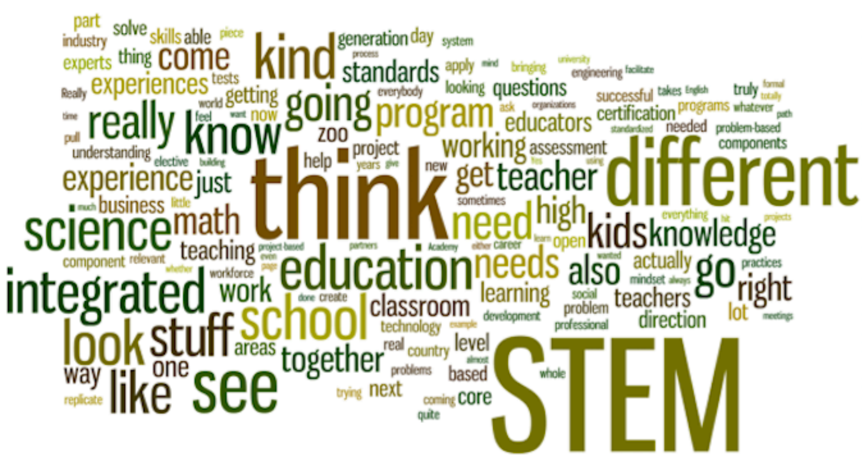

Figure 12. Wordle for interview 9 summary.

Interview 10. Interviewee 10 has a B.S. in electrical engineering and worked as an engineer and project manager for Raytheon and Bechtel. He also has a M.S. in special education – learning disabilities and is a doctoral candidate in educational leadership with an emphasis in STEM education. He taught a STEM based elective course in a large metropolitan school district for nine years. In addition, Interviewee 10 worked collaboratively with an urban university's college of education and engineering to develop and implement the use of robotics as an educational platform. Currently, Interviewee 10 is a K - 12 engineering education instructor at an urban university. He is a member of the American Society for Engineering Education, the International Technology and Engineering Educators Association, and the Association for Supervision and Curriculum Development.

Perceptions of integrated STEM education. Integrated STEM education exposes, engages, educates, and empowers students through application of knowledge using the STEM disciplines. It is taught in an experiential manner through application of knowledge. Integrated STEM utilizes STEM fields to demonstrate challenges in our world in a practical, applicable means. The engineering design process serves as a framework for a challenge or project in which there is evident interdisciplinary support and use of the STEM fields. Teachers need to collaborate with others that have an expertise that they do not. Teachers also need to deeply understand the requirements for science, technology, and mathematics at their grade level. Finally, the more experience a teacher has with the integration of the STEM disciplines, the more successful STEM education will become.

Creation of integrated STEM. To create integrated STEM, students need to be exposed, engaged, and empowered by knowledgeable, innovative educators. The instructor is critical and must have adequate professional development. Professional development is the instructional support that allows a teacher to feel comfortable and credible in an integrated STEM classroom. Additional degrees with a STEM concentration are a viable method to gain additional experience. There is a core knowledge required for true understanding of integrated STEM. Universities need to take the lead and implement programs where teachers can gain this knowledge. Community members and working professionals are an additional resource that is necessary for integrated STEM. These professionals can assist the teacher with the projects and expose students to real life situations, where the knowledge they are learning applies. Internships and service learning is a good way for students to apply their skills and to work on real world challenges facing their community. Integrated STEM needs the support of the administration and all the teachers in the building. Anyone can teach integrated STEM, provided they have been given the proper professional development. The expense related to integrated STEM does not have to be prohibitive. If financial resources are available, upper grade levels could utilize access to technology being used within the business world. Certification and standards need to be developed for the implementation of integrated STEM.

Implementation of integrated STEM. To implement integrated STEM, all involved parties (teachers, administrators, community, school board, etc.) must be involved and collectively decide what it is that an integrated STEM program is trying to accomplish. Collaboratively, a mission must be established with curriculum generated based on that mission. Specific materials cannot be identified until a goal/mission has been solidified. In schools, there needs to be more interdisciplinary planning time, more collaboration, and more partnerships. Integrated STEM uses project-based learning for the application of knowledge to learn additional STEM content. Integrated STEM is an elective course with any passionate teacher who wants to do innovative things with students.

Integrated STEM assessment. For proper assessment to take place, standards or desired outcomes need to be established. Assessments for integrated STEM must be non-traditional. Ultimately, the projects are the assessment and should represent all the knowledge and skills that students learned while working on the project. These projects should be project-based, design-based, or inquiry-based in nature. Other assessment strategies include: student presentations, student demonstrations, student explanations, pre/post attitudinal and affective assessments. Current standards can be matched using integrated STEM as long as projects are designed to cover the requisite standards. Standardized testing is not a good assessment of integrated STEM because what standardized tests measure is not integrated. Integrated STEM often has more than one answer, which is counter to multiple-choice tests.

Figure 13. Wordle for interview 10 summary.

Interview 11. Interviewee 11 has a B.S. in education, a M.S. in mathematics education, and an Ed. D.in mathematics and science education. Areas of concentration and certification are mathematics and physics with the doctoral cognate area being statistics. Currently, Interviewee 11 is a professor of educational leadership at a large urban University. He has received outstanding teaching awards at a large urban university and a large metropolitan community college. In addition, Interviewee 11 has received a Kennedy Professorship, the Milton W. Beckman Lifetime Achievement Award from a state Association of Teachers of Mathematics, and a Meritorious Service Award from the Avenue Scholars Foundation. He is a member of numerous professional associations and will serve in a leadership capacity for a state Association of Teachers of Mathematics in the near future.

Perceptions of integrated STEM education. Integrated STEM is applying information from one field to bolster content in another field and to generate new content. Specifically, integrated STEM must use didactic content from one area to support all the other areas of STEM. There are natural connections between STEM content that need to be built on using technological tools to help solve big problems in other areas. Communication is available through engineering and technology processes, which can be utilized to report findings so that communication becomes inherent to math and science. Assessment of integrated STEM needs to serve more than one academic area. Finally, integrated STEM can be thought of as a learning cycle where math creates models for the world. Science then becomes applied math. Engineering becomes applied science. Technology becomes applied engineering until new mathematical models are needed, which begins the cycle again.

Creation of integrated STEM. To create integrated STEM, specific teacher training/retraining is required either in a STEM learning cycle model or other specific integrated ideas. In addition, a comprehensive definition of integrated STEM must be identified. Professional development for teachers needs to be sustained and ongoing. Teachers need to learn how to teach mathematical topics in the context of science, engineering, and technology. Engineering, as it is often currently applied, is misrepresented and is focused on the engineering design process with haphazard implementations. Integrated STEM requires expert educational leaders with the ability and skills to guide teachers and integrated STEM implementation. Teachers with multiple degrees in different content areas or having a good conceptual knowledge of the crossover between disciplines are needed to instruct the integrated nature of STEM. Collaboration between teachers in grade level teams or professional learning communities is essential, with teachers from all curricular areas planning together to develop connections that can support each other's content area. Assessment strategies are needed to represent multiple content areas. Certification in engineering education is important and needs to be created, but technology certification is not possible because technology changes so rapidly. Engineering needs to be better represented to give a sense of why we are teaching particular math and science concepts. Concrete aspects of engineering and technology need to be available so that students can gain training/experience with mechanical training.

Implementation of integrated STEM. Implementation of integrated STEM will require teachers to be trained to carry out specific tasks. You need to start slowly with a single content area and have everyone work on that broad theme within their own content area. That content area can be extended into other areas by using project-based learning. Implementation of integrated STEM also requires more equipment, better teacher training, and better working partnerships with teacher training institutions. The entire educational spectrum must change for successful implementation to occur at the secondary level. Current teachers can be trained to teach integrated STEM, which must be fit into the existing curriculum through the use of professional learning communities (PLCs). Some content will have to be sacrificed in order to focus on the critical components at a more deep level.

Integrated STEM assessment. Currently, there is not a good way to assess integrated STEM, but this needs to be addressed if integrated STEM is to make inroads in schools. Assessments should ask students pointed questions about their learning and students should be able to apply content from one area into another area without specific instruction. Current standards cannot be matched using integrated STEM because standards deliberately separate topics rather than integrating them. Standardized testing is designed to pull out specific information, which is counter to integrated STEM. With a focus on higher level thinking, integrated STEM might help some national standards. We need to have an earnest attempt to find good ways to measure critical thinking, thought implementation, and integration of content from the STEM areas. As educators, we need a better understanding of assessment vs. evaluation. We need to use data to give us information about how instruction needs to be changed on an individual basis in order to help with the success of integrated STEM. Finally, STEM is not a new idea and it is worth looking at historical educational trends to see how integration was accomplished in the past.

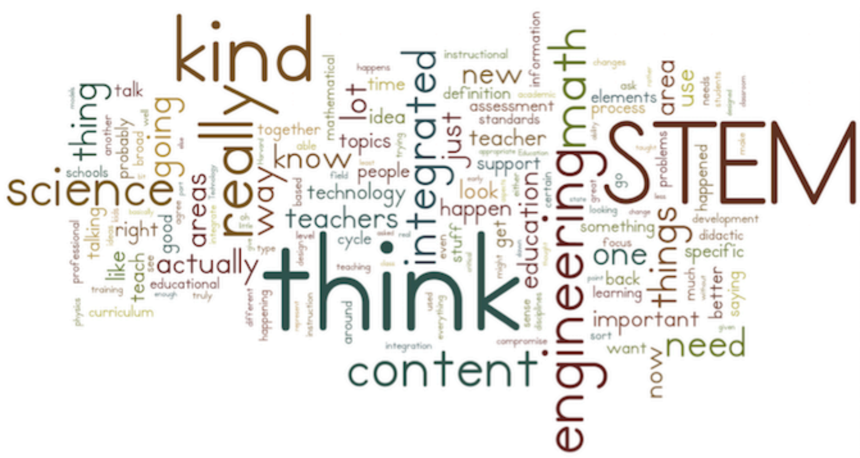

Figure 14. Wordle for interview 11 summary.

Interview 12. Interviewee 12 has a B.A. in mathematics with a dual matriculation in secondary education and a M.A. in curriculum and instruction. Interviewee 12 taught mathematics and computer science for grades 7 though college, has supervised student teachers for a major university, has served as a trainer for EQUALS and Family Math Program from the Lawrence Hall of Science in Berkley. Currently, Interviewee 12 is a Senior Administrator within a state education agency overseeing Mathematics. She has received numerous service awards from professional organizations including a NASA Education Award. Interviewee 12 has participated in the National Science Foundation Math Scholar Program as well as receiving State Honorable Mention for a Presidential Award for Excellence in Mathematics Teaching. Interviewee 12 is a member of NCTM, NATM, PDK, ASC, ASSM, and NSCM.

Perceptions of integrated STEM education. Integrated STEM requires finding applications that will integrate the STEM disciplines. Engineering is a process that supports that integration, and technology becomes a tool. Integrated STEM education occurs when science and math comes alive using technology reinforced with the engineering process, which can be applied to all curricular areas. Integrated STEM requires problem solving, real life applications, communication, multiple representations, computational thinking, reasoning, and logic. Everyone needs to be STEM literate and to be willing to work with others to solve problems using their resources and skills. It is important to relate STEM education to the business world and workforce. A common definition of integrated STEM needs to be found where everyone can find his or her place.

Creation of integrated STEM. The creation of integrated STEM requires the crafting of a definition that all stakeholders can understand and articulate. Teachers must be comfortable with themselves and their content, as well as being willing to co-teach with other teachers. Career Technical Education (CTE) teachers can be a great resource, as well as partners in business for determining necessary real world applications. The creation of integrated STEM will require large blocks of time and the rethinking of how schools systems are organized. Local businesses and professionals are resources that educators can use to help create integrated STEM. Teachers of integrated STEM do not necessarily have to be STEM content teachers, as everyone can contribute to a student's integrated STEM experience. No STEM certification is needed because it is difficult for a single person to have enough knowledge of all the STEM content areas. This is why you need a team of teachers with the necessary backgrounds to figure out how to integrate and create the projects for students to complete. Integrated STEM requires access to technology and the equipment used in manufacturing or STEM careers. Professional associations and community colleges need to take a leadership role related to professional development for integrated STEM, as well as to disseminate and support integrated STEM. Professional development needs to be constant and ongoing.

Academy schools might serve as possible models for integrated STEM education to help determine strengths and weaknesses as well as to develop professional development.

Implementation of integrated STEM. The implementation of integrated STEM requires a leader who will invest their time and energy. Collaboration and team teaching from the math, science, and CTE disciplines are essential, but be sure not to leave out other disciplines. All teachers can teach STEM related skills. If STEM were more broadly defined as a capability, then key behaviors of scientific investigation, mathematical modeling, engineering design, and use of appropriate technology would be easier to fit into all educational disciplines. Integrated STEM does not fit into the curriculum very well because our classes are currently very divided by teaching different disciplines. If more team teaching occurs, natural integration of STEM disciplines can be created, which will help integrated STEM fit into the school system. To truly implement integrated STEM, we need to have a good model in place. We need to seek out those settings where integrated STEM is taking place to see how it functions and can be modified to fit into different settings.

Integrated STEM assessment. Because there is not currently a standardized STEM test, assessment of integrated STEM can be done with students taking current standardized tests and seeing how they perform. If students perform as well as their non-integrated STEM peers, it will show that integrated STEM is successful. Beyond standardized testing, assessments need to include capstone projects for students, student inventories, and attitude and belief assessments. Capstone projects will provide quality assessments of STEM related skills and the processes that a student possesses. Current standards are just one piece of the educational puzzle; it is really how they are implemented that matters. If done carefully, it is possible that integrated STEM can serve as a vehicle for standard implementation. To conclude, integrated STEM is worth trying. The idea of integration is really important, and integration is not currently being done in our classrooms. Ultimately, for integrated STEM to be successful, someone will have to take charge and get people to create a definition and a goal.

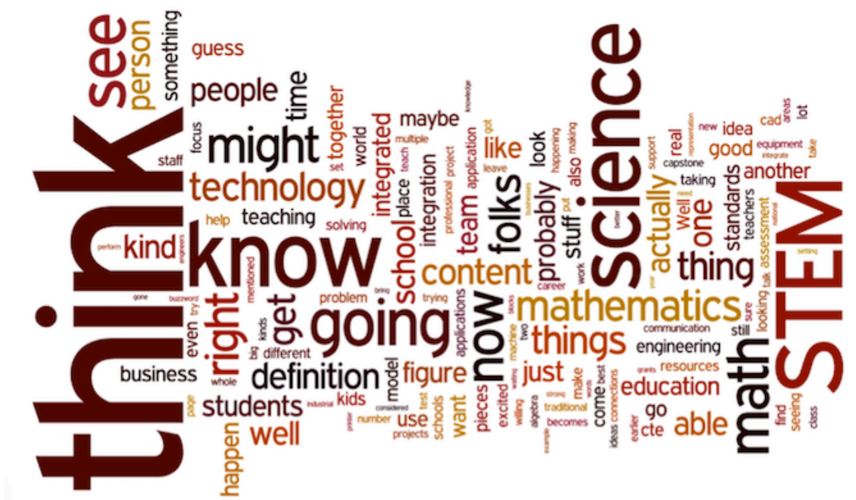

Figure 15. Wordle for interview 12 summary.

Interview 13. Interviewee 13 has an associates of arts in architecture with an emphasis in drafting, a B. S. in education with a concentration in industrial technology, a M. A. in education with an emphasis in technology education, and is a National Board Certified Teacher (Early Adolescence/Generalist). She was a career teacher at the middle and high school level in a large metropolitan school district. Currently, Interviewee 13 is an administrator of a not-for-profit corporation that is dedicated to encouraging K - 12 students to investigate and follow technical career paths by sponsoring hands-on activities in the classroom and learning activities outside the classroom. Interviewee 13 has received numerous awards including: a Distinguished Service Award, a state Industrial and Technology Education Association (NITEA) Program Excellence Award, an International Technology & Engineering Educators Association (ITEEA) and NITEA Teacher Excellence Award, an International Technology & Engineering Educators Association (ITEEA) and NITEA Outstanding Affiliate Representative, an International Technology & Engineering Educators Association (ITEEA), a Distinguished Technology and Engineering Professional (DTE) International Technology & Engineering Educators Association (ITEEA), and three Excellence in Teaching Awards from a large metropolitan school district. Interviewee 13 is also a Standards Specialist for the Standards for Technological Literacy (STL), a Technology Education judge, mentor, and presenter at the 2005 World Expo. She has been a Forum Representative for the Technical Foundation of America, Stockholm, Sweden, and served as an Albert Einstein Distinguished Educator Fellow at the National Science Foundation, Washington, D.C. She is a member of numerous professional including Phi Delta Kappa (PDK) and Epsilon Pi Tau (EPT) among others.

Perceptions of integrated STEM education. Integrated STEM education takes content from multiple disciplines and applies that knowledge toward problem solving. Integrated STEM requires teachers who are willing to work and collaborate with other teachers as a team towards the integration of STEM content. All constituents (students, other teachers, parents, administrators, community) must understand how you are using and what your definition of STEM is. All teachers have contributions to be made toward integrated STEM, from active participants who are teaching integrated STEM to other teachers who are implementing STEM strategies in their classrooms. Business and industry partners can be a good resource to provide expertise and possible access to equipment. Overall, integrated STEM is vitally important because all students need some basic literacy in STEM.

Creation of integrated STEM. To create integrated STEM, it takes collaboration, and partners outside the school, people to advise you, reaching out into the community, and school district leadership to be part of the creative team. It will take commitment from all of those involved, as well as business, industry, and community members. Any teacher who is dedicated and willing to work towards a common goal can teach integrated STEM. If there were particular content deficit areas, you would either need to train or recruit a person with the desired expertise to teach integrated STEM. Community colleges can bring needed expertise into schools and help with staff needs in STEM specialty areas. STEM certifications in selected areas needs to occur, with the possibility that STEM emphasis areas can be added to current certifications. Professional development should center around current school improvement goals. However, there needs to be continuous specific professional development in STEM content for STEM teachers that is tailored toward pedagogy, equipment, and changing technology as well. Professional development related to safety and ethics is also important. We must get students excited about STEM. We want them to want to do inquiry-based activities to get them thinking about the right questions to ask. Integrated STEM is not just for high school. It needs to be incorporated into all levels of the educational system.

Implementation of integrated STEM. To implement integrated STEM, you must start small and work toward larger pieces. As part of that process, we need to be sure that we do not devalue hands-on skills. Leaders need to consider that students and parents can help you guide implementation and decision making. Implementation must begin early in the educational process when curiosity is strong. This should get students excited about STEM, and will hopefully keep students involved in school. Classes need to be longer in length to allow students more time to think through the process. Integrated STEM is a core to the application of what students are learning. Students are currently well versed in base knowledge. However, how they use that information to make decisions is key to STEM education. Students need to know and use the entire engineering design process and learn that failure is a part of learning. All teachers in the school are experts, which can be brought into integrated STEM. Integrated STEM needs to be hands-on and is a place where students can apply knowledge. Another point of consideration is that STEM classes should be used for graduation credit as core classes.

Integrated STEM assessment. Assessments for integrated STEM need to be authentic and include things like portfolios, both physical and electronic. The assessment of these portfolios should be done throughout the project and serve as the final product. Assessments must ask questions at different levels and teachers must know what questions address higher learning. Standards can be matched with integrated STEM through teacher development of questions geared toward those standards. Standardized tests can serve to assess integrated STEM, but teachers must be cognizant of the tests students will take. National standards can be addressed more easily because they can be geared to look at large concepts. The frameworks behind the national standards can be a tremendous resource for understanding and addressing national standards. Overall, we have not thought of all the possible assessments we can use for integrated STEM. We need to get creative and develop different ways to assess integrated STEM that will measure the outcomes we desire for students.

Figure 16. Wordle for interview 13 summary.

Summary of Interview Questions

The analysis of each interview question proceeded with the researcher going back to the raw data and coding it. The process of coding each interview created a summary document for each interview question. Further analysis of the question summary document showed that many of the initial codes were related. The related codes were grouped together. Semantic analysis was utilized with the researcher applying codes to text that had similar meanings, even if the words were not exactly the same. By combining the related codes of the document together with semantic analysis, the researcher then generated themes that were representative of the respondent's comments for each interview question. Each question summary begins with a brief introduction; in some cases, a table representing the identified themes from the code groupings is also included.

Question 1. Interview question 1 was related to the participant's perceptions of integrated STEM education. Generating initial codes for the data and then combining them into general groupings was the process used to analyze the responses for this question. Below is a table listing of the most frequently stated key components of integrated STEM education. It should be noted that there were numerous other key components listed by participants that were very specific to their perceptions, like the need for a large room, specific equipment, etc. The fact that these specific items are not listed in this summary is not to discount their importance to integrated STEM education.

Table 3

Key components of integrated STEM in interview question 1.

Key component	Interview Number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Integration	X	X	X	X	X	X	X	X	X	X	X	X	X
Applications	X	X	X	X	X		X	X	X	X	X	X	X
Problem Solving	X	X		X		X	X	X	X		X	X	X
Project-based	X	X	X		X		X			X			
STEM content	X	X		X					X	X		X	
Authenticity		X	X	X	X				X				
Willingness	X	X											X
Outside experiences/Resources				X					X				X

Integration. All participants see integration as critical for STEM education. This at first might seem obvious, but the perceptions of the interview subjects related to current implementations of STEM education show that STEM has not always been seen as having been integrated. Interviewee 3 partially defined integrated STEM as follows: [integrated STEM means] "that the students don't learn the subjects independently from each other. That the knowledge that they are learning is all related knowledge toward an end goal." This Interviewee went on to state, "That is my perception of what it [integrated STEM] is, I just wished I saw it more than I actually do." Interviewee 11 stated,

> If you are talking about the assumption of integration that is a little bit different. I don't think a lot of people have really thought deeply about what STEM, integrated STEM really looks like…what it is, how it should be assessed, or indeed how it should be instructed….

Interviewee 4 defined integrated STEM as "as an opportunity for students to see connections among different content areas that previously were 'siloed' out into their own specific categories." These examples show that the integration of STEM content cannot currently be assumed. It must be actively pursued.

Problem solving/applications. Unanimously, the participants stated integrated STEM needed to include problem solving or applications on the part of the students. These two concepts have been grouped together because to truly solve problems of a complex nature you must apply knowledge. Interviewee 1 stated, "…find applications of that real world or contrived, but ways that you can demonstrate the usefulness of this in a more practical application." Interviewee 2 stated, "There is an activation of some prior knowledge." Interviewee 4 said, "Take these opportunities where students normally could not see why we do something or what it is used for and just give them a chance to do that." Interviewee 6 stated a key component of integrated STEM is "problem solving and inquiry". When referring to key components, Interviewee 12 said, "problem solving and seeing real life applications are two that should be on there".

Projects. Seven participants see projects as a key component to integrated STEM education. Sometimes the word project is specifically used, and other times it is implied.

Interviewee 1 states you must have the "understanding that projects may not be clean." Interviewee 2 believes integrated STEM is "using those things that they have learned in class to work through a much larger issue at hand." Interviewee 3 states, "It [integrated STEM] is either project or activity based." Interviewee 5 says integrated STEM "is really being able to identify how all those particular content pieces are integrated together through that experience." Interviewee 7 believes, "Integrated STEM, I think, would need to occur in a project-based activity or within a project-based, goal oriented, maybe club." Finally, Interviewee 10 says, "using the engineering design process within that framework of what's required to meet a challenge [project] and the student can learn more in a sense about engineering. "

STEM content. STEM content, is seen by six participants to be a key component of integrated STEM. Again, this might seem obvious but Interviewee 2 believes that "largely the teacher's focus would be course content." Interviewee 4 stated, "Math is the core." Interviewee 9 says "the key component that I see in integrated STEM education is the STEM part of it itself, the science, technology, engineering, and math." Interviewee 10 believes that "the cornerstones will always kind of fall with science and math. The use of technology makes it applicable." Interviewee 12 states "you're going to pull out science. You're going to pull out mathematics. Technology may be considered a discipline, but I think it becomes a tool or application. Engineering right now is not considered a K-12 discipline."

Authentic, relevant, meaningful experiences. Five participants see providing students with authentic and relevant/meaningful experiences as essential to integrated STEM. While authentic, relevant, and meaningful are not defined exactly the same way, these concepts fit a similar mold and were grouped together. Interviewee 2 believes that integrated STEM is “a much more real world and rich educational experience.” Interviewee 3 sees integrated STEM, as “when they are in their math class, the math is relevant to what they're working on.” Interviewee 4 sees “meaningful experiences” as a key component. Interviewee 5 believes, “a key component of integrated STEM is authenticity.” Interviewee 9 says using integrated STEM, students “apply knowledge and solve real-world relevant problems.”

Outside experiences and resources. Three participants specifically stated that outside experiences are vital parts of integrated STEM. Interviewee 4 states, “it [integrated STEM] is opportunities to get involved with career focused individuals outside of the classroom. It might be...going on field trips or it might be meeting with people in their industry that they are possibly interested in.” Interviewee 9 thinks integrated STEM needs to “include and incorporate all of the STEM experts that are out there, whether it's business or universities or informal science organizations like the zoo that has the experts, the researchers that are working in STEM education” and “big picture integrated STEM education is to bring in all the different components and players and everybody have an open mind and working together on educating our youth.” Interviewee 13 believes,

> Another key component and integration of STEM is you have to have business and industry. The people that wish to have the STEM skills taught for the workplace. You need to have them understand what's going on in your school. So, it's all those partnership pieces… Along with that business and industry

partnership, they can also bring in people who have expertise that are not always available to a school and likewise they become your partner.

Willingness of teachers. Three interviews included the concept of willingness to participate in integrated STEM, willingness on the part of teachers, leaders, and students. Interviewee 1 said "Key components are teachers willing to go outside of their area" and "Willingness to explore and to go off on tangents when they present themselves. I think all of that implies that you have an administration that is willing to put trust in the teacher, and teachers that are willing to put trust in the students." Interviewee 2 says "I think you [the teacher] give students a chance to work on that in a larger scope." Interviewee 13 "You have to have teachers who are willing to work with other teachers."

Integrated STEM definitions by Interviewee. As part of interview question 1, each respondent was asked to define integrated STEM education. These definitions are important to the study even though there was not a research question specifically related to a definition of integrated STEM. The data in Table 4 represents the definitions of integrated STEM as stated by the participants. Using these definitions along with other concepts found in the interviews, a tactical or strategic definition was crafted which could then be utilized locally, to possibly create and implement integrated STEM. The following definition is the result.

> *<u>Integrated STEM education</u> involves the purposeful integration of science, technology, engineering, and mathematics as well as other subject areas through project-based learning experiences for students that require the application of knowledge to solve authentic, real-world problems in collaborative environments.*

Table 4

Quoted Definitions of integrated STEM by participant.

Interview	Definition
1	It would use all of the different techniques of science, of mathematics, to get at a larger point. So rather than learning a science topic just to learn it, you would need to know it to prove a larger point in your experiment, your project, in your whatever your quest is.
2	I would define it a lot like that previous statement that it wouldn't focus on a single piece of core knowledge like science in a vacuum. That it would approach the different portions of the four major categories to do some unified task. Again something larger.
3	It is that the students don't learn the subjects independently from each other. That the knowledge that they are learning is all related knowledge toward an end goal. So when they are in their science class they're not just learning science, if it even is a science class, it is science because it's science they need to have knowledge about for whatever they are working on. When they are in their math class, the math is relevant to what they're working on. The students don't think, 'well I don't need to think math when I'm in science and I don't need to think science when I'm in my social studies class or whatever.' They see the connection and need to use the knowledge from all different subject areas.
4	I would define it as an opportunity for students to see connections among different content areas that previously were siloed out into their own specific categories.
5	I think it's how all the content areas interact and how they are really applied beyond the classroom setting and getting into how the specific set of skills and knowledges are also taught. So, to me the integrated piece is really the interaction of math, interaction of science, interaction of agricultural food and natural resources--how all of those pieces really come together in a very authentic manner to be replicated outside of the classroom.
6	I would define integrated STEM education as much more focused on inquiry and problem solving and how the disciplines come together for learning and achieving a deeper understanding of students, and much less about whether they are in a math class or a science class. I would say it is kind of like much more of a true problem solving environment where they learn certain concepts but they don't have to go to math class to do that or go to science class, etc. they can be in STEM class.

Interview	Definition
7	I think integrated STEM is when students are using the skills they've learned maybe in STEM coursework or other places they have learned STEM topics either science topics, computer topics, science topics. They're using the concepts that they have learned in other areas to solve a particular problem or investigate a broader issue.
8	It would be real world topics, real world problems working in collaborative groups in which students have to use their knowledge of science, technology, engineering, and math to come up with potential solutions. Then using the scientific methods of research, solid research, address those problems and come up with solutions. It's all about design and implementation. Getting kids to think outside the box. Thinking critically and doing their best to come up with real-world answers to real-world problems.
9	Integrated STEM education is the combination of all the knowledge that students are learning at a particular age level and building upon what they have learned through their experiences to be able to apply knowledge and solve real-world relevant problems.
10	Integrated STEM education is a discipline that utilizes science, technology, engineering, and mathematics to demonstrate challenges in our world in practical applicable means.
11	Integrated STEM education involves the specific use of didactic content from one area to support any or all of the other areas of STEM. Really, what you are talking about is just the use of one field to bolster content in to another and to develop new content.
12	Seeing science and mathematics come alive through the use of technology and reinforcing the engineering process.
13	Integrated STEM education is when you take the content areas of study in the fields of, not just specific to, but the different fields of science, the different fields of technology and the different fields of engineering and mathematics and you take the content knowledge from that and you put it together into a class where students are able to solve problems; where students are able to figure out what problems are in society or problems that they want to solve and apply that knowledge towards their solution.

Question 2. Interview question 2 was related to the participant's perceptions for what they think it takes to create integrated STEM education in a school setting. An analysis of the responses for this question was conducted by looking at the raw text and generating initial codes for the data. The initial coding was then combined into general groupings which represent themes that were prevalent in the respondent's answers. Several consistent themes emerged from the analysis of this question.

The first theme is the nearly universal affirmation by the Interviewees that integrated STEM takes a team of dedicated practitioners. Semantically, this sentiment was stated as being through collaboration, a cohort, or through co-teaching. Other identified themes were related to willingness (which is an overall interview theme), needed resources, certification (which is also an area of dissent), professional development (not only the need for, but what it should look like), staffing discussions, and some general comments by several Interviewees that were deemed worthy of including.

Collaboration/team teaching/cohorts to create integrated STEM. Eleven of 13 Interviewees spoke about the use of collaboration/team teaching/cohorts as critical to integrated STEM education. The importance of collaboration and a cohort appeared throughout the entire question. It was referred to as a general comment, as an important resource, and as part of professional development. Interviewee 1 said to create integrated STEM, "it starts with a cohort of willing teachers." He went on to say, "I think that you have to have a cohort of people who are all working towards the similar goal." Interviewee 2 said, "It [integrated STEM] takes a lot of cooperation on the part of all the participants. The students. The teachers. The administration. The parents." Interviewee 3 spoke about being part of a team when discussing certification. She said, "I think that it is still very important for people to be knowledgeable about one area but then be willing to work as a team member with people knowledgeable in other subject areas." Interviewee 3 further mentioned a team when discussing integrated STEM in general. In one implementation that she is familiar with, she stated, "the administration actually gives the team of the different subject area matters planning time to talk about things, to talk about the students that are in all those classes." Interviewee 4 believes that to create integrated STEM, "there has to be an integration among the teachers and time to collaborate." She also referred to collaboration related to professional development when she stated, "I think the more opportunities you can take and the more education teachers can get, especially collaborating."

Interviewee 5 said to create integrated STEM "from a teacher perspective, it takes collaboration. It takes opportunities for teachers of different content areas to communicate and work together and to really create some of those authentic types of experiences." Interviewee 5 also said, "resources that I would need to teach…time to collaborate." Interviewee 7 agreed and stated, "I think you need to provide time for coordination and planning." Interviewee 8 spoke about collaboration extensively. He said to create integrated STEM, "a collaborative effort is going to be necessary on this with good administrators and good leaders at the top." When discussing resources, Interviewee 8 said, "it [integrated STEM] should be collaborative, large environments that have access to certainly plenty of technology." He also spoke about school improvement goals and how integrated STEM might play into those.

> When initiatives like reading across the curriculum or science integration or a calc (calculus) class teaming with a physics teacher and getting the collaboration going there, which are really good efforts--a lot of teachers really don't see themselves that way.

Interviewee 9 said the creation of integrated STEM takes, "a cast of numbers that come together to integrate the STEM." She also said this about professional development, "I think it is something that needs to be ongoing throughout the year as a constant, almost like a cohort that goes through." Interviewee 9 further stated, "really it is collaboration and working together" and "it [integrated STEM] takes a lot of people coming together and working together to provide the opportunities for the kids." Interviewee 11 sees the way to create integrated STEM as having "basic grade level teams where they would get together and they would call them professional development communities or professional leadership teams." He further extended this thought to include, "PLC's (professional learning communities) should expand well beyond any given content area." Interviewee 12 said, "you do some STEM education where you're going to be teaming and having someone going to co-team." Interviewee 12 spoke about this collaboration idea related to staffing changes when she said, "I think team teaching is your strongest." Finally, she said to create integrated STEM, we "have to be very comfortable in our content and be willing to work in a team situation to make it come alive for our students." To conclude, Interviewee 13 stated, "it [integrated STEM] takes partnerships and collaboration and you need people to advise you."

Willingness of teachers to create integrated STEM. Willingness of the participants related to the creation of integrated STEM was discussed by six of the 13 Interviewees. Willingness of participants was a theme that evolved out of all the interviews and is detailed in the section of Identified Themes by Interview. Interviewee 1 said, "I think it [integrated STEM] starts with having willing teachers, and that doesn't mean teachers who know everything about technology, or mathematics, or science, or engineering…It means having people who are willing to try new things." Interviewee 2 spoke about willingness related to changes in staffing. He said,

> Direct staffing--I think you can train the teachers that you have got, but it is going to take some time and willingness on the part of those people because, for all intents and purposes starting an endorsement in other areas, or touching on at least having a level of expertise, or being willing to cross pollinate with some other teachers, or possibly even co-teach, takes training.

He further said, "it [integrated STEM] is so much more open and you have to be willing to investigate some content that may not be part of your core." Interviewee 3 stated,

> It [integrated STEM] takes educators who are willing to give up their areas of excellence and are willing to collaborate with others on seeking of different ways to get the core concept of what it is that they want the students to know, learned versus rote memorization of facts.

Interviewee 3 also spoke about willingness related to certification. She said, "I think that it is still very important for people to be knowledgeable about one area but then be willing to work as a team member with people knowledgeable in other subject areas." Interviewee 4 discussed the nature of teaching integrated STEM and how being willing to try things is important. She said, "We cannot be afraid to try new lessons." Interviewee 4 also discussed the extra time that it takes to create and implement integrated STEM when she stated, "I think the teachers have to be willing to put the hours in, especially the first couple of years we set it up." Interviewee 6 also discussed willingness related to the creation of integrated STEM but from more of a political viewpoint when he said, "I think it takes willingness to give up turf." Interviewee 13 summed up the need for willingness of participants to create integrated STEM when she said; "you have to have the teachers with a broad range of experiences who are willing to be involved."

Resources needed to create integrated STEM. The participants also discussed resources related to integrated STEM. Below is a table listing of the most frequently stated key resources of integrated STEM education. It should be noted that there were numerous other key resources listed by participants that were very specific to their perceptions of integrated STEM education. The fact that these specific items are not listed in this summary is not to discount their importance to integrated STEM education.

Table 5

Resources to create integrated STEM.

Resources	Interview number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Software/tools		X	X					X				X	X
Space		X	X				X	X					X
Time				X	X		X					X	
Access to outside experts					X				X	X			
Training/professional development		X								X	X		
Acceptance				X				X					X
Leadership					X	X	X						
Creativity				X									
Flexibility		X				X							
Changes in school structure												X	

Several generalizations can be drawn from the information. First, it should be noted that many of these concepts were spoken about by multiple Interviewees in different parts of the interviews. For instance, leadership, access to outside experts, and professional development exist as themes in their own right. The idea of time appeared repeatedly as part of the discussion on collaboration. Other lesser-represented key resources were cited in this section because they also appeared in other parts of the interviews by other participants, which seemed to illustrate their importance.

To begin, Interviewee 1 stated, “I don't think it takes a lot of resources…most facilities would work.” He went on to say, “I think you go out and find what is available which accomplishes the task that you have already defined and not the other way around.” This might be a reason for there being little overlap in needed resources from the participants. Many of the participants are imagining an integrated STEM environment rather than participating in one. Different perspectives provide different needs. Several participants felt that until you have a curriculum or projects in place, you cannot determine what you need in resources.

With that being said, several Interviewees had general things to say about the physical resources needed to create integrated STEM like software, tools, and technology. Interviewee 2 said, “I think that there is an answer for most software needs out there without having to go through a large expenditure.” Interviewee 3 stated, “It [integrated STEM] would be better if you had access to some level of tools to use and scientific instruments for making measurements. Interviewee 8 said, “It [integrated STEM] should be collaborative, large environments that have access to certainly plenty of technology.” Interviewee 12 believes to create integrated STEM, “having access to technology is number 1.” She went on to say that, students should “actually use equipment that would happen to be used in manufacturing or actually in a career.” Interviewee 13 said, “You have to have equipment [to created integrated STEM].” There were numerous specific resources like CAD software, CNC machines, 3D printers, and specific software that were presented through the interviews. These refer to the Interviewee’s particular instances or theories about integrated STEM. As Interviewee 1 stated, “I think you go out and find what is available which accomplishes the task that you have already defined, and not the other way around." The lack of overlap in specifics is likely a result of not having a specific integrated STEM curriculum in place.

Multiple respondents cited the need for space in an integrated STEM program. Interviewee 2 said, "Certainly you need some space." Interviewee 3 stated, "the resources it is going to take…an education facility that has project space associated with it, not just traditional classrooms with desks in rows." Interviewee 7 believes that, "there's going to be a maker space, a place where groups can meet." Interviewee 8 said, "It [integrated STEM] should be collaborative large environments." Finally, Interviewee 13 stated, "Well you have to have space."

Time for various uses and instances was cited as a key resource. Interviewee 4 believes that "it [integrated STEM] takes a lot of time." She further stated, "it [integrated STEM] takes a commitment to the district to provide time for planning." Interviewee 5 said that a resource "that I would need to teach…time to collaborate." Interviewee 5 further stated, "I think that another key resource, is the time to collaborate in the PD [professional development]." Interviewee 7 said, " The most critical resource is time." Interviewee 12 believes that the creation of integrated STEM needs, "blocks of time in which students get to explore and see those connections and hopefully see some real life things happening."

The necessity of seeking outside experts to help schools create integrated STEM was also cited as a key component by four Interviewees. Interviewee 5 said this when asked about a key component for integrated STEM, "I think just [have] access to experts." Interviewee 9 said schools should, "bring in quite a few experts in the field to come in and work." She reiterated this when she stated, "So they [schools] have to open up the doors and really let the experts…come in." Interviewee 10 stated schools need,

> Professionals who can not only come to the class, we're not talking about show and tell, we're not talking about career day, but you truly assist and help that educator with projects and so on to also help expose the students to professionals, working professionals.

Three Interviewees referenced the need for training to create integrated STEM. Interviewee 2 said this about training as a key component.

> I think training. You have got to have a teacher who is really comfortable with a lot of different material. If your background is simply that of a mathematics teacher or a science teacher you may not feel comfortable enough in some of the other areas that you are going to be pulling in.

Interviewee 11 echoed this sentiment. He said to create integrated STEM it will take "professional development on a broad scale." Interviewee 10 said the creation of integrated STEM requires "having a clearly defined consistent professional development process, a program which would include certification and training, on-going availability, and to also provide the teachers with credit."

Three interviews spoke to the need for the community and stakeholders to accept the move to integrated STEM. Interviewee 4 said, "it [integrated STEM] takes support from the district and buy in from the parents." Interviewee 8 stated, "It [integrated STEM] is going to have to be embraced by the community." Interviewee 13 believes that, "you have to have commitment. A commitment from your school, your teachers, all of those constituents that are involved and it has to be a very strong commitment that they are still wanting this [integrated STEM]."

Three interviews cited leadership as a key component of integrated STEM. Interviewee 5 stated, "You may need someone who's able to coach and to provide that support in terms of improvement of instruction." Interviewee 6 agreed and said, "I think it [integrated STEM] needs some sort of faculty specialist in STEM with a vision for it." Interviewee 7 stated, "It's really leadership, I think from both the teacher's perspective and the student's perspective as well. I think you have to have leadership in the school from the adult side and from the student side."

Less frequently cited concepts that were spoken about in other parts of the interview, by other participants were creativity, flexibility, and structure changes to schools. Interviewee 4 said, "It [integrated STEM] takes a lot of creativity." Interviewee 6 stated, "Much more flexibility is needed." Interviewee 2 agreed. He said,

> I'd say the biggest thing is to be flexible and approach it with a sense of adventure, because putting all these things together you never know quite exactly what you are going to get and that is part of the beauty of this.

Interviewee 12 said, "It [integrated STEM] is rethinking actually how our school systems are organized."

Certification and the creation of integrated STEM. Respondents also spoke in question 2 about certification of teachers and integrated STEM. The idea of certification of teachers also appears in the analysis as an area of dissent. Seven of the respondents stated that certification is not needed for integrated STEM teachers. Interviewee 3 said, "I don't think the educator with a STEM certificate or a STEM degree would have a deep enough knowledge in any one of the areas to excel.” Interviewee 4 believes, “I don't know if it [certification] is necessarily a requirement in my eyes.” Interviewee 5 emphatically stated, “I don't think we need a certification on STEM.” Interviewee 7 said, “I don't know if there would be a general STEM certification and what that would involve and whether somebody could conceivably do all of that in four years.” Interviewee 8 believes,

> Certification, it could be a specialty area but I don't want it to be. We could get a specialist certification in STEM education. That's fine, I don't have a problem with it. I would rather see a dedication to the philosophy than a certification necessarily in order to be a STEM teacher.

Interviewee 9 said this when discussing the topic, “certifications, that one I kind of have mixed feelings about.” Interviewee 12 stated this when discussing certification. “Don't touch it. I do not see, I don't know, I do not see a STEM certification.”

Two respondents see certain STEM disciplines need a certification that currently does not exist. Interviewee 6 said, “Computer science and engineering desperately need their own certification.” Interviewee 11 stated, “I would like to see engineering education certification.”

Several respondents had answers regarding certification that were between ‘yes, it is necessary’ and ‘no, it is not necessary’. Interviewee 1 called the certification area of integrated STEM “grey”. He said,

> I think this is where it gets grey because I don't know that a STEM class fits one certification. I don't think that you need to necessarily have a math certified person and a science certified person and so on down the line.

Interviewee 2 skirted the issue and stated the current status of STEM certification when he stated, “I don't believe that we have an actual STEM certification right now.” Interviewee 10 believes that “Certification is something that would be accepted by the state” and it could be a “secondary certification, not a whole degree in a sense.” Interviewee 13 took a different approach to certification than most states have for educators. She said,

> I think that we also need to go and look at certification pieces, so that if we become certified like at a community college or at a college and we have a piece of certification, that [certification] can be added onto our state certification certificates and reflect the STEM area that we have an emphasis in.

Professional development and the creation of integrated STEM. Another area that the Interviewees responded to in the second interview questions was professional development. There were many relevant general comments about professional development as well as some specific references to what professional development for integrated STEM might look like. Interviewee 1 stressed the importance of “making sure that it [professional development] is actually focused and driven.” Interviewee 4 stated, “I think consistently revisiting your curriculum is a must.” She also feels that as part of professional development teachers should be “constantly communicating with the employers and with the colleges associated with our programs to see what they want from our students and what is expected of them within the STEM program.” Interviewee 5 said, “We have to help all teachers see that they are STEM teachers.” Interviewee 5 thinks professional development needs to focus on that idea. This was emphasized when he said,

> STEM is really about the pedagogical approach to teaching the content, and how it can be applied. Then every teacher, no matter what grade level, would walk away from that experience saying I am a STEM teacher and here's how I utilize STEM concepts and how I utilize and help students become STEM capable.

Interviewee 7 talked about teachers and pre-service teachers having freedom to pursue their STEM passion. He said, “Give the pre-service teachers an opportunity or suggestion or requirement that they just pursue their passion in STEM.” Interviewee 7 further stated this as a possible means of professional development,

> Giving the teachers the freedom or the suggestion to figure out what they really want to do themselves within integrated STEM, what they enjoy doing, what they feel comfortable doing, what do they want to do, what do they want to learn more about, and have them figure that out before they enter the classroom and have them understand that, that's important to know.

Interviewee 10 talked about professional development and what its goals and outcomes should be. He said,

> Professional development will be the educational supports that are put in play to help whatever teacher is trying to go into this area, to help them get to the point to where they feel comfortable, they feel credible in the classroom before their students and in the content that they're presenting to their students

Interviewee 11 said that integrated STEM needs “a broad-based professional development.” Interviewee 12 felt that professional development should “model not only what good mathematics is, but also doing the integration and seeing integration ideas.”

Interviewee 13 spoke about specific professional development needs when she said, “professional development that needs to take place…Safety is one, Ethics is two.”

Two Interviewees spoke about the need for specific training on tools and equipment. Interviewee 9 mentioned, “another piece is the training for the teachers on this equipment.” Interviewee 13 agreed and said, “professional development has to be tailored toward equipment and the changing technology.”

Seven of the Interviewees spoke about professional development for integrated STEM educators providing them with experiences in integrated environments that model what students will do in integrated STEM classes. Interviewee 1 alluded to this type of experience for teachers when he said, “I think that kind of training, work-shopping, experience is necessary for teachers to feel comfortable and be effective STEM educators.” Interviewee 2 described teachers needing integrated experiences this way when he stated, “you need to go through some sort of trial by fire, where there is some practicum side to this as well.” Interviewee 3 believes, “professional development, I think, is needed so that they can experience what it looks like or what it can look like because sometimes you just need that experience.” She went on to say; “personally I would structure it [professional development] by having the teachers play the role of the student and leading them through an integrated design...an integrated STEM project.” Interviewee 6 believes, “integrated STEM education requires a variety of experiences [for teachers].” Interviewee 7 agrees. He said, “I think teachers need to be given the experience of doing some kind of integrated project.” Interviewee 8 described integrated STEM professional development this way. He said, “we need to show them tangible examples, and they're hard to find, of what STEM education looks like. What does that classroom look like? What philosophical attitudes should they consider in terms of what it takes?" Interviewee 9 stated, "I think the professional development needs to look like whatever industry the teacher is trying to replicate, or whatever component of the STEM education career path. I think they need to go out and get those experiences." Her rationale for this is experiential. She has observed that,

> Teachers that have that real world experience or that experience outside of the classroom, not going right from college into a classroom, tend to be able to build activities with lessons, ask questions, facilitate, have the kids lead the conversation.

Two Interviewees spoke about project-based learning needing to be a part of integrated STEM professional development. Interviewee 2 stated, "I am touching back on that project-based learning" when referring to professional development. Interviewee 9 believes teachers need "professional development training to get them onto the same page as that problem based learning, or project-based learning, or experiential learning, or however you want to define it." It should be noted that project-based learning which is one of the pedagogical methods of the study's conceptual framework emerged unanimously from all Interviewees when searching for entire interview themes.

Two Interviewees spoke about collaboration related to integrated STEM professional development. Interviewee 2 sees integrated STEM professional development this way.

> If they feel comfortable maybe some sort of workshop that says, hey, here are some of the best practices. Here are some strategies that may improve your instructions and maybe find out some of the things that have worked for them. I

> think it is a two way street. I certainly think educators, when they get a chance to, come together and discuss things and share their ideas.

Interviewee 4 believes professional development must involve “constantly collaborating with a community.” Collaboration between teachers also emerged as a key component of integrated STEM from the summary analysis of this question.

Staffing changes and the creation of integrated STEM. Interview question 2 also asked respondents about whether staffing changes are needed to create integrated STEM. No participant said we should fire personnel and hire new people to replace them. As a result, there were two different answers to the staffing discussions. Five respondents said that the creation of integrated STEM would not require staffing changes. Interviewee 1 said, “I don't know that there is. I think anybody could do it. I don't think that it takes a well trained individual to come in and they are the only ones who can do this.” Interviewee 3 stated, “I don't think there has to be any change in staffing.” Interviewee 5 agreed and said, “I don't know that you need any changes in staffing.” Interviewee 8 believes, “I don't know that we need huge staffing changes.” Interviewee 13 spoke to staffing changes in this way. She said, “If you have dedicated teachers who are willing to work towards a common goal, and committed teachers who want to do that, you wouldn't have to change your staff.” In the analysis of this interview question, respondents said that no staffing changes are necessary to create integrated STEM. In this question specifically, they did not mention whether training or retraining is required. However, it does seem likely that some training for current staff will be needed.

Seven of the respondents believed that training or retraining of people or augmenting the staff with some specialty personnel is necessary to create integrated

STEM. Interviewee 1 said, “I think that you do need a couple of specialty trained people.” Interviewee 2 stated,

> I think you can train the teachers that you have got, but it is going to take some time and willingness on the part of those people, because for all intents and purposes, starting an endorsement in other areas, or touching on at least having a level of expertise, or being willing to cross pollinate with some other teachers, or possibly even co-teach, takes training.

Interviewee 7 said that schools “looking at hiring people with the needed background is certainly important, or training people.” Interviewee 10 stated, “I would say that you would almost have to repurpose, and I know that sounds bad, but repurposing some educators in a sense of providing them the opportunity to obtain training.” Interviewee 13 believes that, “if you have a deficit of a knowledge base in your staff, you would definitely want to recruit that person [with the requisite training].”

Interviewee 11 spoke about the necessary knowledge that teachers of integrated STEM need which implies training that might need to occur. He said integrated STEM needs people who are,

> Either fully degreed in two or more of the subject areas, or have at least a very good concept of the crossover of how all those really are used from one field to the next. So to have some knowledge in engineering for a math teacher would be extremely important.

Interviewee 9 discussed the experiences that an integrated STEM teacher needs to have which also implies training of existing staff. She said,

> Those teachers that have that real world experience or that experience outside of the classroom, not going right from college into a classroom, tend to be able to build activities with lessons, ask questions, facilitate, have the kids lead the conversation. I don't know if that's because of their experiences that they are bringing into the classroom and that they have been out and they're able to use relevant examples.

General thoughts related to the creation of integrated STEM. At the end of this question, the respondents were asked if they had any final thoughts. There were some important ideas presented in this section. Interviewee 2 said this about how to create integrated STEM, “I think getting all the players involved is the first key thing. The next is time and resources. Time being most critical, in so many of our classrooms we have this rush to get through content.” Interviewee 3 believes that, “the administrator has to buy in to, because it's not what has been done traditionally and to do it well.” Interviewee 4 stated, “it [integrated STEM] takes networking” and “setting up a clearly defined goal of what your STEM education is [essential]." This comment by Interviewee 4 summarized her perspective on creation of integrated STEM, “I think put a foot forward and take a risk. Just to summarize, get a goal. Get teachers on board who want to do it. Talk to the administration and go forward from there.”

Interviewee 6 spoke about reducing restrictions on student technology use. He said, “at the high school and college level, but particularly the high school, level there has to be more opportunity to engage in cloud-based computing without a lot of restrictions.” Interviewee 8 stated,

> It [integrated STEM] has to be sold to the community to make the effort, to our administrators to find the gains, and even as far as government educational policy is going to have to change because on the one hand there are great STEM idea thinkers out there.

He concluded to create integrated STEM, "we are going to have to find those beacons of light who are doing it." Interviewee 9 said, "it [integrated STEM] is a totally different paradigm shift way of teaching where you need to bring in one of those experiential learning experience either project-based or problem-based." She went on to say, "I think a STEM high school needs to be set up to replicate what is going on out in the industry and the business world." Interviewee 11 said, "I think a more coherent and comprehensive definition of STEM education is kind of important." Interviewee 12 agreed and stated, "We should be able to craft a definition in which all of us understand and can articulate."

Question 3. Interview question 3 was related to the participant's perceptions about how to integrate STEM education in a school setting. By generating initial codes for the data and then combining them into general groupings, the analysis of the responses for this question was completed. Several consistent themes emerged from the analysis of this question, which can be found in table 6.

Table 6

Themes generated from the analysis of interview question 3.

Theme
Teachers of integrated STEM
Integrated STEM and the school curriculum
Integrated STEM and changes to school structures
General responses to implementation of integrated STEM

One area explored is related to who can teach integrated STEM. The next area explored was how integrated STEM fits into the school curriculum. Interviewees also spoke to possible changes in the structure of schools that might be needed to implement integrated STEM. Other themes like collaboration and integration resurfaced in this interview question. Finally, there were some interesting comments related to curriculum challenges as well as some general comments that are worth considering.

Teachers of integrated STEM. First from the interview content, it seems that almost any teacher can be a STEM teacher with the proper attitude, training, and resources. This means, in the opinion of the Interviewees, current staff does not have to change to implement integrated STEM.

When asked who they saw teaching integrated STEM, the eight Interviewees had a consensus that it could be any teacher, not just a current STEM discipline teacher. Interviewee 1 said, “I really don't think that there is a specific person…I think it is a willing teacher.” He went on to describe a STEM teacher this way, “someone who is already operating in that domain, but someone who is willing to learn, someone who is willing to push themselves, and someone who is willing to become the expert I think is just as viable.” Interviewee 2 said, “I think you can't limit yourself to, ‘here's a certain teacher’. I think it is an attitude more than just what you teach.” Interviewee 4 stated, “I see teachers that are not afraid to try teaching it. You have to be willing.” Interviewee 5 said, “any teacher [can teach it].” Interviewee 7 summed up a STEM teacher this way.

> I suppose it does help to have particular skills in STEM areas, but I have seen all kinds of people teach really good programs, or moderate, or lead, or organize really good programs in STEM education that aren't even necessarily who you

> would even think…what it really takes is a real desire and motivation from the adult leader to want to make this [integrated STEM] happen one way or another.

Interviewee 8 believes, "STEM is going to require some real creative thought and some very dynamic educators in the classroom." Interviewee 10 stated a STEM teacher can be, "any teacher with a passion to truly want to engage...do something innovative, have fun, who do not mind students being the little 'wunderkinds' that they can be." He went on to say, "Personally, I don't see a rigid educator being an effective STEM educator because as with engineering, as with science, as with mathematics, there is room for mistakes." Interviewee 13 sees "all teachers in the school as experts that can be brought into the STEM piece."

Four Interviewees see an integrated STEM teacher as a person in a STEM discipline. Interviewee 3 described integrated STEM teachers this way. "I see math teachers and science teachers and technology shop teachers who could also be an engineering teacher, or there could be a separate engineering class working together to teach this." Interviewee 6 sees STEM teachers as "people with expertise in certain areas teaching it, like math, science, physics, chemistry, that sort of thing, but calling themselves a STEM teacher and becoming STEM teachers." Interviewee 9 stated, "If you look at the STEM part of it, I see math teachers and science teachers...CTE (career technical education) or the industrial tech teachers." However, as a qualifier, she went on to say, "it's not unheard of and you look across the country and visit to see that some of these programs do have a dedicated English teacher who was part of that STEM program. Interviewee 12 believes,

> It has to be a team of folks. Math, science, technology, CTE folks, it could be any combination. Whoever wants to be that champion and look at it [integrated STEM] quite a bit differently than a page in the book and we go to the next set of problems.

The last Interviewee that spoke to this question, Interviewee 11, was somewhere in the middle. He said, "I think our current workforce can do that and the new people coming in are obviously able to do that, but only if they have a good sense of what integrated STEM really is." This can be taken as any teacher or a current STEM teacher.

Integrated STEM and the school curriculum. Participants were asked how integrated STEM fits into the curriculum. Twelve of the Interviewees spoke to this topic with almost an even split between them. Three respondents felt that integrated STEM is a core class, four felt that it is an elective, and five respondents felt that integrated STEM is somewhere in between. Interviewee 3 said, "I think it's a core course…integrated STEM is just separate core courses working together for a common goal." Interviewee 4 is an integrated STEM teacher in a large metropolitan school district. This is what she said about integrated STEM being an elective vs. core class.

> We decided to make ours a replacement for the first two years for core classes and then as they get into their junior and senior year it becomes an elective. That way... Ideally I think it would be an elective all the way through, but for staffing and for funding within the school, it is much more practical to make it a replacement course for one of the standard classes that they would have to take as a freshman or sophomore or at least by the time they graduate from high school.

Interviewee 6 stated that integrated STEM is a "core class."

Interviewee 2 sees integrated STEM differently. He said that, “I can see upper divisions being an elective. Something akin to nationwide contests and challenges. I do see that you could really expand and take the top tiers as an elective.” Interviewee 9 stated,

> I see it [integrated STEM] more as an elective. I see it more as a career exploration pathway with STEM introducing children who have an interest in science, technology, engineering, and math to give them opportunities to explore all the options.

Interviewee 10 said, “I would say elective” when asked about integrated STEM. Interviewee 1 stated,

> I think that STEM is a core concept that works best in an elective setting. I think that electives have the freedom to explore ideas rather than to teach specific topics. Core classes teach the STEM foundations but electives get to put them to practical uses.

Some other Interviewees see integrated STEM as something different from an elective or a core class. Interviewee 5 said, “I think it [integrated STEM] is everywhere. If we're talking true integration.” He went on to say that, “I think the most important thing is that it's intentional. I think that's a key word.” Interviewee 6 stated, “It [integrated STEM] needs to be an evolution of the curriculum structure of schools. It needs to cross disciplines.” Interviewee 7 said, “I think it [integrated STEM] would be integrating it within the courses and then maybe doing something with school-based projects possibly something like that.” Interviewee 8 sees integrated STEM completely differently. He said, “No it's a track. It's large chunks of time spent with multiple team teachers in an incubator of creativity utilizing science, technology, engineering, and math." Interviewee 12 believes,

> Right now, it doesn't fit very well. Again, if it fits in curriculum-wise you would see some of it in science, some of it in mathematics, and you would see technology to probably support the effort, and you would see it in CTE actually. Industrial technology would be a good idea for an area that would model a STEM application. So there are bits and pieces, but it isn't a package; let's put it that way.

Integrated STEM and changes to school structures. The Interviewees also spoke to how integrated STEM education might require changes in the structure of schools. One theme that was voiced by eight of the respondents is that schools need more flexibility: flexibility with scheduling, flexibility with planning time and teaching methods, and flexibility for student assignments. Interviewee 1 posed questions relating to the scheduling in schools that point out that flexibility is needed. He said, "Scheduling is an issue. Obviously if you have the dedicated block teacher that are working together, how do you schedule them? How do you get them common planning time? How do you get that kind of thing?" Interviewee 3 stated, "I don't think it [changes to school structure] is necessary, it would certainly help it. The 45 or 50 minute period makes it challenging to get deep enough into something, so a longer block of time would be an advantage." Interviewee 4

> I don't know if they are necessary but I think they help. I am fortunate to be in the setting where modular scheduling allows a lot more flexibility. I think as I mentioned earlier you could restructure courses so that students who want to be

> involved [can be]…eventually it all comes down to choices. Students still have to make a choice.

Interviewee 8 noted large changes in school structures that will require flexibility. He said, “we really need to get off this agricultural calendar…so we can have year round school and do STEM.” Interviewee 9 stated,

> Yes. I am a firm believer that there needs to be some structural changes in order for this to occur. It has to be...Like I said flexibility, a different way of pedagogy, a different way of teaching has to be established into the system. The way that the school day looks needs to be different…you really have to look at it and evaluate it, but an eight period bell schedule doesn't tend to work for the program that we have here.

Interviewee 13 has proposed some significant changes to the school schedule that will require great flexibility by schools. She said,

> I think that we have to have more classes during the day that aren't always limited to that time continuum. STEM classes have to be longer to be able to allow students more time to think the process through. It can't always be before and after school. Maybe school needs to have night classes. Maybe we can reach some of these students in night classes. Have three different times during the school day that students can choose to have their education take place. So give them three different choices throughout the day and start school early and end school late, but each segment addresses the STEM piece.

Interviewee 10 looked at flexibility by schools related to the implementation of integrated STEM. He stated, “I would say yes in that it will require more interdisciplinary planning on various department." Interviewee 12 looked at flexibility related to school structures in this way.

> I think for it to be maybe the best situation, would be for allowing for some team teaching along with staff cooperating together, and doing even some capstone or graduation projects with seniors or juniors or whatever year they decide.

Interviewee 2 mentioned,

> You would need to make sure that there is a way to some degree, level the playing field, as far as you don't want to have a class where there are expectations that would be beyond what a learner is capable of…I think you can always adapt your projects upward or downward as needed and certainly a lot of those tools would not be necessary.

Two respondents did not feel any real structural changes would need to be made in schools to implement integrated STEM. Interviewee 5 said, "I don't think there's huge structural changes, I think it's tweaks. I think it's talking more about contextual teaching and learning vs. learning for the sake of a test or a test score." Interviewee 7 agreed when he stated, "Well I don't think there has to be huge changes for integrated STEM to take place. I think all of that can be done within school and through the use of after school programs."

Two Interviewees responses were much more general. Interviewee 6 believes, "There has got to be a better structure than departments that constantly defend turf." This implies some type of structural change, but not necessarily related to student teaching and learning. Interviewee 11 approached changes in school structures in this way. He believes schools need,

> More equipment and better teacher training. I would add to that, probably better working partnerships with teacher training institutions. The whole spectrum of it has to change I think in order for real changes to happen in the classroom at the secondary level.

General responses to implementation of integrated STEM. The two themes of collaboration and integration that showed up in other parts of the interview and analyses resurfaced in this question. Seven respondents in this question mentioned collaboration. Interviewee 1 said, "I think you need to get a cohort of these people together." He went on to say it is important for schools to "really come up with a team of people who are willing to work together and are willing to try new things that they haven't tried before." Interviewee 4 stated this about school structural changes,

> The district setting up time for teachers to collaborate. In retrospect, we certainly would have enjoyed a lot more time on a daily basis to collaborate. We don't have that, so, if I were an administrator in a building I would want to allow that time for my teachers to work together on a new program such as this.

Interviewee 5 believes this about collaboration and school structural changes, "I think it's perhaps a change in how we view team teaching opportunities. How we view, or the importance we place, on common planning time." When speaking about structural changes Interviewee 6 stated, "I think the first thing it [changes to school structures] needs to have is kind of joint planning and joint super units." Related to changes in school structure, Interviewee 9 said, "Another thing that needs to look different is co-teaching." Interviewee 10 said school structures need to change to include "more collaboration, more partnerships for it to be integrated across the board, I think it is a great avenue for there to be a whole grade level or school-wide purpose for a particular subject or area." Interviewee 12 related collaboration to school structural changes when she said, "I think for it to be maybe the best situation, would be for allowing for some team teaching along with staff cooperating together." Interviewee 12 went on to elaborate on the changes needed to school structures when she said, "So I think you would want to organize your staff to actually have time to put those things together or explore them."

Integration of subject matter was also addressed related to school structural change by two participants. Interviewee 1 said,

> You need to identify that you will be teaching some sort of integrated STEM sort of thing. I think you need to start with some ideas of problems that students might tackle that would involve learning a science, that was part of the curriculum and is necessary for the solution of the problem. Talk about the math that would be involved. Talk about the technology that would be involved and the engineering that would be involved.

According to Interviewee 1, all of this would be completed "with the goal of STEM education of integrating all their classes together." Interviewee 7 stated this about school structural changes. "I think more integration in the curriculum would be a benefit, and more open-ended opportunities for students to investigate in an open-ended manner would be a benefit."

To conclude, two Interviewees spoke about curricular changes that would need to occur for the implementation of integrated STEM to occur. Both of these respondents spoke about streamlining or loosening the curriculum. Interviewee 1 said,

> Probably the other thing that would be tricky is a class may not cover every topic. So in a geometry class or in an algebra 2 or pre-calculus class you have set objectives and you have to teacher this topic...this topic...this topic. A loosening of that to the point where you want to focus on these topics, but not every year might one topic come up. It just didn't come up organically in anyone's project so it was never addressed. Being ok with not teaching some things some years.

Interviewee 11 discussed needed curricular changes to schools in this way.

> One thing that has to happen is objective abandonment. We have to be willing to sacrifice some of the stuff we teach in each of the content areas right now to get a better view of how the important concepts can really be overlapped.

He further stated, “streamlining the curriculum to hit the critical components would be very important, because there just isn't enough room right now to be able to teach everything we need to teach.”

Question 4. Interview question 4 addressed the participant’s perceptions related to the assessment of integrated STEM. The analysis was completed by generating initial codes for the data, and then combining them into general groupings for the responses to this question. The themes found in the analysis of this question can be found in table 7.

Table 7

Themes generated from the analysis of interview question 4.

Theme
Non-traditional assessment
Integrated STEM and state standards
Integrated STEM and standardized testing
Integrated STEM and national standards
Concluding thoughts related to integrated STEM assessment

The responses to this question centered on the type of assessments that are required for integrated STEM, how integrated STEM can be matched to state standards, how integrated STEM fits into standardized testing, and how integrated STEM matches national standards.

Non-traditional assessment. When considering integrated STEM assessment, the type of assessment the participants feel will best represent the integrated content is some form of non-traditional assessment. Interviewee 2 believes that teacher developed rubrics would be beneficial. He said that, "I also see a real strong value in student self evaluation." In assessment, we are really looking at the higher levels, application and synthesis. He stated that "evaluation in the context of a rubric or in the context of a one page summary, a written summary or asking a student to reflect on mathematics that you needed to complete the activity" might be possible assessment strategies. Ultimately he thinks that "student evaluation gives a lot of chance for real metacognition about what I know, what I had to do. Really getting them to reflect is crucial." Interviewee 3 agrees when she said, "it [assessment] would be best if they were not paper and pencil and in a way that the students could interact with either an individual or a system to explain, justify, rationalize their knowledge about something." Interviewee 13 thinks assessments "need to also take the questioning and put it at different levels, different thought levels through their students, and they need to know which ones address the higher learning so that they are able to assess students in that."

Interviewee 4 thinks the "soft skills that we are trying to develop, I think need to be assessed in some way." Interviewee 4 also mentioned soft skills specifically when she said, "we think about career readiness skills that students will learn through STEM experiences, the problem solving, the critical thinking; I think that those become more difficult to assess."

There were other non-traditional assessments cited by the Interviewees. Interviewee 7 thinks that a possible assessment could be "how much work has a student been able to share and make public for others to use? How much have they engaged in a community?" Interviewee 10 mentions an assessment of "service learning where the students actually go out and they work on a real world challenge." Two interviews mentioned possible attitudinal surveys as assessment possibilities. Interviewee 10 thought about assessment as,

> Assessing that like pre/post, how did you feel going into it? How did you feel coming out of it, those types of things? Do you feel like you gained knowledge, just very broad general things. What did you expect to learn? Did you learn it? Kind of like those KWL (know, want, and learned) type of things.

Interviewee 12 echoed this as a possible assessment technique when she said, "you could do an inventory with whether the students like it in this format better than they do in a traditional format." She also thought that integrated STEM could "use some traditional testing, test content questions, and then I think the other assessment would be attitudinal and how they feel about liking math and science and technology."

Aside from integrated STEM being difficult and non-traditional, the interviews did have some consensus as to what assessment might look like or contain. Eight of the Interviewees specifically mentioned that assessment of integrated STEM should contain a project. Interviewee 1 said that, "general assessments will be projects" which should include "interviews, talking to people about their [student's] project, talking about what they think value point-wise or grade-wise of what they did is and was." Interviewee 2 thinks "there is some sort of product [project]" and that "there is some assessment going on through the project in the form of journaling or discussion with teachers." Interviewee 4 stated that, "assessments that are maybe more project-based" when referring to integrated STEM." She said that would "facilitate their learning in a way that is different than a traditional high school test would look like" and that "project assessments are equally as important, if not more important, than standardized testing." Interviewee 6 said that integrated STEM assessments should be "project-based, problem solving based and higher level inquiry." He thinks this is the best way to assess integrated STEM "because a project gives a student [the chance] to really demonstrate their connections and their understanding." Interviewee 7 said that assessment should be "project-based activities and competition based activities."

Interviewee 8 agrees with the project nature of integrated STEM assessment and what the project should entail. He said,

> The types of assessments that we need to be more invested in are product-based, project-based, and outcome-based. Show me what you know. Demonstrate what we have been talking about for the last three weeks. Build me something. Create me something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

He thinks this type of assessment creates "a healthy overall learning environment for kids that's much more exciting than sitting in rows and being addicted to a textbook." Interviewee 9 says that assessment of integrated STEM should be,

> Capstone projects. I think it should all be project-based, problem-based where the kids are exploring and asking questions or trying to solve a problem or come up with a new technology or come up with something innovative to help solve a problem in the world and there's different levels that are different degrees, so they're building up all those skills and knowledge to hit this major project.

Interviewee 11 stated that the assessments should be "project-based, design-based, and inquiry based." In fact, "I think the project itself should be the assessment."

Five of the Interviewees felt that the assessment of integrated STEM should be portfolio-based. Interviewee 1 feels that the assessment should be "student defined and student solved real world or contrived problems that they have come up with, that they have found solutions to. I think that it is much more of a portfolio of work rather than individual tests." Interviewee 7 said the end assessment would be "their portfolio of work. Their resume of work. Their online presence and how integrated STEM is included in their online presence." He went on to say; "I think what I'm talking about really goes beyond the portfolio into community presence, virtual community, and real community presences of the students in their projects." Interviewee 9 said that the assessments should be "portfolio and project-based." Interviewee 13 believes that the assessment should be "portfolio development." She went further stating that, "portfolios-- those are huge, physical and electronic" and "portfolio assessment…that is done throughout but is also as a final product."

Six of the interviews believed that the assessment of integrated STEM must be authentic and competency based. Interviewee 3 discussed the competency that students need to display related to integrated STEM when she said,

> The best assessment strategies would probably be ones that allowed for students to show some level of reasoning or logic or approach so either one-on-one discussions with students or maybe some virtual interactive thing where they are manipulating things, and saying why they are doing what they are doing.

She further stated that students should “be able to argue from evidence or use modeling, mathematical modeling, or physical modeling of things or software modeling to demonstrate knowledge” and “you have to have very fluid ways for them to demonstrate or discuss their approaches and thoughts.” Interviewee 5 agreed. He said, “It [assessment] is definitely a movement to more of a competency-based model.” He went on to say that assessment would be “competency-based models or authentic assessments such as portfolios. Performance assessments, moving beyond the traditional as we think of tests, but definitely competency-based.” Interviewee 8 said, assessment needs to be like “real-world environments...On the job training.” He elaborated on what assessment should look like when he said,

> The types of assessments that we need to be more invested in are product based, project-based, outcome-based. Show me what you know. Demonstrate what we have been talking about for the last three weeks. Build me something. Create me something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

Interviewee 10 said integrated STEM assessment needs to be,

> Something that you can explain. Something that you can present. Something that you can demonstrate that does what it is supposed to do…Shows its function, so

> to me it doesn't have to be an assessment outside of the project itself. I think that type of assessment; that would be vital.

Interviewee 11 said assessments need to ask, “can kids ask very appropriate pointed questions and can they employ didactic content from one area into another without being taught specifically to do that.” Students need to “look at the appropriate use of technology to solve bigger types of problems in science or in engineering, but use science and engineering content and synthesize information from math and science to create some new sort of idea for a problem that they're trying to solve.” Further, assessments need to have “a focus on higher level thinking and an earnest attempt to find good ways to measure critical thinking through the implementation and integration of didactic content from the different STEM areas.” Interviewee 13 said that integrated STEM needs “authentic assessment with teachers asking why…you have to have authentic assessment all the time.”

It can be argued that both project-based assessments and portfolio-based assessments fit as authentic and competency based models for assessment. In fact, several of the interviews used project-based or portfolio-based models in their description of authentic, competency-based assessments. Ultimately, the assessments of integrated STEM are going to be non-traditional where students create a product that demonstrates their skills in a real life authentic setting.

Integrated STEM and state standards. When considering state standards and integrated STEM, seven participants stated at some level there could be a connection, two emphatically said there is no connection, three do not appear to be sure, and one respondent is taking a wait and see approach. Interviewee 1 said, “I think that a lot of our standards are vague enough that you can find ways that they do relate, so I think that it might not look the same as it has always looked. Otherwise, some current standards will need to change. That is going to be a really tricky part and that goes back to implementation." Interviewee 2 feels that "the science standards deal with the scientific process and technology and utilization so you can certainly do some mapping there. There is also room for content mapping." Interviewee 6 strongly believes that, "the standards, although they have small things that need to be taught that are in there…all the narrative in the beginning of the standards say that you can couch some of that in bigger environments." Interviewee 7 matched integrated STEM to state standards in this way. "They do have process standards, I guess in different areas. I think if you really select the process standards from the list of standards." Interviewee 8 state standards could be addressed by "the matching of standards with activities and daily curriculums." Interviewee 10 said,

> All my projects were based on the current standards either from the school district or the state. So, I could create a challenge that at its roots was based upon what the state required, what the district required, but was still its own challenge.

Interviewee 13 thought that state standards could be addressed "with teacher questioning." She felt that state standards could be met, "if the teachers develop their questioning [toward] standards or multiple standards."

Several participants were not sure if integrated STEM could be matched to state standards largely due to ambiguity around definitions. Interviewee 3 said, "I don't know. It depends which current standards you're talking about. There are a lot of current standards." Interviewee 9 said, "It depends on how you define current standards."

Interviewee 12 stated, “I don't know because I don't know what our definition of integrated STEM is yet.”

One interview participant is currently an integrated STEM teacher who’s class replaces core content. This participant has taken a wait and see approach to matching integrated STEM to state standards until more data is collected. Interviewee 4 said, “well one of the things that we are going to do is track the students that are in this program and compare their NeSA test, their standardized testing, to the students that are not in STEM and just to see their retention of those core topics.”

Two participants specifically stated that integrated STEM would not match current state standards. Interviewee 5 said, “I think they [integrated STEM and content standards] are two separate things.” Interviewee 11 believes that, “I'm not sure that [matching integrated STEM and state standards] can actually happen. Our standards are setup so that they deliberately isolate the topics rather than deliberately integrate them.”

Integrated STEM and standardized testing. When looking at standardized testing and integrated STEM, there is much division among the participants. Eight of the participants clearly believe that standardized testing and integrated STEM are not compatible. Interviewee 1 believes that integrated STEM and standardized testing fit together,

> Poorly. Again, I think that the end result of STEM project or products would be sort of a portfolio of work. I think that is hard to fit into bubbles. I think that it's hard to demonstrate on a multiple-choice test. I think multiple choice tests and standardized tests can change and I think you can still ask problem solving

> questions that require the same skill set that we currently test for, but I don't think the answer is the same.

Interviewee 2 believes that “unless carefully crafted it [integrated STEM] could be detrimental to standardized testing because it is not looking at the ideas in isolation. It is looking at the big picture.” Interviewee 3 said something similar with a qualifying statement. When asked how integrated STEM will fit into standardized testing, she said,

> Not well. Actually, that's not true because there is a chance if it's done well and the teachers point out what the concepts are that they are learning, if a student then takes traditional standardized tests they might go, ‘oh yeah, yep, I know how to do linear equations’ or ‘I remember how a voltmeter is set up to read’, or whatever it is.

Interviewee 5 believes, “if you want to assess STEM instruction for integrated STEM or whatever you're calling it, then it probably does not fit very well within the current state assessment process.” Interviewee 7 stated, “I think, standardized testing assumes a content base and I think in integrated STEM, really good integrated STEM, you're not going to know what the content is.” Interviewee 9 said, “I have no idea how you're going to do that if you're going to go in the direction that I’m thinking.” Interviewee 10 agrees. He said,

> I don't see it [standardized testing] happening and I would not be a proponent of it because that is not STEM. To me STEM is not standardized. STEM is too open. There is more than one answer, more than one solution to a challenge.

Interviewee 11 summed up the concerns of the other respondents when he said,

> I don't think it does. I think standardized tests are designed at this point to pull out specific information about what students know about math and science…The attempts to actually integrate topics on standardized tests from what I have seen really don't exist in a form that is going to tell us much.

Three respondents felt that integrated STEM and standardized testing could coexist or even be beneficial to standardized test scores. Interviewee 6 said, "first of all, I think contrary to popular opinion, it will help as opposed to hinder that [standardized testing]. If anybody...people haven't looked at the standardized tests lately and it is all about higher order thinking." He further stated that, "I personally believe that the standardized tests are just fine. The curriculum is what needs to change and the integrated STEM will help achieve on those more thoughtful interdisciplinary [assessments]." Interviewee 12 said,

> If there's content in the integrated presentation or content, you ought to be able to see if they meet that on the tests themselves or on the standards. So you have to be able to do an alignment to the standards get some fashion, the science standards, the math standards, and the technology expectations.

Interviewee 13 believes, "It [standardized testing] can happen in a STEM class. The teachers just have to be cognizant of it."

Two interviews were not clear as to how integrated STEM and standardized testing would function together. Interviewee 4 did not speak specifically to this topic. Interviewee 8 said that, "I think there is room for both. I think we need both," but did not elaborate on how this might work.

Integrated STEM and national standards. Not all participants spoke to how integrated STEM could be aligned to the national standards for the STEM disciplines. However, the majority of those who did (7 out of 9) said that integrated STEM and national standards could be aligned. Interviewee 1 said, "The national standards should all have aspects of problem solving and of problem identification. I think our STEM classes would match those." Interviewee 2 thinks that, "the rubric or reflection that is guided to some of the different standards would align very well." He went on to say, "I think that there is a way to integrate the material learned, the knowledge gained by the students in the project to the [national] standards." Interviewee 6 strongly believes that,

> Standards are changing this way. The next generation science standards have engineering and technology in there. The NCTM math standards certainly has problem solving connections, representations, and things like that.

He further stated,

> I think higher-order thoughtful questions and rubric sort of environments and stuff...Standardized tests just like on the essay exams that they have for ACT and SAT...there is going to be, I predict eventually, that there will be much more project-based standardized assessment.

Interviewee 7 said that integrated STEM could be aligned by "looking through the national standards for each of the STEM areas and pulling out the process standards out of those and then looking at those or using those as a basis for evaluation." Interviewee 8 believes,

> If the curriculum were written correctly, if we have good people doing the writing and taking those standards and weaving the critical learning outcomes into a

> STEM environment, I don't think we would have any problems passing those [national standards].

Interviewee 9 thinks, “the next generation science standards align.” Her rationale is that if,

> You look at the next generation science standards, those are designed in a way that makes it easier for an integrated STEM program because if you look at all the cross-cutting concepts and dimensions…it is truly an application project-based kind of mindset.

Interviewee 13 stated that, “I think as teachers when we plan our content, we have to look at the overall concepts and your assessment is definitely geared to the overall concept of your national standard.”

Only one participant clearly stated that integrated STEM and national standards are not compatible. Interviewee 10 said, “I don't see any type of standardized assessment attached to STEM.” The response from Interviewee 11 was not clear. He said integrated STEM could be addressed by,

> A focus on higher-level thinking and an earnest attempt to find good ways to measure critical thinking through the implementation and integration of didactic content from the different STEM areas.

This comment speaks to some of the other respondent’s comments about higher level thinking on the national standards, but remains unclear as to where the Interviewee actually sees integrated STEM fitting into the national standards.

To conclude, Interviewee 13 talked about the frameworks for the national standards that no one else mentioned. She felt that the frameworks might be more important then the standards themselves because the frameworks help understand the standards. She stated,

> I think even more important then the national standards, is knowing the framework behind it. If you look the national standards, I don't know a national standard that doesn't have a framework piece. The framework is valuable to go through and understand national standards. I think I would throw in frameworks in there as well. It just really helps the teachers form their thoughts behind what the student should be able to know and do.

Concluding thoughts related to integrated STEM assessment. At the conclusion of the interview, each participant was asked if they had any other thoughts or comments that the researcher needed to consider. Many of the respondents reiterated things that were previously stated in the interview but felt there were some additional comments that were worth citing.

Interviewee 1 stated, “I don't think it has to exclude the softer sciences like English, history and arts.” He further believes that,

> The goal of education forever has been to make somebody who is able to critically think to look at a problem and find a solution. To go and find resources and tools that they don't have, learn them, and apply them.

Interviewee 1 felt that integrated STEM addresses this goal better than traditional instruction. Interviewee 2 feels that “you are looking at the higher levels of thought to be successful with this [integrated STEM].” Interviewee 3 believes that, “integrated STEM is a really great thing for the learner because it finally gives relevance to the stuff that they have just been memorizing.” Interviewee 4 considers integrated STEM “as a way of thinking or a way of teaching versus the content they are learning." Interviewee 5 agrees and stated, "it [integrated STEM] is more of almost an instructional approach or instructional strategy, but to me it's more of a way you would get to the actual content standard itself." Interviewee 10 said, "I am looking forward to you...to what your definition will be of integrated STEM education because I cannot find a definition." He went on to say that,

> If you talk to and read up on the National Academy of Engineering all these different places on K - 12 STEM...all these committees that put out stuff, there is nothing consistent. I am looking forward to what you have because I don't have a problem using that going forward because at least we would all be on the same page around here in a sense. That is kind of what we need.

Interviewee 11 talked about the history of integrated STEM. He said,

> It's not a new idea and everybody seems to think it is a new idea. It's been around basically since the dawn of Education or at least formal American Education happened with the report of the Committee of 10 at Harvard. They talked about the ideas of integrated topical instruction and that was in the early 1890s. Activities integrating math and science, all these things have been around far longer than the STEM acronym has.

He further discussed the history of integrated STEM and mentioned a possible avenue to explore related to today's struggle with what integrated STEM is and how to implement integrated STEM. He stated,

> It would probably be worth going back and looking at educational trends from things that happened after the Industrial Revolution, things that happened when

> apprenticeships in companies were designed, things that happened immediately after the Defense Education Act in the late 1950s happened, what kind of things were going on that worked during those times that actually looked like integrated STEM would be great things to revisit and add to what is happening in STEM now.

Interviewee 12 said, "It's that idea of integration of STEM is important, but I think there's a lot of people to get on the group." Interviewee 13 discussed current STEM programs and what she sees as deficiencies. She believes that "when you look at STEM programs throughout the United States, they aren't integrated." These comments are relevant because they provide insight into what the Interviewee is thinking and their perceptions beyond the interview questions.

Identified Themes across Interviews

To identify themes across interviews, all the names and questions were removed from the text and the raw data for each interview was coded. Similar codes were grouped together to identify themes in the data. If other Interviewees did not use the exact words, but the researcher could imply that the context of what the participant meant was the same, this information was grouped together as being semantically identical. Further detail related to this process and how it was applied will appear in the expanded themes below.

Theme 1: Subject integration/project-based learning/design-based education. The conceptual framework of the study has three supporting legs. The first leg consists of three pedagogical methods identified in the literature: project-based learning, design-based education, and subject integration (Kelley, 2012). As the interviews were analyzed codes related to project-based learning, subject integration, and design-based education began to surface.

Most Interviewees (12 out of 13) specifically stated that integrated STEM education must have a project-based learning approach. Project-based learning is defined by Dym, et al., (2005) as a multidisciplinary approach combining design-oriented project-organized education and problem-oriented organized project-education. Design-oriented project-organized education is related to 'know how'. Specifically, the problems students encounter are related to constructing and designing using the synthesis of knowledge from many disciplines. Problem-oriented project-organized education is related to 'know why'. This is specifically related to the solution of theoretical problems through the use relevant knowledge from any discipline. Together, the 'know how' and 'know why' that students learn and use to solve problems in a project setting make up project-based learning.

The importance of project-based learning to integrated STEM is highlighted by the responses of the interview participants. Most of the participants specifically referenced project-based learning as part of their definition and consequently project-based learning arose as a primary vehicle for integrated STEM. For example, Interviewee 3 said, "it [integrated STEM] is either project or activity based and that it is active and not passive." Interviewee 5 believes, "it's [integrated STEM] all project-based." Interviewee 6 stated, "I would say certainly project-based learning. Because a project gives a student [the chance] to really demonstrate their connections and their understanding." Interviewee 7 believes, "integrated STEM I think would need to occur in a project-based activity" and that students need "project-based experiences."

Interviewee 8 says, "It [integrated STEM] is project-based, outcome-based, real world." Interviewee 9 thinks integrated STEM is an "experiential learning experience either project-based or problem-based." Interviewee 10 says students in integrated STEM should need "to do a project of something based on the engineering design process." He goes on to say that when standards for different disciplines align, "that is when you approach a STEM type of project for the school or the class or the grade or whatever." Interviewee 11 thinks that integrated STEM consists of "a broad project in career-based or project-based learning or even some product that you want to come up with and affix certain academic content to that project."

Several respondents related assessment of integrated STEM to long term or extended projects. Interviewee 1 stated, "you can show their math learning through these projects, through their demonstrated knowledge on final results and what they have done. Understanding that is acceptable and finding a way to make that meet your criteria." Interviewee 2 says, "do a project, try it, explore it, and then again some sort of evaluation in the context of a rubric or in the context of a one page summary, a written summary." Interviewee 4 believes that integrated STEM assessments should be "assessments that are maybe more project-based." She goes on to state, "so we do our projects [and] that is actually a part of their grade." Interviewee 10 believes that "the project itself should be the assessment. That method [of] project-based learning and assessment would be it."

Many Interviewees responded and considered project-based learning from an integrated STEM curricular standpoint. Interviewee 1 stated this about integrated STEM, "so rather than learning a science topic just to learn it, you would need to know it to prove a larger point in your experiment, your project, or whatever your quest is." He further states that teachers must have the "understanding that projects may not be clean." Interviewee 2 was talking about what resources you might need for integrated STEM when he stated, "I would say that depending on your projects you would almost need a shop-like environment in which to do this." Interviewee 3 said this when discussing resources,

> What are the four projects that we are to have the students work on, and what level of math do they need to know, and what's the science subjects that they're going to be doing, and what do they have access to for materials? So they think pretty strategically about where they are going to be in the year and which subject and topics within the subject are going to be covered simultaneously, and how to tie all those into a relevant integrated STEM project.

Interviewee 12 stated that resources need to change "based on the project they might be doing."

The conceptual framework of the study continued to be strengthened when the concept of subject integration surfaced unanimously among the respondents. As one respondent (Interviewee 13) stated, "When you look at STEM and STEM research, integration is assumed. So that when you look at STEM programs throughout the United States, they aren't integrated." Another Interviewee (Interviewee 11) said something similar, "So, the assumption of integration really has been happening forever. I think each content area maintains its own kind of unique didactic content but there has been natural spill over." Both of these comments speak to the fact that integration might not be as prevalent as first thought. The second statement also speaks to the fact that there are natural overlaps in the STEM disciplines that can be exploited to provide opportunities for learning.

The subject of integration of the STEM disciplines continued to surface throughout all the interviews. For example, Interviewee 1 said, he sees “integrated STEM technology as a science class using computer science topics and ideas to prove a science fact or do a science experiment. Similarly with math being applied in science, being applied in a technology or engineering as part of their quest, but we have to use these ideas from other areas” and “using technology to further your understanding of science or mathematics or using mathematics to further the understanding of computer science is STEM.” He believes that people should come together to create “STEM education with the goal of integrating all their classes together and intertwining their topics” and that “it [integrated STEM] is a class of multiple classes combined together.

Interviewee 2 sees integrated STEM as “taking concepts from a lot of different areas like natural sciences and mathematics in order to design a solution to a problem.” Interviewee 3 sees integrated STEM where “students don't learn the subjects independently from each other. That the knowledge that they are learning is all related knowledge toward an end goal” and that students “see the connection and need to use the knowledge from all different subject areas.” Further Interviewee 3 believes that teachers need to carefully think about “where they are going to be in the year and which subject and topics within the subject are going to be covered simultaneously, and how to tie all those into a relevant integrated STEM project.”

Interviewee 4 defines integrated STEM as “an opportunity for students to see connections among different content areas that previously were ‘siloed’ out into their own specific categories" and thinks "it's a lot more meaningful if they [students] can have some connections to different content areas that they are currently studying and/or different fields that they might be interested in going into." Interviewee 5 continues the integration theme by defining integrated STEM as "how all the content areas interact and how they are really applied beyond the classroom setting and getting into how the specific set of skills and knowledge are also taught," and expects teachers to "continue to show how content areas are connected and how they would show the application of it beyond the classroom."

Interviewee 6 says integrated STEM "needs to cross disciplines" and that he sees "integrated STEM education as where science, technology, engineering, and mathematics are much more interdisciplinary perspective." Interviewee 7 believes "integrated STEM education is bringing math, science, engineering, and technology into all classes where they apply, and doing that through projects that students do within the class that have math or science STEM topics embedded in them, and also doing focused classroom activities on particular topics." Further, Interviewee 7 thinks, "more integration in the curriculum would be a benefit and more open-ended opportunities for students to investigate in an open-ended manner would be a benefit."

Interviewee 8 states that integrated STEM is where the "subject areas of science, technology, engineering, and math are not isolated within their school day" and that it incorporates "real world topics, real world problems working in collaborative groups in which students have to use their knowledge of science, technology, engineering, and math to come up with potential solutions." Interviewee 9 believes that integrated STEM is "integrating all the core areas of curriculum into STEM education" and "is the combination of all the knowledge that students are learning at a particular age level and building upon what they have learned through their experiences to be able to apply knowledge and solve real-world relevant problems." Interviewee 10 believes that integrated STEM is "[where students are] taking knowledge from each one of their classes and they are applying it in their other classes or they are seeing the connection between everything" and that "STEM is not a 'siloed' enterprise and all four of those ought to come together."

Interviewee 11 says, "Integrated STEM education involves the specific use of didactic content from one area to support any or all of the other areas of STEM" and that it should include "the use of one field to bolster content into another and to develop new content." Interviewee 12 thinks that integrated STEM is "finding out the applications that would bring science, math, and technology together." Finally, Interviewee 13 believes "integrated STEM education is when you take multiple discipline contents and you use the knowledge that you gain from those content areas and apply them toward problem solving." The evidence from the interviews regarding subject integration is clear. All participants see STEM education containing some aspect of integration of subjects.

Design-based education is the third leg of the pedagogical model that Kelley (2012) outlines, which also serves as part of the conceptual frame work for the study. Design-based education is described as education in a full range of real-life activities and using a hands-on approach to teaching. This aspect of Kelly's pedagogy was not nearly as evident as project-based learning or subject integration. In those cases, participants used words like "project," "project-based," or "integration" that clearly showed their importance to the Interviewee. Design-based education (DBE) was equally prevalent but it took a semantic analysis of the text to garner the underlying meaning. For the analysis, the researcher coded text related to real life applications, real world experiences, relevance, and other text like demonstrate, explore, etc. that had meaning related to a hands-on approach.

DBE was found in Interviewee 1 when he stated, "you would find applications of that real world or contrived but ways that you can demonstrate the usefulness of this in a more practical application," and "the teacher must build a culture where they [students] are allowed to define problems, explore the problems, and use you as a guide...use the teacher as a guide and a resource, but not use them as the absolute purveyor of knowledge." Interviewee 2 was more directly related to DBE. He said "I think it is a much more real world and rich education experience" and when referring to integrated STEM resources, "with the hands on...certainly you need some space."

Interviewee 3 believes that "integrated STEM is a really great thing for the learner because it finally gives relevance to the stuff that they have just been memorizing." Interviewee 4 said that integrated STEM teachers are "trying to put them [students] into situations where the line has a meaning and the slope has a meaning and the y-intercept has a meaning" and integrated STEM is a place where, "students that really excel with projects, and really excel through hands-on situations, can still learn the content." In addition, Interviewee 4 thinks educators need to "give them [students] opportunities to get more of a real world setting, I think project assessments are equally as important, if not more important, than standardized testing."

Interviewee 5 thinks educators should be “creating authentic experiences for students” and sees integrated STEM as more about how a class “would be taught and how students would apply that beyond the classroom.” Interviewee 8 sees students in integrated STEM addressing “real world topics, real world problems, working in collaborative groups in which students have to use their knowledge of science, technology, engineering, and math to come up with potential solutions.” In addition, he believes that students should be “thinking critically and doing their best to come up with real-world answers to real-world problems” and that “real-world problems change the nature of how students address the subject matter.”

Interviewee 9 thinks a “STEM high school needs to be set up to replicate what is going on out in the industry and the business world” and that teachers need “to be able to create some of these problem-based, relevant, application kind of problems and lessons” where “the kids could apply the knowledge to real world experiences.” Interviewee 10 sees integrated STEM as where students “work on a real world issue in their community, in their neighborhood, their school, or whatever it may be” and “they are applying all that knowledge and it's even taught that way in that it's more experiential.” Interview 12 sees integrated STEM as where “students get to explore and see those connections and hopefully see some real life things happening” and that a key component of integrated STEM is “problem solving and seeing real life applications.”

Interviewee 13 specifically references the hands on nature of integrated STEM. She says “public education is very good at devaluing hands-on skills, but being able to take an electron microscope and being able to apply that in different areas, that shouldn't be devalued.” This implies that we need the hands on nature of DBE. The remaining interviews had a lesser connection to DBE. They all spoke about problem solving and application of knowledge, which is loosely connected, to DBE. Interviewee 6 sees integrated STEM as “Interdisciplinary. Big ideas. Problem solving and inquiry” and says, integrated STEM is “much more of a true problem solving environment where they learn certain concepts.” Interviewee 7 says that integrated STEM instructions should “give students project-based experiences that allow them to utilize their STEM knowledge and skills.” Interviewee 11 says integrated STEM students should be able to “apply information from a given field that crosses over into another area.” Overall, a strong case can be made for the interviews containing evidence to support design-based education as a part of integrated STEM.

In summary, all the Interviewees either mentioned or referred to the pedagogical methods as referenced in the conceptual framework of the study without being prompted. The emergence of this theme shows strong support for the conceptual framework of the study and strongly infers that project-based learning, subject integration, and design-based education should be included in integrated STEM implementations.

Theme 2: Leadership. All participants (13 of 13) in the interviews specifically stated some form of leadership is necessary for successful integrated STEM education. From the literature, leadership, specifically school administrators, were cited as a key support structure for integrated STEM education. While the participants of the study did discuss the need for strong school leadership, their thoughts on the leadership related to integrated STEM education was far broader in scope. They included such ideas as leadership by teachers, shared leadership, student leadership, and leadership by outside experts.

School leadership can be defined in many ways. For the purpose of the analysis, the researcher had combined comments about school leadership from anyone directly attached to the school except teachers and students. This included building and district level administrators, curriculum specialists, and school board members. Interviewee 1 believes that you must “have an administration that is willing to put trust in the teacher, and teachers that are willing to put trust in the students” and further, that “you have an administration that is allowing this [integrated STEM] to take place.” Interviewee 3 said “the administrator has to ‘buy in’.” In addition to facilitating curriculum and teaching, “the administration actually gives the team of the different subject area matters planning time to talk about things, to talk about the students that are in all those classes.” When developing an integrated STEM curriculum, Interviewee 4 believes that you must

> Talk to the administration and go forward from there. So from a teacher's perspective, if you have the passion for it, go for it, and find people that will support you. From an administrative position, see teachers that are passionate and want something like this [integrated STEM] and just talk to them and see what they're willing to do.

Interviewee 4 agrees with Interviewee 3 when she said, “If I am an administrator in a building I would want to allow that time for my teachers to work together on a new program such as this [integrated STEM].”

Interviewee 5 said for implementation of integrated STEM, “you may need an instructional coach…someone who's able to coach and to provide that support in terms of improvement of instruction.” Interviewee 6 thinks that there “needs to be a STEM curriculum director who oversees those departments and has some sort of control over it.”

He further reiterated, “Whether it is someone designated as the STEM leader of the school where they lead an interdisciplinary committee or better, they have a designated curriculum director who is the STEM curriculum director.” Interviewee 8 believes a “collaborative effort is going to be necessary on this [integrated STEM] with good administrators and good leaders at the top.” Interviewee 10 believes that to implement integrated STEM, “administration and curriculum and professional development those three things are needed.” He further believes that STEM certification is needed and that “that can be done with the support of the administration in that building or maybe the school district and the other teachers to provide a course.”

Interviewee 11 believes that staffing will require, “educational leaders in integrated STEM who have a lot of the abilities and knowledge that I have been talking about.” He elaborated teachers need to be, “fully degreed in two or more of the subject areas, or have at least a very good concept of the crossover of how all those really are used from one field to the next.” He also believes that integrated STEM requires “educational leaders who have the ability to very specifically guide teachers in that process.”

Leadership by teachers, students and outside the school was also mentioned as important to integrated STEM. Interviewee 2, feels that teachers need to have leadership experiences. He is a practicing high school teacher who feels he has “enough experience either formally or informally with engineering and mathematics, that I feel pretty comfortable in either leading something or finding out the information I need.” Interviewee 6 thinks, “it [integrated STEM] needs some sort of faculty specialist in STEM with a vision for it. Interviewee 7 strongly believes that “it [integrated STEM] takes leadership from students that are interested in pursuing STEM activities." He further states that the creation of integrated STEM "takes leadership I think from both the teacher's perspective and the student's perspective as well." Interviewee 9 believes that when professional development is needed, you need to "find community leaders to kind of help out with that training so that you're on top of it." Interviewee 12 stated, "[It would be the] Nebraska Association of Teachers of Mathematics [for math]. It would be NETA for technology. It would be NATS for science. I think all of those leadership groups would be the ones who would help disseminate and support the idea of STEM integration."

Possibly the best way to sum up the leadership needs for integrated STEM, is through shared leadership. Eight of the 13 interviews spoke to the shared leadership needs of integrated STEM. Interviewee 2 said, "it [integrated STEM] takes a lot of cooperation on the part of all the participants. The students. The teachers. The administration. The parents." Interviewee 4 stated, "The teachers, the teacher's organizations, and the administration have to be on the same page and have to make sure that their goals are all the same." Interviewee 5 believes that "it [the leader] is someone taking the lead and saying let's think differently on how we view STEM and let's think differently on how we communicate to our teachers and our students." Interviewee 6 spoke about the importance of leadership when he stated,

> If you don't have any person to develop a STEM course, or an engineering course, or a computer science course, and it counts for university entry requirements and moves from an elective to a required [course], one of the options for required courses, then who does that? Who leads that conversation?

Interviewee 7 believes that integrated STEM takes “leadership, I think from both the teacher's perspective and the student's perspective as well.” He further stated this about shared leadership,

> I think you have to have leadership in the school from the adult side and from the student side. From the adult side, you'll see that leadership, possibly you'll see that leadership in the administration, in some cases where an administrator did see the importance of STEM experiences for their students.”

Interviewee 8, Interviewee 12, and Interviewee 13 spoke about shared leadership in term of vision and collaboration. Interviewee 8 stated, “I think we need practical visionaries...Practical visionaries...What I mean by that are people who can lead and demonstrate.” Interviewee 12 says to implement integrated STEM it “takes a champion.” Interviewee 13 summed up leadership related to integrated STEM this way. “It takes partnerships and collaboration and you need people to advise you…the partnership has to go outside the school doors. You have to reach out into the community. Your school board definitely has to be a part of that creative team as well.”

The theme of leadership being essential to integrated STEM resounded across all the interviews. Each interview respondent put a unique spin on exactly who and how the leadership must be applied; nevertheless, it appears leadership is an important aspect of integrated STEM.

Theme 3: Outside support of integrated STEM. The concept of outside support was prevalent in the interview as 10 out of 13 respondents mentioned outside support in various ways. There was general support for different outside of school entities, helping with the creation and implementation of integrated STEM. Interviewee

9 was concerned about listening to the business communities needs when creating an implemented STEM program. She said, "The educators need to know what the business community people are saying to them." Interviewee 12 said we need to be careful to "not leave the business people out".

One way that outside entities were seen as being able to help schools with integrated STEM is through the possibilities of providing resources. Interviewee 4 said, "I think seeking outside funds is huge" and "I think awareness within the community is huge." Interviewee 10 spoke about business and industry in this way. "The supports, the resources, whether it's human resources community members, professional members coming in to help out." Interviewee 12 spoke about looking for outside investment in an integrated STEM program. She mentioned "the Perkins funding for CTE (Career and Technical Education), they have a bucket load full of dollars you're not going to find those same funds to even have the tools or the resources technology-wise." Also, when speaking about businesses she said, "they [businesses] are willing to cough up and do some investment. So, I think business associations, working with your CTE staff, and seeing what we can leverage." Interviewee 1 said to implement integrated STEM you need "to go and find resources and tools that they [teachers] don't have, learn them, and apply them." This implies the need for outside support of integrated STEM.

Outside entities in business and industry as well as higher education were thought to be able to provide input beyond financial resources. Interviewee 9 believes that,

> The educational reform that's going on right now needs to include and incorporate all of the STEM experts that are out there whether it's business or universities, or

> informal science organizations like the zoo that has the experts, the researchers that are working in STEM education.

Interview 11 thinks schools need "better working partnerships with teacher training institutions" for integrated STEM staffing. Interviewee 12 mentioned, "I think making a connection with your community college" is important for integrated STEM. Interviewee 13 echoed that sentiment when she said integrated STEM could benefit from "involving some of the community colleges to bring that expertise into your school."

Seven of the 13 respondents said that expertise related to integrated STEM could be found in the world of business and industry. Ultimately, they thought educational support by providing expertise was also seen as a way that business and industry can help schools with integrated STEM. Interviewee 2 thought that integrated STEM could benefit from "pulling people from local business to give some insight." He further mentioned students taking field trips to see real world applications and experiences. Interviewee 4 said students need "opportunities to get involved with career focused individuals outside of the classroom. It might be…going on field trips or it might be meeting with people in their industry that they are possibly interested in." Interviewee 5 states for integrated STEM "that is really critically important to…I think just [have] access to experts." He wonders if you are the teacher and,

> You know if I am not the expert in a scientific area, but I want to be able to utilize that, who can I reach out to in my community? Who can I partnership with from a business and industry perspective? Businesses can possibly fill that role.

Interviewee 9 says "they [schools] have to open up the doors by really letting in the experts, but there needs to be an understanding from some of the experts out in the field, some of the researchers, some of the other organizations, for example like the zoo that come in." She further stated that schools cannot "be afraid to ask others to come in and kind of help out." Interviewee 10 said this of business expertise,

> The community resources once again would be professionals who can not only come to the class, we're not talking about show and tell, we're not talking about career day, but you truly assist and help that educator with projects and so on to also help expose the students to professionals, working professionals. Then also to get those students out to community and that's also in a sense how those students can see their part in the community.

Interview 12 stated, "we can throw in business to try to help us figure out what the real world is asking for," [schools can] "team up with maybe local businesses that would be interested," and "get the business people that talk about STEM careers and for education." Finally, Interviewee 13 said this of business and industry expertise, "along with that business and industry partnership, they can also bring in people who have expertise that are not always available to a school and likewise they become your partner if you need equipment of any kind."

Several respondents saw collaboration between outside entities as important for successful integrated STEM in schools. Interviewee 4 feels that "it [integrated STEM] may be more of an internship where they work more in collaboration with an organization or business in the community." Interviewee 8 said, "it [integrated STEM] is going to have be embraced by the community." Interviewee 9 said, "the big picture of integrated STEM education is to bring in all the different components and players and everybody have an open mind by working together on educating our youth." She further stated, “the educational reform that's going on right now needs to include and incorporate all of the STEM experts that are out there whether it's business or universities, or informal science organizations like the zoo that has the experts, the researchers that are working in STEM education.”

The final way seen by the Interviewees that outside entities could help with integrated STEM in schools is through training. Interviewee 9 thought businesses could help teachers get training on specific equipment and techniques. She said,

> Partnering with a business partner or an industry partner where they're helping maintain some of that [equipment] or heading out in the next generation when they get the top-level thing. Another piece is the training for the teachers on this equipment. I think that's where you start referring to your business partners and community leaders to kind of help out with that training, so that you're on top of it. You're able to replicate so that the kids can experience.

Interviewee 12 thinks professional groups can help with providing teacher training. She said this when speaking about professional development.

> [It would be the] Nebraska Association of Teachers of Mathematics [for math]. It would be NETA for technology. It would be NATS for science. I think all of those leadership groups would be the ones who would help disseminate and support the idea of STEM integration.

Interviewee 13 believes that “it's so important to have the business and industry and the people in your community involved, because they can help you see and you can help them see how you are training in working with kids to fill their needs within the community with jobs and quality workers and that type of stuff.” She further stated that, "it [integrated STEM] takes partnerships and collaboration and you need people to advise you. The partnership has to go outside the school doors."

The concept of outside support for integrated STEM ran throughout all the interviews from their different perspectives. Outside support for training, collaboration, expertise, and providing resources were all cited by multiple Interviewees which showed that outside support is a critical need for integrated STEM.

Theme 4: Professional development needs. During the interview, the respondents were asked about professional development as a sub-question. This was specifically done because professional development was identified in the literature as critical to successful integrated STEM. This means that all respondents were asked to speak to professional development. In doing so, a number of themes related to professional development emerged.

There were some very powerful general responses to professional development needs related to integrated STEM. Interviewee 2 does not think that you need to hire new teachers for an integrated STEM program. He says,

> I think you can train the teachers that you have got, but it is going to take some time and willingness on the part of those people because, for all intents and purposes starting an endorsement in other areas, or touching on at least having a level of expertise, or being willing to cross pollinate with some other teachers, or possibly even co-teach, takes training.

Interviewee 4 stated that to create integrated STEM education "it takes the same skills we are asking our STEM students to do." For the integrated STEM implementation in her school, they received a grant, which allowed them to get some training. Interviewee 5 thinks, "STEM is really about our pedagogical approach to teaching the content and how it can be applied." This implies that training in the pedagogical approach is needed. Interviewee 7 thinks integrated STEM is about providing teachers freedom to learn and explore integrated STEM activities. He stated we need to "give the pre-service teachers an opportunity or suggestion or requirement that they just pursue their passion in STEM." He further believes that,

> Giving the teachers the freedom or the suggestion to figure out what they really want to do themselves within integrated STEM, what they enjoy doing, what they feel comfortable doing, what do they want to do, what do they want to learn more about, and have them figure that out before they enter the classroom and have them understand that, that's important to know.

Interviewee 8 said, "we need to show them [teachers] tangible examples, and they're hard to find, of what STEM education looks like. What does that classroom look like? What philosophical attitudes should they consider in terms of what it takes?" Interviewee 10 feels that,

> Professional development will be the educational supports that are put in play to help whatever teacher is trying to go into this area, to help them get to the point to where they feel comfortable, they feel credible in the classroom before their students and in the content that they're presenting to their students.

Interviewee 10 further stresses that "getting them [teachers] educated with a proper adequate professional development that they would need" is very important.

Interviewee 11 says that we need “specific teacher training and retraining” including professional development on a broad scale. He believes that for integrated STEM education to be implemented there needs to be,

> Extensive training needing to happen in either a STEM learning cycle model or in specific integrated ideas, in other words how to teach mathematical topics in the context of science engineering or technology. How to teach an engineering topic and to pull out the most critical elements of the math that needs to be used for that.

Interviewee 12 feels that professional development needs to include “sharing of a common definition.” Interviewee 13 specifically spoke to, “professional development that needs to take place…Safety is one. Ethics is two” and “you have to get the professional development specific for the teacher who is in STEM.”

Six of the Interviewees specifically referenced that professional development for teachers of integrated STEM included experiences in an integrated environment similar to what we will expect of students. Interviewee 1 alluded to this when he said, “I think the biggest thing is that, loosening the teacher role. I think that if you have never experienced that before, and most of us haven't, growing up in our existing education system.” He went on to say that “extra training, work-shopping, experience, would be useful.” Interviewee 3 firmly believes that “professional development, I think is needed so that they can experience what it looks like or what it can look like because sometimes you just need that experience.” She further stated that,

> I think that if STEM teachers had the opportunity to have a truly rich experience doing an integrated STEM project and could try taking it back and seeing how

> their students reacted to it, that would help in terms of getting buy in on why it should be done differently than it is currently being done.

She believes that "giving those teachers [integrated STEM teachers] that experience is a critical piece to the implementation" and "having the teachers play a role of the student and leading them through an integrated design...an integrated STEM project" is important.

Interviewee 6 believes that "integrated STEM education requires a variety of experiences." This is echoed by Interviewee 7 who stated, "teachers need to be given the experience of doing some kind of integrated project." Interviewee 8 spoke about pre-service teachers and said, "the students who are coming through our university in the college of education don't have any hooks to latch onto based on their educational experience and that's what these kids come here with." Interviewee 9 feels that non-traditional teachers have experiences that make them better at integrated STEM than career teachers. She said this about non-traditional teachers,

> Those teachers that have that real world experience or that experience outside of the classroom, not going right from college into a classroom, tend to be able to build activities with lessons, ask questions, facilitate, have the kids lead the conversation. I don't know if that's because of their experiences that they are bringing into the classroom and that they have been out and they're able to use relevant examples.

These kind of statements about teachers having experiences in integrated environments need to be considered when creating and conducting professional development for teachers who might be teaching in an integrated STEM environment.

Several Interviewees specifically mentioned that professional development needs to occur in project-based learning. This type of training would seem to be very applicable to getting teachers experience in integrated environments as stressed in the previous section. Interviewee 2 has learned project-based learning by doing it in the classroom. He said this when referring to other teachers that are interested in teaching in an integrated STEM environment.

> I think training. You have got to have a teacher who is really comfortable with a lot of different material. If your background is simply that of a mathematics teacher, or a science teacher you may not feel comfortable enough in some of the other areas that you are going to be pulling in. I know certainly, I have learned a lot about project-based learning, or problem-based learning and that has been really useful when it comes to trying to develop new ideas.

He went on to say that,

> I have been involved in several programs over the years that, I think, have improved my ability to think about and design some of these activities, but it certainly is time consuming and you need to go through some sort of trial by fire where there is some practicum side to this as well.

Interviewee 9 agreed with the need for project-based learning professional development. She believes that teachers need "professional development training to get them onto the same page as that problem-based learning, or project-based learning, or experiential learning, or however you want to define it."

Collaboration was also mentioned as an area needing professional development. Interviewee 4 stated, "the training, I think, comes in constantly collaborating and adapting to the change that is happening around us." She further said that, "I think consistently revisiting your curriculum is a must. Constantly collaborating with a community is a must." Interviewee 2 thinks professional development needs to include situations for "educators when they get a chance to come together and discuss things and share their ideas." Interviewee 5 echoed this sentiment when he said, "you need professional development. I think that another key resource, is the time to collaborate in the PD."

The manner of professional development was also a point of discussion. Five respondents felt professional development was needed to be ongoing, focused, and driven. Interviewee 1 said, "making sure that it [professional development] is actually focused and driven and I think that kind of training, work-shopping, experience is necessary for teachers to feel comfortable and be effective STEM educators." Interviewee 9 said,

> Professional development is a constant and it cannot be a one hit wonder where you come in and have an eight-hour day or a two a day session. I think it is something that needs to be ongoing throughout the year as a constant, almost like a cohort that goes through. I think the professional development needs to look like whatever industry the teacher is trying to replicate, or whatever component of the STEM education career path. I think they need to go out and get those experiences. They have to be immersed in it so they have a better understanding, so that they can actually teach from their experiences by referring to their experiences working in those different industries.

This speaks not only to the constant, on-going nature of needed professional development, it also stresses the importance of the experiential nature of professional development that can help teachers understand and instruct in an integrated STEM environment. Interview 10 feels that there needs to be a “clearly defined consistent professional development process, a program which would include certification and training, on-going availability, and to also provide the teachers with credit” and that “there needs to be something that is kind of standardized, something that is consistent.” Interviewee 11 agrees and stated that a key is to “focus on professional development, but it would need to be sustained rather than just kind of ‘here's your professional development for the day, now go and do this stuff.’ It needs to be kind of a sustained really kind of a habitual sort of arrangement.”

The nature of the conversations around professional development and integrated STEM education has implications related to this study. All the participants spoke to professional development because it was identified as an integrated STEM support structure. However, their comments related to the nature, content, and delivery of professional development should help provide a frame of reference for those school leaders who want to implement integrated STEM education.

Theme 5: Non-traditional assessment. Each participant was asked about assessment related to integrated STEM and several participants spoke about the difficulty with assessment. Interviewee 1 said that, “it [assessment] is the hardest part.” Interviewee 3 stated, “I ultimately think that [assessment] is what is going to stop it because no one is going to be able to figure out how to assess it.” Interviewee 11 said, “I don't think there is a great way to assess integrated STEM yet.” Other participants spoke to how the assessment process will need to change. Interviewee 9 believes that “we need to get creative and redefine what we consider assessment” and that assessment of integrated STEM is “totally different then what is occurring now.” Interviewee 10 stated, that we “have to think in a nontraditional manner of assessment when it comes to STEM.” Interviewee 10 said, “In STEM education, you have a great opportunity to have nontraditional assessment of students.” Interviewee 12 thinks that assessment is “definitely something that would be a thing in progress.” Finally, Interviewee 13 stated, “we haven’t thought of all the possible assessment that we really can use.”

Some non-traditional assessment methods did surface during the interviews. Interviewee 2 believes that teacher developed rubrics would be beneficial. He also said that, “I also see a real strong value in student self evaluation.” In assessment, we are really looking at the higher levels, application and synthesis. He stated that “evaluation in the context of a rubric or in the context of a one page summary, a written summary, or asking a student to reflect on mathematics that you needed to complete the activity,” might be possible assessment strategies. Ultimately he thinks that, “student evaluation gives a lot of chance for real metacognition about what I know, what I had to do. Really getting them to reflect is crucial.” Interviewee 3 agrees when she said that, “it [assessment] would be best if they were not paper and pencil, and in a way that the students could interact with either an individual or a system to explain, justify, rationalize, their knowledge about something.” Interviewee 13 thinks assessments “need to also take the questioning and put it at different levels, different thought levels through their students, and they need to know which ones address the higher learning, so that they are able to assess students in that.”

Interviewee 4 thinks the "soft skills that we are trying to develop, I think need to be assessed in some way." Interviewee 4 also mentioned soft skills specifically as "we think about career readiness skills that students will learn through STEM experiences, the problem solving, the critical thinking; I think that those become more difficult to assess."

There were other non-traditional assessments cited by the Interviewees. Interviewee 7 thinks that a possible assessment could be "how much work has a student been able to share and make public for others to use? How much have they engaged in a community?" Interviewee 10 mentions an assessment of "service learning where the students actually go out and they work on a real world challenge." Two interviews mentioned possible attitudinal surveys as assessment possibilities. Interviewee 10 thought about assessment as,

> Assessing that like pre/post, how did you feel going into it? How did you feel coming out of it? Those types of things. Do you feel like you gained knowledge? Just very broad general things. What did you expect to learn? Did you learn it? Kind of like those KWL (knows, wants to know, learned) type of things.

Interviewee 12 echoed this as a possible assessment technique when she said, "you could do an inventory with whether the students like it in this format better than they do in a traditional format." She also thought that integrated STEM could "use some traditional testing, test content questions, and then I think the other assessment would be attitudinal and how they feel about liking math, science, and technology."

Aside from integrated STEM being difficult and non-traditional, the interviews did have some consensus as to what assessment might look like or contain. Eight of the Interviewees specifically mentioned that assessment of integrated STEM should contain a project. Interviewee 1 said that, "general assessments will be projects" which should include "interviews, talking to people about their [student's] project, talking about what they think the value point-wise or grade-wise of what they did is and was." Interviewee 2 thinks, "there is some sort of product [project]" and that "there is some assessment going on through the project in the form of journaling or discussion with teachers." Interviewee 4 stated that, "assessments that are maybe more project-based" when referring to integrated STEM. She said that would "facilitate their learning in a way that is different than a traditional high school test would look like" and that "project assessments are equally as important, if not more important, than standardized testing." Interviewee 6 said that integrated STEM assessments should be "project-based, problem solving based and higher level inquiry." He thinks this is the best way to assess integrated STEM "because a project gives a student [the chance] to really demonstrate their connections and their understanding." Interviewee 7 said that assessment should be "project-based activities and competition based activities."

Interviewee 8 agrees with the project nature of integrated STEM assessment and what the project should entail. He said,

> The types of assessments that we need to be more invested in are product based, project-based, outcome-based. Show me what you know. Demonstrate what we have been talking about for the last 3 weeks. Build me something. Create me something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

He thinks this type of assessment creates "a healthy overall learning environment for kids that's much more exciting than sitting in rows and being addicted to a textbook." Interviewee 9 says that assessment of integrated STEM should be

> Capstone projects. I think it should all be project-based, problem-based where the kids are exploring and asking questions, or trying to solve a problem, or come up with a new technology, or come up with something innovative to help solve a problem in the world and there's different levels and different degrees so they're building up all those skills and knowledge to hit this major project.

Interviewee 11 stated that the assessments should be "project-based, design based, and inquiry based." In fact, "I think the project itself should be the assessment."

Five of the Interviewees felt that the assessment of integrated STEM should be portfolio-based. Interviewee 1 feels that the assessment should be "student defined and student solved real world or contrived problems that they have come up with, that they have found solutions to. I think that it is much more of a portfolio of work rather than individual tests." Interviewee 7 said the end assessment would be "their portfolio of work. Their resume of work. Their online presence and how integrated STEM is included in their online presence." He went on to say "I think what I'm talking about really goes beyond the portfolio into community presence, virtual community, and real community presences of the students in their projects." Interviewee 9 said that the assessments should be "portfolio and project-based." Interviewee 13 believes that the assessment should be "portfolio development." She went further stating "portfolios--those are huge, physical and electronic" and "portfolio assessment…that is done throughout, but also as a final product."

Six of the interviews believed that the assessment of integrated STEM must be authentic and competency based. Interviewee 3 discussed the competency that students need to display related to integrated STEM when she said,

> The best assessment strategies would probably be ones that allowed for students to show some level of reasoning or logic or approach so either one-on-one discussions with students, or maybe some virtual interactive thing where they are manipulating things, and saying why they are doing what they are doing.

She further stated that students should “be able to argue from evidence or use modeling, mathematical modeling, or physical modeling of things, or software modeling to demonstrate knowledge” and “you have to have very fluid ways for them to demonstrate or discuss their approaches and thoughts.” Interviewee 5 agreed and stated, “It [assessment] is definitely a movement to more of a competency-based model.” He went on to say that assessment would be “competency-based models or authentic assessments such as portfolios. Performance assessments, moving beyond the traditional as we think of tests, but definitely competency-based.” Interviewee 8 said, assessment needs to be like “real-world environments...On the job training.” He elaborated on what assessment should look like when he said,

> The types of assessments that we need to be more invested in are product based, project-based, outcome-based. Show me what you know. Demonstrate what we have been talking about for the last three weeks. Build me something. Create me something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

Interviewee 10 said integrated STEM assessment needs to be,

> Something that you can explain. Something that you can present. Something that you can demonstrate that does what it is supposed to do…Shows its function, so to me it doesn't have to be an assessment outside of the project itself.

Interviewee 11 said that assessments need to ask, “can kids ask very appropriate pointed questions and can they employ didactic content from one area into another without being taught specifically to do that?” Students need to,

> Look at the appropriate use of technology to solve bigger types of problems in science or in engineering, but use science and engineering content and synthesize information from math and science to create some new sort of idea for a problem that they're trying to solve.

He went on to state; assessments need to have “a focus on higher level thinking and an earnest attempt to find good ways to measure critical thinking through the implementation and integration of didactic content from the different STEM areas.” Interviewee 13 said that integrated STEM needs “authentic assessment with teachers asking why…you have to have authentic assessment all the time.”

It can be argued that both project-based assessments and portfolio-based assessments fit as authentic and competency based models for assessment. In fact, several of the interviews used project-based or portfolio-based models in their description of authentic, competency-based assessments. Ultimately, the assessments of integrated STEM are going to be non-traditional where students create a product that demonstrates their skills in a real life authentic setting.

Theme 6: Willingness. The concept of willingness related to the teacher came out as a theme in the interviews. Eight out of 13 respondents specifically utilized the word willingness related to teachers and integrated STEM and two out of the thirteen implied willingness of the teacher in the context of their interview. This means that ten out of 13 interviews see the willingness of teachers as important to integrated STEM education.

The idea of willing teachers and how willingness applies to their situation was less specific. However, it can be argued that there is some overlap. Four respondents specifically spoke about teachers being willing participants in cohorts or on teams. Interviewee 1 stated, "It [integrated STEM] starts with a cohort of willing teachers." Interviewee 3 agrees. She said, "you have teachers that are willing to work together instead of individually on their independent things." Interviewee 3 further stated, "it is very important for people to be knowledgeable about one area but then be willing to work as a team member with people knowledgeable in other subject areas." Interviewee 12 believes that, "teachers have to be very comfortable in our content and be willing to work in a team situation to make it come alive for our students." She further said that the teaching of integrated STEM would be done by "a team of folks. Math, science, technology, CTE folks, it could be any combination." Interviewee 13 summed up these comments. She said, "You have to have teachers who are willing to work with other teachers…you have to have the teachers with a broad range of experiences who are willing to be involved." Finally, "we need the willingness of all teachers to be a part of it [integrated STEM]." This concept of a cohort, team, or collaboration of teachers, also was prevalent when analyzing question 2 and likely is a critical implementation factor for the integrated STEM classroom.

Two respondents spoke about the willingness of teachers to go beyond their current area of specialization. Interviewee 1 thinks, "it [integrated STEM] starts with teachers who are willing to go beyond just their topic…with teachers willing to go outside of their area." Teachers need a "willingness to explore and to go off on tangents when they present themselves." Finally, Interviewee 1 thinks, "it [integrated STEM] starts with having willing teachers, and that doesn't mean teachers who know everything about technology, or mathematics, or science, or engineering." Interviewee 2 supported this idea. He said, "you have to be willing to investigate some content that may not be part of your core." Interviewee 2 further believes that teachers need "a level of expertise, or being willing to cross pollinate with some other teachers or possibly even co-teach."

Three respondents said that teachers must be willing to change. Interviewee 2 said this when asked about who will teach integrated STEM.

> Some people are very set in 'I know what I know', and going beyond that is tough, and some are willing to accept and adopt any sort of new changes. I think you can't limit yourself to, 'here's a certain teacher'. I think it is an attitude more than just what you teach.

Interviewee 9 implied that integrated STEM teachers must be willing to change when she said, "it [integrated STEM] starts with the teacher. It's a totally different mindset. It's a totally different paradigm shift in the way of teaching."

Three respondents stated that teachers must be willing to try integrated STEM. Interviewee 1 said this of an integrated STEM teacher. "I think you need those people who are willing to try, willing to learn, and willing to be the guide of the class." He further implied that an integrated STEM teacher must be willing to try integrated STEM when he said an integrated STEM teacher is "someone who is willing to learn, someone who is willing to push themselves, and someone who is willing to become the expert I think is just as viable. So an excited person." Interviewee 4 sees an integrated STEM teacher as someone who is "not afraid to try teaching it. You have to be willing..." She further said that an integrated STEM teacher needs "a willingness to change and a willingness to try something." Interviewee 10 implied that a teacher needs to try integrated STEM when he said an integrated STEM teacher is "an informed, enthusiastic, innovative educator." He further said, "you can't have somebody in there who...I don't want to say is not learning it themselves...but who is not vested in it." An integrated STEM teacher is "any teacher with a passion to truly want to engage."

Two Interviewees spoke about teachers being willing to put in the time to implement integrated STEM. Interviewee 4 said, "I think the teachers have to be willing to put the hours in, especially the first couple of years we set it up." Interviewee 7 stated this about willing teachers, "it [creation of integrated STEM] is really based on dedicated teachers that are willing to put in time to try create something that isn't really out there right now…or to learn what's out there."

One respondent talked about teachers being willing to give up "turf". Interviewee 6 stated that, "I think it takes willingness to give up turf" when he spoke about how to create integrated STEM.

While different Interviewees spoke about willingness related to teachers in different conceptual ways, it can be argued that there is significant overlap. If as a teacher you are willing to try integrated STEM, will you not have to change? Will you not have to develop other expertise? Will you not have to dedicate time to the initiative? Finally, is it out of the realm of possibility that you would have to collaborate with other teachers? From the perspective of this study, all of these different references to willing teachers are considered as the same, which appears to be an interview theme and a critical implementation factor.

Theme 7: Time. The idea of time was a prevalent theme in the interviews. Twelve out of 13 interviews specifically mentioned the need for time related to integrated STEM education. Time is needed for collaboration, for planning, for exploring (for students and teachers), and thinking.

Time is seen as a resource for teachers by the interview participants. Interviewee 1 said, “I think that the biggest thing is time.” Interviewee 2 stated, “I think the idea of setting aside finances, and space, and time, and resources for this, as a class that is just doing all of these in one place, is really kind of lacked (does not really exist).” Interviewee 4 believes, “it [integrated STEM] takes a lot of time.” Interviewee 7 thinks, “there are some things that can be done with minimal resources, but I think the biggest, probably most critical resource is time. Time for the teacher and the student to engage in the activity.” Interviewee 8 believes, “large blocks of time is required. There's no doubt about it, large blocks of time are required. Large blocks of time for students and teachers to write, test, and examine the curriculum.” Interviewee 9 stated, “it [integrated STEM] takes a lot of money, time, and effort.”

Some Interviewees spoke about the need for time for teachers to plan and collaborate. Interviewee 1 posed this question, “How do you get them common planning time?" Interviewee 3 was discussing an integrated STEM program when she said this, "the administration actually gives the team of the different subject area matters planning time to talk about things, to talk about the students that are in all those classes." Interviewee 4 stated, "it [integrated STEM] takes a commitment to the district to provide time for planning" and "there has to be time dedicated to allowing the teachers to find the meaningful connections among the content prior to instructing that content or providing activities and lessons that connect the content together." She went on to say, "there has to be more instructional planning time than a traditional classroom setting." Interviewee 5 believes, "if I am thinking about it from the perspective of a teacher, resources that I would need to teach…time to collaborate." Interviewee 6 believes that "the curricular structure of schools must evolve to include joint planning time for teachers." Interviewee 7 thinks, "you need to provide time for coordination and planning." Interviewee 10 agrees and said "there needs to be more interdisciplinary planning time, more collaboration, and more partnerships." Interviewee 12 stated, "I think you would want to organize your staff to actually have time to put those things together or explore them."

Two respondents mentioned that teachers have to be willing to spend their own time to teach integrated STEM. Interviewee 2 stated, "when you are talking about, things that are digging a lot deeper, it is certainly a time commitment and you don't want to spread yourself too thin." Interviewee 7 agrees and said integrated STEM needs "teachers that are willing to put in the time to try create something that isn't really out there right now…or to learn what's out there."

The respondents also mentioned time for students as a need in integrated STEM. Interviewee 2 said, "we are going to give students a little more time because this isn't just a step a, b, c, d process when you are looking at really integrating all of those aspects." He went on to state that, "I think reasserting that it is time consuming, because students really should do their best to understand what is going on behind the scenes." He summarized it this way when discussing the students' need for time. "Time being most critical in so many of our classrooms, we have this rush to get through content." Interviewee 3 stated, "the 45 or 50 minute period makes it challenging to get deep enough into something, so a longer block of time would be an advantage [for students]." Interviewee 12 sees blocks of time for students as a resource. She said, "If there are blocks of time in which students get to explore and see those connections, and hopefully they see some real life things happening." Interviewee 13 believes, "STEM classes have to be longer to be able to allow students more time to think the process through." Interviewee 8 sees integrated STEM this way. "No it's a track. It's large chunks of time spent with multiple team teachers, in an incubator of creativity, utilizing science, technology, engineering, and math."

The theme of time is prevalent throughout the interviews, not just time for teaching and learning, but time for planning and collaboration. When considering integrated STEM education, it would seem that time for the process in all of its aspects is important from the Interviewees' perspective.

Theme 8: Dissention. As the interviews were conducted, the respondents agreed on many things that were developed into themes. However, not all the respondents agreed on the content. As the literature notes, there is much disagreement related to integrated STEM. With that being the case, it is worth noting the discrepancies found in the interviews, and developing them into a theme related to disagreement in the interviews.

One area about which the respondents disagreed was whether integrated STEM is an elective or a core class. Twelve of the Interviewees spoke to this topic with almost an even split between them. Three respondents felt that integrated STEM is a core class, four felt that it is an elective, and five respondents felt that integrated STEM is somewhere in between. Interviewee 3 said, "I think it's a core course…integrated STEM is just separate core courses working together for a common goal." Interviewee 4 is an integrated STEM teacher in a large metropolitan school district. This is what she said about integrated STEM being an elective vs. core class.

> We decided to make ours a replacement for the first two years for core classes, and then as they get into their junior and senior year it becomes an elective. That way...Ideally I think it would be an elective all the way through, but for staffing and for funding within the school it is much more practical to make it a replacement course for one of the standard classes that they would have to take as a freshman or sophomore, or at least by the time they graduate from high school.

Interviewee 6 stated that integrated STEM is a "core class."

Interviewee 2 sees integrated STEM differently. He said that, "I can see upper divisions being an elective. Something akin to nationwide contests and challenges. I do see that you could really expand and take the top tiers as an elective." Interviewee 9 stated,

> I see it [integrated STEM] more as an elective. I see it more as a career exploration pathway with STEM introducing children who have an interest in

> science, technology, engineering, and math to give them opportunities to explore all the options.

Interviewee 10 said, “I would say elective” when asked about integrated STEM. Interviewee 1 stated,

> I think that STEM is a core concept that works best in an elective setting. I think that electives have the freedom to explore ideas rather than to teach specific topics. Core classes teach the STEM foundations, but electives get to put them to practical uses.

Some other Interviewees see integrated STEM as something different from an elective or a core class. Interviewee 5 said, “I think it [integrated STEM] is everywhere. If we're talking true integration.” He went on to say that, “I think the most important thing is that it's intentional. I think that's a key word.” Interviewee 6 stated, “It [integrated STEM] needs to be an evolution of the curriculum structure of schools. It needs to cross disciplines.” Interviewee 7 said, “I think it [integrated STEM] would be integrating it within the courses and then maybe doing something with school-based projects possibly something like that.” Interviewee 8 sees integrated STEM completely differently. He said, “No it's a track. It's large chunks of time spent with multiple team teachers in an incubator of creativity utilizing science, technology, engineering, and math.” Interviewee 12 believes,

> Right now, it doesn't fit very well. Again, if it fits in curriculum-wise, you would see some of it in science, some of it in mathematics, and you would see technology to probably support the effort, and you would see it in CTE actually.

> Industrial technology would be a good idea for an area that would model a STEM application. So there's bits and pieces, but it isn't a package, let's put it that way.

Another area of disagreement was related to certification of teachers of integrated STEM. Seven of the respondents stated that certification is not needed for integrated STEM teachers. Interviewee 3 said, “I don't think the educator with a STEM certificate or a STEM degree would have deep enough knowledge in any one of the areas to excel.” Interviewee 4 believes, “I don't know if it [certification] is necessarily a requirement in my eyes.” Interviewee 5 emphatically stated, “I don't think we need a certification on STEM.” Interviewee 7 said, “I don't know if there would be a general STEM certification, and what that would involve, and whether somebody could conceivably do all of that in 4 years.” Interviewee 8 believes,

> Certification, it could be a specialty area but I don't want it to be. We could get a specialist certification in STEM education. That's fine, I don't have a problem with it. I would rather see a dedication to the philosophy than a certification necessarily in order to be a STEM teacher.

Interviewee 9 said this when discussing the topic, “certifications, that one I kind of have mixed feelings about that with certifications.” Interviewee 12 stated this when discussing certification. “Don't touch it. I do not see, I don't know, I do not see a STEM certification.”

Two respondents see certain STEM disciplines need a certification that currently does not exist. Interviewee 6 said, “Computer science and engineering desperately need their own certification.” Interviewee 11 stated, “I would like to see engineering education certification.”

Several respondents had answers regarding certification that were between 'yes, it is necessary', and 'no, it is not necessary'. Interviewee 1 called the certification area of integrated STEM "grey". He said,

> I think this is where it gets grey, because I don't know that a STEM class fits one certification. I don't think that you need to necessarily have a math certified person and a science certified person, and so on down the line.

Interviewee 2 skirted the issue and stated the current status of STEM certification when he stated, "I don't believe that we have an actual STEM certification right now." Interviewee 10 believes that "Certification, that is something that would be accepted by the state," and it could be a "secondary certification, not a whole degree in a sense." Interviewee 13 took a different approach to certification than most states have for educators. She said,

> I think that we also need to go and look at certification pieces, so that if we become certified like at a community college or at a college, and we have a piece of certification, that [certification] can be added onto our state certification and reflects the STEM area that we have an emphasis in.

Another area of dissent among the interview participants is whether integrated STEM will help or hinder the standardized testing culture found in education. Seven respondents believe that integrated STEM cannot be assessed through standardized testing. Interviewee 1 discussed the difficulty with standardized tests and what integrated STEM looks like.

> Again, I think that the end result of STEM projects or products would be sort of a portfolio of work. I think that is hard to fit into bubbles. I think that it's hard to demonstrate on a multiple-choice test.

Interviewee 1 also mentioned that for standardized testing to work for integrated STEM it will have to be modified.

> I think multiple choice tests and standardized tests can change and I think you can still ask problem solving questions that require the same skill set that we currently test for, but I don't think the answer is the same.

Interviewee 2 said this about standardized testing, “unless carefully crafted it [integrated STEM] could be detrimental to standardized testing, because it is not looking at the ideas in isolation. It is looking at the big picture.” Interviewee 5 said, “if you want to assess STEM instruction for integrated STEM, or whatever you're calling it, then it probably does not fit very well within the current state assessment process.” Interviewee 7 agrees. He stated, “I think, standardized testing assumes a content base and I think in integrated STEM, really good integrated STEM, you're not going to know what the content is.” Interviewee 9 said, “I have no idea how you're going to do that, [standardized testing] if you're going to go in the direction that I'm thinking.” Interviewee 10 agreed and said this about standardized testing, “I don't see it happening and I would not be a proponent of it because that is not STEM.” Interviewee 11 stated this about standardized testing as it relates to integrated STEM, “I don't think it does.”

Four respondents feel that standardized testing results would not be hindered by integrated STEM. Interviewee 6 was the strongest proponent. He stated, “I personally believe that the standardized tests are just fine. The curriculum is what needs to change.”

Interviewee 6 further stated, "The standardized tests, I think, are fine. I think it is not time to change the test, it is changing the instruction." To conclude, Interviewee 6 said, "If a math teacher says they're not going to learn how to do this on a standardized test, the research is showing the opposite in a lot of ways." Interviewee 13 believes, "it [standardized testing] can happen in a STEM class. The teachers just have to be cognizant of it." Interviewee 3 initially said standardized testing and integrated STEM would not be compatible. However, on reflection she said,

> Actually, that's not true because there is a chance if it's done well and the teachers point out what the concepts are that they are learning, if a student then takes traditional standardized tests they might go, 'oh yeah, yep, I know how to do linear equations' or 'I remember how a voltmeter is set up to read', or whatever it is.

Interviewee 8 stated this, "I think there is room for both [integrated STEM and standardized testing]. I think we need both."

Another area of contention is the cost of an integrated STEM program. Not all Interviewees spoke to this topic, but those who did were emphatic in their opinions. Three respondents think that integrated STEM can be done for very little expense. Interviewee 8 stated, "it [integrated STEM] doesn't have to be high and expensive things, but it should be collaborative, large environments that have access to certainly plenty of technology. It doesn't have to be off the hook or expensive." Interviewee 10 agrees when he said, "it can be done for little or nothing." Interviewee 1 feels that integrated STEM would not have to be expensive. He said,

> Again, most facilities would work…Equipment and software licensure, I think most of this is free. I don't think that there is a lot of expensive stuff that needs to be bought. I think that a lot of stuff exists, that allows you to explore. I don't think that there is one technology or one piece of software that is the STEM learning software. I think you go out and find what is available which accomplishes the task that you have already defined, and not the other way around.

Interviewee 4 is an integrated STEM teacher in a large metropolitan high school and she disagrees. She said, “It [integrated STEM] costs. It is an expensive thing to do.” This school got a large grant to establish their integrated STEM program, which has teachers co-teaching a STEM class that replaces core curriculum.

The areas of dissent between the Interviewees related to cost, certification, standardized testing, and core class vs. elective class are worth noting. These are exactly the types of discussions that must be conducted, and where compromise must be found, if integrated STEM is going to gain traction in public schools. Knowing the areas of agreement provides common ground for possible integrated STEM implementations, and areas of disagreement can drive discussions that make integrated STEM better, if handled correctly.

Conclusion

The data from each interview was fully transcribed for the analysis process. After which, the transcription and initial analysis of the content was then sent to the Interviewee who had a chance to add, detract, or clarify anything that they felt was necessary. The analysis of data was then completed by coding Interviewee comments that had similar words and semantic meanings. This data was then analyzed three different ways: by Interviewee, by question, and across all interviews. That analysis was presented here in Chapter 4. A number of themes became evident in each of the analysis categories, which will be synthesized in Chapter 5: Synthesis of Data.

Chapter 5: Synthesis of Data

The synthesis of data presented in Chapter 5 was conducted after the analysis of data from Chapter 4 and is structured to strengthen the argument that a particular concept is a phenomenon of integrated STEM, as well as to illustrate the interconnected nature of the identified phenomena. An identified phenomenon of integrated STEM education was stated with a logical argument to support the importance of the phenomenon. The logical argument contains the data (interview quotes) related to that phenomenon and how it was related to other identified phenomena. This data was included to illustrate the preponderance of evidence available from the interviews related to a particular phenomenon and its connections to other phenomena. While this approach might seem redundant as many quotes appear multiple times, the interconnected nature of the identified phenomena becomes apparent throughout the synthesis because many quotes fit into different phenomena when used in different contexts. The nature and importance of the interconnectedness of the identified phenomena would not be as easily observed without the inclusion of the data.

To synthesize data, themes that emerged from the three ways that the data were analyzed (by Interviewee, by question, and across interviews) were compared. The synthesis was completed using the technique that Creswell outlined for layering themes from qualitative data (Creswell, 2015, p. 251).

Themes were generated as the data was analyzed in each of the three different ways. However, when the identified themes began to surface in more than one of the analyses, the themes became something more important. Some of the identified themes in Chapter 4 rise to the level of phenomena that the Interviewees see as necessary for integrated STEM to exist. Creswell (2007) describes phenomenology as a research approach that attempts to uncover what multiple participants who experience a phenomenon have in common. The Interviewees have all "lived" or have deeply thought about integrated STEM. The interviews and analysis of those interviews from different perspectives, demonstrates that the phenomena identified in the Chapter 5 are what the participants believe integrated STEM must include.

To rise to the level of a phenomenon, a high number of Interviewees had to mention the phenomenon as important to integrated STEM either explicitly or through semantic meaning in more than one analysis that was conducted in Chapter 4. The 10 identified phenomenon had 10 or more Interviewees who discussed the phenomenon related to integrated STEM.

The goal of this study was to describe the phenomenon of integrated STEM education and to identify integrated STEM education phenomena related to "expert" practitioner's experiences. As the interviews were analyzed, several phenomena emerged that the researcher considered as necessary for integrated STEM to become realized in public schools. The identified phenomena are interconnected in such a way that it appears if any of them were missing, integrated STEM education would be less than ideally realized.

Two research questions were addressed by the study. First, what were the critical components of an integrated STEM definition? Second, what critical factors were necessary for an integrated STEM program's implementation? When the research questions were developed, the researcher anticipated that Interviewees would mention "things" that could be considered critical components of integrated STEM education.

While the participants did mention things like 3D printers, CNC machines, specialized software, etc.; there were not universal enough responses, in the interviews, to conclude that a particular “thing” is necessary for integrated STEM education. This may be because implementations of integrated STEM are different enough that it is not possible to identify a particular “thing” or set of “things” that would fit all settings. Several respondents alluded to this fact, when they said that you must create your integrated STEM project and then figure out what resources students need to accomplish that project. Interviewee 7 put it this way, “you need to be able to gather the materials needed for that project. I don't know if I can really come up with a specific list.”

Instead of citing “things” as critical components, respondents spoke about intangible qualities like “willingness,” or methods like “project-based learning,” or needs like “leadership” or “outside expertise,” or processes like “collaboration”. These intangible qualities are really implementation factors for integrated STEM. Ultimately, the lack of stated specific critical components and the nature of the Interviewees’ responses lead the researcher to come to the conclusion that the “critical components” of research question 1 and the “implementation factors” of research question 2, are in fact the same thing.

With this realization, the phenomena that were identified in the synthesis can be considered both critical components for the definition and implementation factors. There are two broad classes of implementation phenomena: structural and interpersonal. The structural implementation phenomena include: subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, and outside support (from businesses and industry). The interpersonal implementation phenomena include: leadership, collaboration, willingness, authentic/meaningful/relevant experiences for participants, and outside support (from people in business and industry). The interconnectedness of these phenomena is shown in Figure 17.

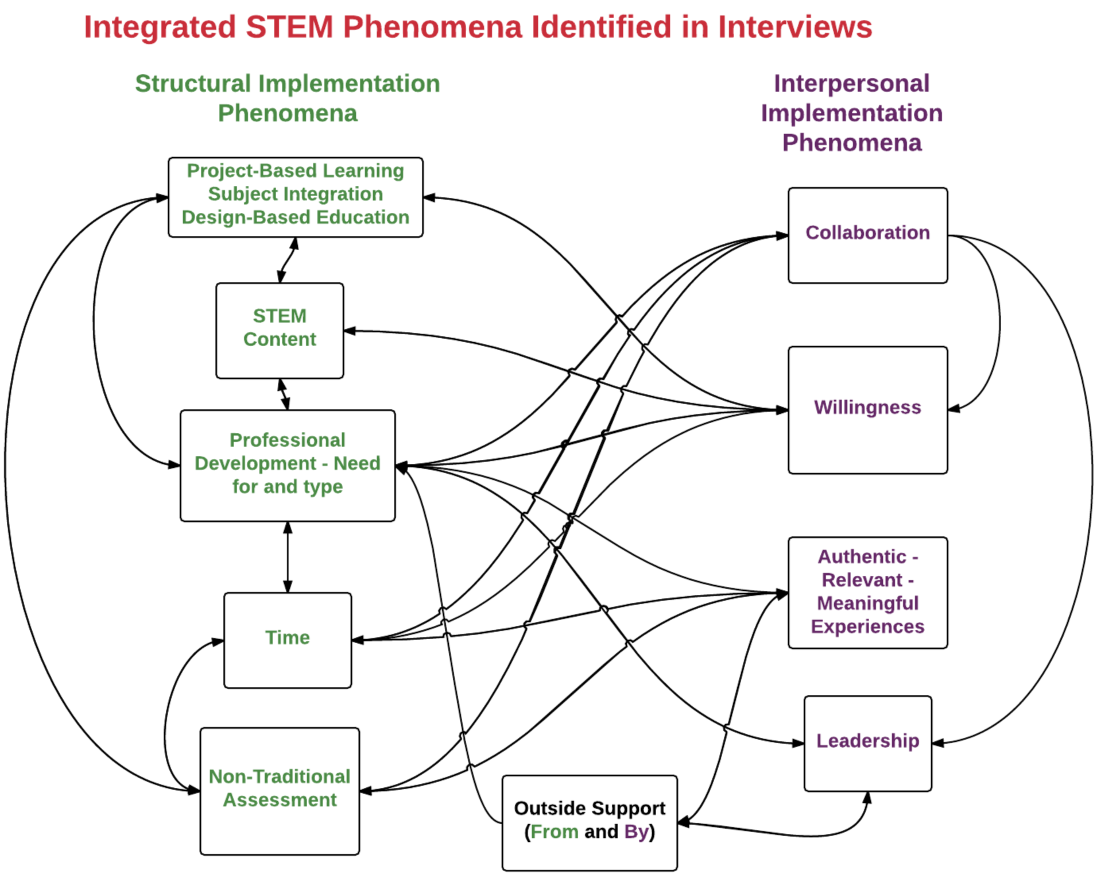

Figure 17. Integrated STEM phenomena identified in Interviews.

It can be argued that these phenomena are indeed critical components because if any one of them were missing, integrated STEM, as envisioned by the Interviewees, would be greatly diminished. It can also be argued that these phenomena are also implementation factors because you cannot implement integrated STEM without the identified phenomena being present. The interconnectedness of the phenomena and the fact that they are all necessary for integrated STEM, as well as being necessary for implementation of integrated STEM, makes the identified phenomena both critical components, and implementation factors.

With this realization, the researcher thought that it was impossible and redundant to attempt to separate the phenomena into critical components and implementation factors. Therefore, the synthesis of data proceeded as if they are, in fact, the same thing. Future verbiage related to either critical components or implementation factors should be taken to have the same meaning and implications for the research questions of the study.

Structural Implementation Phenomena

The structural implementation phenomena that were identified all relate to physical things, strategies, or quantities, which according to the Interviewees must be in place for successful integrated STEM to occur. These are things that schools strongly need to consider if they are going to create and implement an integrated STEM program.

Phenomenon 1: Subject integration/project-based learning/design-based education. The phenomenon of subject integration/project-based learning/design-based education surfaced in all the interviews and throughout the entire interview. Twelve out of 13 interviews specifically stated that integrated STEM education must have a project-based learning approach. The concept of subject of integration of the STEM disciplines surfaced throughout all the interviews. All 13 interviews also mentioned or implied the real world nature of design-based education. The phenomenon of subject integration/project-based learning/design-based education was found when respondents spoke about their perceptions of integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM in all four interview questions.

This phenomenon was related to other phenomena by the Interviewees including assessment, professional development, willingness, and STEM content. The relationship between the subject integration/project-based learning/design-based education phenomenon and assessment can be found in the words of the Interviewees. Interviewee 1 said that, “general assessments would be projects” which should include “interviews, talking to people about their [student’s] project, talking about what they think the value point-wise or grade-wise of what they did is and was.” Interviewee 2 thought “there is some sort of product [project]” and that “there is some assessment going on through the project in the form of journaling or discussion with teachers.” Interviewee 4 stated that, “assessments that are maybe more project-based” when referring to integrated STEM. She said that would “facilitate their learning in a way that is different than a traditional high school test would look like” and that “project assessments are equally as important, if not more important, than standardized testing.” Interviewee 6 said that integrated STEM assessments should be “project-based, problem solving based and higher level inquiry.” He thought this is the best way to assess integrated STEM, “because a project gives a student [the chance] to really demonstrate their connections and their understanding.” Interviewee 7 said that assessment should be “project-based activities and competition based activities.”

Interviewee 8 agreed with the project nature of integrated STEM assessment and what the project should entail. He said,

> The types of assessments that we need to be more invested in are product based, project-based, outcome-based. Show me what you know. Demonstrate what we have been talking about for the last three weeks. Build me something. Create me

> something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

He thought this type of assessment creates “a healthy overall learning environment for kids that's much more exciting than sitting in rows and being addicted to a textbook.” Interviewee 9 says that assessment of integrated STEM should be,

> Capstone projects. I think it should all be project-based, problem-based where the kids are exploring and asking questions, or trying to solve a problem, or come up with a new technology, or come up with something innovative to help solve a problem in the world, and there's different levels or different degrees so they're building up all those skills and knowledge to hit this major project.

Interviewee 11 stated that the assessments should be “project-based, design based, and inquiry based.” In fact, “I think the project itself should be the assessment.”

The relationship between the subject integration/project-based learning/design-based education phenomenon and professional development, was also strong throughout the interviews. Six of the Interviewees specifically referenced that professional development for teachers of integrated STEM includes experiences in an integrated environment, similar to what we would expect of students. These types of experiences are similar to what we expect of students in design-based education. Interviewee 1 alluded to this when he said, “I think the biggest thing is that, loosening the teacher role. I think that if you have never experienced that before, and most of us haven't, growing up in our existing education system.” He went on to say that “extra training, work-shopping, and experience, would be useful.” Interviewee 3 firmly believed that “the professional development, I think is needed so that they can experience what it looks like or what it can look like because sometimes you just need that experience." She further stated that,

> I think that if STEM teachers had the opportunity to have a truly rich experience doing an integrated STEM project and could try taking it back and seeing how their students reacted to it, that would help in terms of getting buy in on why it should be done differently than it is currently being done.

She believed that "giving those teachers [integrated STEM teachers] that experience is a critical piece to the implementation" and "having the teachers play a role of the student and leading them through an integrated design...an integrated STEM project" is important.

Interviewee 6 believed that "integrated STEM education requires a variety of experiences." This was echoed by Interviewee 7 who stated, "teachers need to be given the experience of doing some kind of integrated project." Interviewee 8 spoke about pre-service teachers and said, "the students who are coming through our university in the college of education don't have any hooks to latch onto based on their educational experience and that's what these kids come here with." Interviewee 9 felt that non-traditional teachers have experiences that make them better at integrated STEM than career teachers. She said this about non-traditional teachers,

> Those teachers that have that real world experience or that experience outside of the classroom, not going right from college into a classroom, tend to be able to build activities with lessons, ask questions, facilitate, have the kids lead the conversation. I don't know if that's because of their experiences that they are

> bringing into the classroom, and that they have been out and they're able to use relevant examples.

The relationship between the subject integration/project-based learning/design-based education phenomenon and professional development can be found in the words of the participants. This type of training relates closely to the design-based educational experiences in integrated environments that are outlined above. Interviewee 2 has learned project-based learning by doing it in the classroom. He said this when referring to other teachers that are interested in teaching in an integrated STEM environment.

> I think training. You have got to have a teacher who is really comfortable with a lot of different material. If your background is simply that of a mathematics teacher, or a science teacher you may not feel comfortable enough in some of the other areas that you are going to be pulling in. I know certainly, I have learned a lot about project-based learning or problem based learning, and that has been really useful when it comes to trying to develop new ideas.

He went on to say that,

> I have been involved in several programs over the years that, I think, have improved my ability to think about and design some of these activities, but it certainly is time consuming, and you need to go through some sort of trial by fire where there is some practicum side to this as well.

Interviewee 9 agreed with the need for project-based learning professional development. She believed that teachers need “professional development training to get them onto the same page as that problem based learning, or project-based learning, or experiential learning, or however you want to define it.”

The relationship between the subject integration/project-based learning/design-based education phenomenon and the willingness of teachers was evident from the following quotes, since the Interviewees are speaking about integrated, project-based environments. Interviewee 1 said this of an integrated STEM teacher. "I think you need those people who are willing to try, willing to learn, and willing to be the guide of the class." He further implied that an integrated STEM teacher must be willing to try integrated STEM when he said an integrated STEM teacher is "someone who is willing to learn, someone who is willing to push themselves, and someone who is willing to become the expert, I think is just as viable. So an excited person." Interviewee 4 saw an integrated STEM teacher as someone who is "not afraid to try teaching it. You have to be willing..." She further said that an integrated STEM teacher needs "a willingness to change and a willingness to try something." Interviewee 10 implied that a teacher needs to try integrated STEM when he said an integrated STEM teacher is "an informed, enthusiastic, innovative educator." He further said, "you can't have somebody in there who...I don't want to say is not learning it themselves...but who is not vested in it." An integrated STEM teacher is "any teacher with a passion to truly want to engage."

The relationship between the subject integration/project-based learning/design-based education phenomenon and STEM content which must be integrated is evident in the words of these respondents. Six participants saw STEM content as a key component of integrated STEM. Again, this might seem obvious but Interviewee 2 believed that "largely the teacher's focus would be course content." Interviewee 4 says, "Math is the core." Interviewee 9 stated, "the key component that I see in integrated STEM education is the STEM part of it itself, the science, technology, engineering, and math."

Interviewee 10 believed that "the cornerstones will always kind of fall with science and math. The use of technology makes it applicable." Interviewee 12 stated, "you're going to pull out science. You're going to pull out mathematics. Technology may be considered a discipline but I think it becomes a tool or application. Engineering right now is not considered a K - 12 discipline."

The prevalence of the subject integration/project-based learning/design-based education phenomenon, and due to the sheer number of participants that spoke about it in multiple places in the interviews, made it a strong implementation factor related to integrated STEM education. This phenomenon also tied directly to the conceptual framework for the study, which again emphasized its importance. According to the current data, it would seem that integrated STEM cannot take place without subject integration, project-based learning, and design-based education.

Phenomenon 2: STEM content. The phenomenon of the importance of STEM content was evident throughout the entire interview, in all four-interview questions, when respondents spoke about their perceptions of integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM. This phenomenon was related to the other identified phenomena by the Interviewees including subject integration/project-based learning/design-based education, professional development, and willingness.

The importance of STEM content can be found in these respondent comments. Interviewee 2 believed that "largely the teacher's focus would be course content." Interviewee 4 says, "Math is the core." Interviewee 9 stated, "the key component that I see in integrated STEM education is the STEM part of it itself, the science, technology, engineering, and math." Interviewee 10 believed that "the cornerstones will always kind of fall with science and math. The use of technology makes it applicable." Interviewee 12 stated, "you're going to pull out science. You're going to pull out mathematics. Technology may be considered a discipline but I think it becomes a tool or application. Engineering right now is not considered a K - 12 discipline."

STEM content is logically connected to subject integration/project-based learning/design-based education, professional development, and willingness in the following ways. STEM content is what is being delivered by the pedagogical method of subject integration/project-based learning/design-based education. Teachers must be knowledgeable in STEM content and need continued training to gain skills related to additional STEM content to provide the best integrated STEM environment possible for students. Finally, teachers must have the willingness to teach STEM content.

STEM content is an important implementation factor for integrated STEM. While it was not mentioned specifically by all the Interviewees, its importance seemed to be assumed by the participants when they continually mentioned science, technology, engineering, and math in the interview. STEM content is also one of the legs of the conceptual framework of the study, which again demonstrates its importance.

Phenomenon 3: Professional development (the need for and the type of). The phenomenon of professional development was found in all the interviews, specifically in interview question 2, which was related to the creation of integrated STEM. The need for training (professional development) was also mentioned in other parts of the interview by several participants. This phenomenon was related to other phenomena found in the synthesis of the Interviewees including subject integration/project-based learning/design-based education, authentic/relevant/real-world experiences, STEM content, collaboration, leadership, authentic/relevant/real-world experiences, outside support, and willingness. The following comments demonstrate these connections. While these comments are not grouped specifically by their relationships to other phenomena, as you read the comments by the participants, it is obvious that the professional development of them is highly connected to numerous other identified phenomena related to integrated STEM.

Interviewee 2 does not think that you need to hire new teachers for an integrated STEM program. He says,

> I think you can train the teachers that you have got, but it is going to take some time and willingness on the part of those people because, for all intents and purposes starting an endorsement in other areas, or touching on at least having a level of expertise, or being willing to cross pollinate with some other teachers, or possibly even co-teach, takes training.

Interviewee 4 stated that to create integrated STEM education "it [integrated STEM] takes the same skills we are asking STEM students to do." For the integrated STEM implementation in her school, they received a grant, which allowed them to get some training. Interviewee 5 thought, "STEM is really about a pedagogical approach to teaching the content and how it can be applied." This implied that training in the pedagogical approach is needed. Interviewee 7 thought integrated STEM is about providing teachers freedom to learn and explore integrated STEM activities. He stated we need to "give the pre-service teachers an opportunity, or suggestion, or requirement that they just pursue their passion in STEM." He further believed that,

> Giving the teachers the freedom or the suggestion to figure out what they really want to do themselves within integrated STEM, what they enjoy doing, what they feel comfortable doing, what do they want to do, what do they want to learn more about, and have them figure that out before they enter the classroom and have them understand that, that's important to know.

Interviewee 8 said, “we need to show them [teachers] tangible examples, and they're hard to find, of what STEM education looks like. What does that classroom look like? What philosophical attitudes should they consider in terms of what it takes?” Interviewee 10 felt that,

> Professional development will be the educational supports that are put in play to help whatever teacher is trying to go into this area, to help them get to the point to where they feel comfortable, they feel credible in the classroom before their students and in the content that they're presenting to their students.

Interviewee 10 further stresses that “getting them [teachers] educated with a proper adequate professional development that they would need,” is very important.

Interviewee 11 says that we need “specific teacher training and retraining,” including professional development on a broad scale. He believed that for integrated STEM education to be implemented there is,

> Extensive training needing to happen in either a STEM learning cycle model, or in specific integrated ideas. In other words, how to teach mathematical topics in the context of science, engineering, or technology. How to teach an engineering topic and to pull out the most critical elements of the math that need to be used for that.

Interviewee 12 felt that professional development needs to include “sharing of a common definition.” Interviewee 13 specifically cited, “professional development that needs to take place…Safety is one. Ethics is two” and “you have to get the professional development specific for the teacher who is in STEM.”

Six of the Interviewees specifically referenced that professional development for teachers of integrated STEM include experiences in an integrated environment similar to what we would expect of students. Interviewee 1 alluded to this when he said, “I think the biggest thing is that, loosening the teacher role. I think that if you have never experienced that before, and most of us haven't, growing up in our existing education system.” He went on to say that “extra training, work-shopping, experience, would be useful.” Interviewee 3 firmly believed that “the professional development, I think is needed, so that they can experience what it looks like or what it can look like because sometimes you just need that experience.” She further stated that,

> I think that if STEM teachers had the opportunity to have a truly rich experience doing an integrated STEM project and could try taking it back and seeing how their students reacted to it, that would help in terms of getting buy in on why it should be done differently than it is currently being done.

She believed that “giving those teachers [integrated STEM teachers] that experience is a critical piece to the implementation” and “having the teachers play a role of the student and leading them through an integrated design...an integrated STEM project” is important.

Interviewee 6 believed that “integrated STEM education requires a variety of experiences.” This is echoed by Interviewee 7 who stated, “teachers need to be given the experience of doing some kind of integrated project." Interviewee 8 spoke about pre-service teachers and said, "the students who are coming through our university in the college of education don't have any hooks to latch onto based on their educational experience and that's what these kids come here with." Interviewee 9 felt that non-traditional teachers have experiences that make them better at integrated STEM than career teachers. She said this about non-traditional teachers,

> Those teachers that have that real world experience, or that experience outside of the classroom, not going right from college into a classroom, tend to be able to build activities with lessons, ask questions, facilitate, have the kids lead the conversation. I don't know if that's because of their experiences that they are bringing into the classroom and that they have been out and they're able to use relevant examples.

These kind of statements about teachers having experiences in integrated environments need to be considered when creating and conducting professional development for teachers who might be teaching in an integrated STEM environment.

Several Interviewees specifically mentioned that professional development needs to occur in project-based learning. This type of training would seem to be very applicable to getting teachers experience in integrated environments as stressed in the previous section. Interviewee 2 has gained the skills to teach project-based learning by doing it in the classroom. He said this when referring to other teachers that are interested teaching in an integrated STEM environment.

> I think training. You have got to have a teacher who is really comfortable with a lot of different material. If your background is simply that of a mathematics

> teacher or a science teacher, you may not feel comfortable enough in some of the other areas that you are going to be pulling in. I know certainly I have learned a lot about project-based learning or problem based learning, and that has been really useful when it comes to trying to develop new ideas.

He went on to say that,

> I have been involved in several programs over the years that I think have improved my ability to think about and design some of these activities but it certainly is time consuming, and you need to go through some sort of trial by fire where there is some practicum side to this as well.

Interviewee 9 agreed with the need for project-based learning professional development. She believed that teachers need "professional development training to get them onto the same page as that problem based learning, or project-based learning, or experiential learning, or however you want to define it."

Collaboration was also mentioned as an area needing professional development. Interviewee 4 stated, "The training, I think, comes in constantly collaborating and adapting to the change that is happening around us." She further said that, "I think consistently revisiting your curriculum is a must. Constantly collaborating with a community is a must." Interviewee 2 thought professional development needs to include situations for "educators when they get a chance to come together and discuss things and share their ideas." Interviewee 5 echoed this sentiment when he said, "you need professional development. I think that another key resource, is the time to collaborate in the PD."

The manner of professional development was also a point of discussion. Professional development was needed to be ongoing, focused, and driven by five respondents. Interviewee 1 said, “making sure that it [professional development] is actually focused and driven and I think that kind of training, work-shopping, experience is necessary for teachers to feel comfortable and be effective STEM educators.” Interviewee 9 said,

> Professional development is a constant and it cannot be a one hit wonder, where you come in and have an eight-hour day or a two a day session. I think it is something that needs to be ongoing throughout the year as a constant, almost like a cohort that goes through. I think the professional development needs to look like whatever industry the teacher is trying to replicate, or whatever component of the STEM education career path. I think they need to go out and get those experiences. They have to be immersed in it so they have a better understanding so that they can actually teach from their experiences by referring to their experiences working in those different industries.

This speaks not only to the constant, on-going nature of needed professional development, it also stresses the importance of the experiential nature of professional development that can help teachers understand and instruct in an integrated STEM environment. Interviewee 10 felt that there needs to be a “clearly defined consistent professional development process, a program which would include certification and training, on-going availability, and to also provide the teachers with credit” and that “there needs to be something that is kind of standardized, something that is consistent.” Interviewee 11 agreed and stated that a key is to “focus on professional development, but it would need to be sustained rather than just kind of ‘here's your professional development for the day, now go and do this stuff.’ It needs to be kind of a sustained really kind of a habitual sort of arrangement.”

The nature of the conversations around professional development and integrated STEM education have implications related to this study. All the participants spoke to professional development because it was identified as an integrated STEM support structure. However, their comments related to the nature, content, and delivery of professional development should help provide a frame of reference for those school leaders who want to implement integrated STEM education.

With the sheer volume of comments related to the need for and type of professional development related to integrated STEM from the Interviewees, it should be obvious that professional development is a critical implementation factor for integrated STEM. Teachers must have diverse experiences related to the type of instruction that they are providing students. This involves teachers having authentic/relevant/real-world experiences provided by school leadership with the willingness to learn STEM content using subject integration/project-based learning/design-based education through a collaborative process. Professional development was also one of the support structures identified in the conceptual framework. The identification of professional development as an implementation factor for integrated STEM was not surprising, nor was the type of professional development that is needed.

Phenomenon 4: Time. The phenomenon of time surfaced in all the interviews and throughout the entire interview. Twelve out of 13 interviews specifically mentioned the need for time related to integrated STEM education. Time is needed for collaboration, for planning, for exploring (for students and teachers), and thinking. The phenomenon of time was found in all four interview questions, when respondents spoke about their perceptions of integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM.

This phenomenon was related to other phenomena by the Interviewees including collaboration, professional development, assessment, and authentic/relevant/real world experiences. The relationship between the time phenomenon and collaboration can be found in the words of the Interviewees. Interviewee 1 posed this question, "How do you get them common planning time?" Interviewee 3 was discussing an integrated STEM program when she said this, "The administration actually gives the team, of the different subject area matters, planning time to talk about things, to talk about the students that are in all those classes." Interviewee 4 stated, "it [integrated STEM] takes a commitment to the district to provide time for planning" and "there has to be time dedicated to allowing the teachers to find the meaningful connections among the content prior to instructing that content or providing activities and lessons that connect the content together." She went on to say, "there has to be more instructional planning time than a traditional classroom setting." Interviewee 5 believed, "if I am thinking about it from the perspective of a teacher, resources that I would need to teach…time to collaborate." Interviewee 6 believed that "the curricular structure of schools must evolve to include joint planning time for teachers." Interviewee 7 thought, "You need to provide time for coordination and planning." Interviewee 10 agreed and said "there needs to be more interdisciplinary planning time, more collaboration, and more partnerships." Interviewee

12 stated, “I think you would want to organize your staff to actually have time to put those things together or explore them.”

The relationship between the time phenomenon and professional development is evident in these Interviewee comments. Interviewee 2 does not think that you need to hire new teachers for an integrated STEM program. He says, “I think you can train the teachers that you have got, but it is going to take some time and willingness on the part of those people.” Interviewee 4 stated, “The training, I think, comes in constantly collaborating and adapting to the change that is happening around us.” She further said that, “I think consistently revisiting your curriculum is a must. Constantly collaborating with a community is a must.” Interviewee 2 thought professional development needs to include situations for “educators when they get a chance to come together and discuss things and share their ideas.” Interviewee 5 echoed this sentiment when he said, “you need professional development. I think that's another key resource, is the time to collaborate in the PD.” All these comment either specifically state or imply that time is needed for teachers in professional development related to integrated STEM.

The relationship between the time phenomenon and willingness can be found in the following comments. Interviewee 2 stated, “when you are talking about, things that are digging a lot deeper, it is certainly a time commitment and you don't want to spread yourself too thin.” Interviewee 7 agreed and said integrated STEM needs “teachers that are willing to put in the time to try create something that isn't really out there right now…or to learn what's out there.”

The relationship between the time phenomenon and assessments as well as authentic/relevant/real world experiences can be found in the words of the Interviewees.

The rationale for this relationship is that even though the participants did not specifically mention time in conjunction with assessment and authentic/relevant/real world experiences, these things take more time than traditional assessments in the classroom.

Interviewee 2 said, “We are really looking at the higher levels, application and synthesis.” He went on to say integrated STEM is “a much more real world and rich educational experience.” Interviewee 4 believed that “students that really excel in projects, and really excel through hands-on situations, can still learn the content.” Interviewee 9 says using integrated STEM students “apply knowledge and solve real-world relevant problems.” Interviewee 13 said that integrated STEM needs “authentic assessment with teachers asking why…you have to have authentic assessment all the time.”

In addition to the connections between the phenomenon of time related to collaboration, professional development, and authentic/relevant/real-world experiences and assessment, many participants spoke about time as a general resource for integrated STEM. Interviewee 1 said, “I think that the biggest thing is time.” Interviewee 2 stated, “I think the idea of setting aside finances, space, time, and resources for this, as a class that is just doing all of these in one place, is really kind of lacking.” Interviewee 4 believed, “it [integrated STEM] takes a lot of time.” Interviewee 7 thought, “there are some things that can be done with minimal resources, but I think the biggest, probably most critical resource is time. Time for the teacher and the student to engage in the activity.” Interviewee 8 believed, “large blocks of time required. There's no doubt about it, large blocks of time are required. Large blocks of time for students and teachers to write, test, and examine the curriculum." Interviewee 9 stated, "It [integrated STEM] takes a lot of money, time, and effort."

The respondents also discussed time as a resource for students in integrated STEM environments. Interviewee 2 said, "we are going to give students a little more time, because this isn't just a step a, b, c, d process when you are looking at really integrating all of those aspects." He went on to state that, "I think reasserting that it [integrated STEM] is time consuming, because students really should do their best to understand what is going on behind the scenes." He summarized his comments this way when discussing the students' need for time. "Time being most critical in so many of our classrooms, we have this rush to get through content." Interviewee 3 stated, "the 45 or 50 minute period makes it challenging to get deep enough into something, so a longer block of time would be an advantage [for students]." Interviewee 12 saw blocks of time for students as a resource. She said, "If there are blocks of time in which students get to explore and see those connections, and hopefully see some real life things happening." Interviewee 13 believed, "STEM classes have to be longer to be able to allow students more time to think the process through." Interviewee 8 saw integrated STEM this way. "No it's a track. It's large chunks of time spent with multiple team teachers in an incubator of creativity utilizing science, technology, engineering, and math."

The phenomenon of time is prevalent throughout the interviews, not just time for teaching and learning, but time for planning and collaboration. Time is also mentioned as necessary for professional development. In addition, it is considered a general resource for both teachers and students in integrated STEM environments. When considering integrated STEM education, the collected data shows that time for the process of integrated STEM education in all of its aspects, is important from the Interviewees' perspective.

Phenomenon 5: Non-traditional assessment. The phenomenon of non-traditional assessment was found in all the interviews, specifically in interview question four, which was related to assessment. This phenomenon was also related to other phenomena found in the analysis of the Interviewees, including subject integration/project-based learning/design-based education, authentic/relevant/real-world experiences, time, and collaboration.

The relationship between non-traditional assessments and subject integration/project-based learning/design-based education is evident in the following responses. Interviewee 1 said that, "general assessments will be projects," which should include "interviews, talking to people about their [student's] project, talking about what they think the value point-wise or grade-wise of what they did is and was." Interviewee 2 thought "there is some sort of product [project]" and that "there is some assessment going on through the project in the form of journaling or discussion with teachers." Interviewee 4 stated that, "assessments that are maybe more project-based" when referring to integrated STEM." She said that type of assessment will "facilitate their learning in a way that is different than a traditional high school test would look like" and that "project assessments are equally as important, if not more important, than standardized testing." Interviewee 6 said that integrated STEM assessments should be "project-based, problem solving based and higher level inquiry." He thought this is the best way to assess integrated STEM "because a project gives a student [the chance] to really demonstrate their connections and their understanding." Interviewee 7 said that assessment should be "project-based activities and competition based activities."

Interviewee 8 agreed with the project nature of integrated STEM assessment and what the project should entail. He said,

> The types of assessments that we need to be more invested in are product-based, project-based, outcome based. Show me what you know. Demonstrate what we have been talking about for the last three weeks. Build me something. Create me something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

He thought this type of assessment creates "a healthy overall learning environment for kids that's much more exciting than sitting in rows and being addicted to a textbook." Interviewee 9 says that assessment of integrated STEM should be,

> Capstone projects. I think it should all be project-based, problem-based where the kids are exploring and asking questions or trying to solve a problem or come up with a new technology or come up with something innovative to help solve a problem in the world, and there's different levels that are different degrees, so they're building up all those skills and knowledge to hit this major project.

Interviewee 11 stated that the assessments should be "project-based, design-based, and inquiry based." In fact, "I think the project itself should be the assessment."

The relationship between non-traditional assessments and authentic/relevant/real-world experiences can be found in the following comments. Interviewee 3 discussed the competency that students need to display related to integrated STEM when said,

> The best assessment strategies would probably be ones that allowed for students to show some level of reasoning or logic or approach, so either one-on-one discussions with students or maybe some virtual interactive thing where they are manipulating things, and saying why they are doing what they are doing.

She further stated that students should "be able to argue from evidence or use modeling, mathematical modeling, or physical modeling of things, or software modeling to demonstrate knowledge," and "you have to have very fluid ways for them to demonstrate or discuss their approaches and thoughts." Interviewee 5 agreed when he clearly stated, "It [assessment] is definitely a movement to more of a competency-based model." He went on to say that assessment would be "competency-based models or authentic assessments such as portfolios. Performance assessments, moving beyond a traditional, as we think of test, but definitely competency-based." Interviewee 8 said assessment needs to be like "real-world environments...On the job training." He elaborated on what assessment should look like when he said,

> The types of assessments that we need to be more invested in are product based, project-based, outcome-based. Show me what you know. Demonstrate what we have been talking about for the last three weeks. Build me something. Create me something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

Interviewee 10 said that the assessment needed to be,

> Something that you can explain. Something that you can present. Something that you can demonstrate that does what it is supposed to do…Shows its function, so

> to me it doesn't have to be an assessment outside of the project itself. I think the type of assessment; that would be vital.

Interviewee 11 said that assessments needed to ask “can kids ask very appropriate pointed questions and can they employ didactic content from one area into another without being taught specifically to do that.” Students need to “look at the appropriate use of technology to solve bigger types of problems in science or in engineering, but use science and engineering content and synthesize information from math and science to create some new sort of idea for a problem that they're trying to solve.” Further, assessments need to have “a focus on higher level thinking and an earnest attempt to find good ways to measure critical thinking through the implementation and integration of didactic content from the different STEM areas.” Interviewee 13 said that integrated STEM needs “authentic assessment with teachers asking why…you have to have authentic assessment all the time.”

The relationship between non-traditional assessments and time and collaboration is not as specific but can be logically implied. If the assessments for integrated STEM is project-based and contains authentic/relevant/real-world aspects, these types of assessments are going to take more time than traditional assessments. These types of assessments would also logically contain collaborative aspects between students. Individuals do not solve real-world problems in isolation. Instead, they tend to be solved over extended periods of time by groups of people. With this reality, it is not surprising that there is a logical link between non-traditional integrated STEM assessment and time as well as collaboration.

Besides the relationships to other phenomena found between the non-traditional nature of integrated STEM assessment found in the interviews, the respondents had a number of other relevant comments that demonstrated why non-traditional assessment was an important implementation factor for integrated STEM. Interviewee 1 felt that the assessment should be "student defined and student solved real world or contrived problems that they have come up with, that they have found solutions to. I think that it is much more of a portfolio of work rather than individual tests." Interviewee 7 said the end assessment would be "their portfolio of work. Their resume of work. Their online presence and how integrated STEM is included in their online presence." He went on to say, "I think what I'm talking about really goes beyond the portfolio. Into community presence, virtual community, and real community presences of the students in their projects." Interviewee 9 said that the assessments should be "portfolio and project-based." Interviewee 13 believed that the assessment should be "portfolio development." She went further stated that "portfolios-- those are huge, physical and electronic" and "portfolio assessment…that is done throughout, but also as a final product."

Interviewee 2 believed that teacher developed rubrics would be beneficial. He also said that "I also see a real strong value in student self evaluation." In assessment, we are really looking at the higher levels, application, and synthesis." He stated that "evaluation in the context of a rubric, or in the context of a one page summary, a written summary, or asking a student to reflect on mathematics that you needed to complete the activity" might be possible assessment strategies. Ultimately he thought that, student evaluation gives a lot of chance for real metacognition about what I know, what I had to do. Really getting them to reflect is crucial." Interviewee 3 agreed when she said that "it [assessment] would be best if they were not paper and pencil, and in a way that the students could interact with either an individual or a system to explain, justify, rationalize their knowledge about something." Interviewee 13 thought assessments "need to also take the questioning and put it at different levels, different thought levels through their students, and they need to know which ones address the higher learning so that they are able to assess students in that."

Interviewee 4 thought the "soft skills that we are trying to develop I think need to be assessed in some way." Interviewee 4 also mentioned soft skills specifically when she said, "we think about career readiness skills that students will learn through STEM experiences, the problem solving, the critical thinking; I think that those become more difficult to assess."

There were other non-traditional assessments cited by the Interviewees. Interviewee 7 thought that a possible assessment could be "how much work has a student been able to share and make public for others to use? How much have they engaged in a community?" Interviewee 10 mentioned an assessment of "service learning where the students actually go out and they work on a real world challenge." Two interviews mentioned possible attitudinal surveys as assessment possibilities. Interviewee 10 thought about assessment as,

> Assessing that like pre/post, how did you feel going into it? How did you feel coming out of it? Those types of things. Do you feel like you gained knowledge? Just very broad general things. What did you expect to learn? Did you learn it? Kind of like those KWL type of things.

Interviewee 12 echoed this as a possible assessment technique when she said, “you could do an inventory with whether the students like it in this format better than they do in a traditional format.” She also thought that integrated STEM could “use some traditional testing, test content questions, and then I think the other assessment would be attitudinal and how they feel about liking math and science and technology.”

There was an interview question related to assessment of integrated STEM because assessment is an important part of today’s educational culture. Several respondents stated that assessment (or the lack of good assessments) of integrated STEM is going to be the reason that integrated STEM would not become mainstreamed in public schools. From the comments of the participants, it is apparent that schools would have to think differently about assessment for integrated STEM environments. The non-traditional nature of integrated STEM assessment is what makes it an important implementation factor.

Phenomenon 6: Outside support from organizations. The phenomenon of outside support from organizations for integrated STEM surfaced in most of the interviews and throughout the entire interview. Outside support was prevalent in the interview as 10 out of 13 respondents mentioned outside support in various ways. This phenomenon was related to professional development which is another structural phenomenon by the Interviewees. Several respondents discussed that outside support for integrated STEM can help with training and professional development.

Interviewee 9 thought businesses could help teachers get training on specific equipment and techniques. She said,

> Partnering with a business partner or an industry partner where they're helping maintain some of that [equipment], or heading out in the next generation when they get the top-level thing. Another piece is the training for the teachers on this equipment. I think that's where you start referring to your business partners and community, leaders to kind of help out with that training so that you're on top of it. You're able to replicate, so that the kids can experience.

Interviewee 12 thought professional groups could help with providing teacher training. She said this when speaking about professional development.

> [It would be the] Nebraska Association of Teachers of Mathematics [for math]. It would be NETA for technology. It would be NATS for science. I think all of those leadership groups would be the ones who would help disseminate and support the idea of STEM integration.

Another way outside entities were seen as being able to help schools with integrated STEM, is through the possibilities of providing resources. While specific resources are not clearly identified as integrated STEM phenomenon, integrated STEM would need some resources even if those resources cannot be specifically determined. The following comments by the respondents mention outside resources as a way integrated STEM can gain access to resources.

Interviewee 4 said, “I think seeking outside funds is huge” and “I think awareness within the community is huge.” Interviewee 10 spoke about business and industry in this way. “The supports, the resources, whether it's human resources community members, or professional members coming in to help out.” Interviewee 12 spoke about looking for outside investment in an integrated STEM program. She mentioned that, “the Perkins funding for CTE (Career and Technical Education), they have a bucket load full of dollars, you're not going to find those same funds to even have the tools or the resources technology-wise." In addition, when speaking about businesses she said, "they [businesses] are willing to cough up and do some investment. So, I think business associations, working with your CTE staff, and seeing what we can leverage." Interviewee 1 said to implement integrated STEM you need "to go and find resources and tools that they [teachers] don't have, learn them, and apply them." This implied the need for outside support of integrated STEM.

These comments helped strengthen outside resources into an important phenomenon related to integrated STEM education. The concept of outside support for integrated STEM ran throughout all the interviews, from their different perspectives. Outside support for training and providing resources were all cited by multiple Interviewees, which shows that outside support is an important implementation factor for integrated STEM. It should be noted that outside resources are also highly related to the interpersonal implementation phenomena identified in the interviews. Those relationships are detailed in the next section.

Interpersonal Implementation Phenomena

The interpersonal implementation phenomena that were identified all relate to people skills and abilities that, according to the Interviewees, must be in place for successful integrated STEM to occur. These are things that schools strongly need to consider if they are going to create and implement and integrated STEM program.

Phenomenon 7: Collaboration. The phenomenon of the importance of collaboration was evident throughout the entire interview, but primarily in interview question 2 where respondents spoke about their perceptions related to the creation of integrated STEM. Eleven of 13 Interviewees spoke about the importance of collaboration/team teaching/cohort as critical to integrated STEM education. This phenomenon was related to other phenomena found in the data including professional development, time, leadership and willingness of teachers.

The relationship between collaboration, professional development, and time are inexplicably linked in the responses, and can be found in the following comments. Interviewee 1 said to create integrated STEM "it starts with a cohort of willing teachers." He went on to say that, "I think that you have to have a cohort of people who are all working towards the similar goal." Interviewee 2 said, "It [integrated STEM] takes a lot of cooperation on the part of all the participants. The students. The teachers. The administration. The parents." Interviewee 3 spoke about being part of a team when discussing certification. She said, "I think that it is still very important for people to be knowledgeable about one area but then be willing to work as a team member with people knowledgeable in other subject areas." Interviewee 3 further mentioned a team when discussing integrated STEM in general. In one implementation that she is familiar with, she stated, "the administration actually gives the team of the different subject area matters planning time to talk about things, to talk about the students that are in all those classes." Interviewee 4 believed that to create integrated STEM, " there has to be an integration among the teachers and time to collaborate." She also referred to collaboration related to professional development when she stated, "I think the more opportunities you can take and the more education teachers can get, especially collaborating."

Interviewee 5 said to create integrated STEM “from a teacher perspective, it takes collaboration. It takes opportunities for teachers of different content areas to communicate and work together and to really create some of those authentic types of experiences.” Interviewee 5 also said, “resources that I would need to teach…time to collaborate.” Interviewee 7 agreed and stated, “I think you need to provide time for coordination and planning.”

In the following comments by the Interviewees, the phenomenon of collaboration was related to the phenomena of leadership and the willingness of teachers. While all these comments do not specifically state leadership and willingness of teachers, the comments logically imply that these things must be present for integrated STEM to take place. Interviewee 8 spoke about collaboration extensively. He said to create integrated STEM; “a collaborative effort is going to be necessary on this, with good administrators and good leaders at the top.” When discussing resources, Interviewee 8 said, “it [integrated STEM] should be in collaborative large environments, that have access to certainly plenty of technology.” He also spoke about school improvement goals and how integrated STEM might play into those.

> When initiatives like reading across the curriculum, or science integration, or a calc (calculus) class teaming with a physics teacher and getting the collaboration going there, which are really good efforts--a lot of teachers really don't see themselves that way.

Interviewee 9 said the creation of integrated STEM takes, “a cast of numbers that come together to integrate the STEM.” She also said this about professional development, “I think it is something that needs to be ongoing throughout the year as a constant, almost like a cohort that goes through." Interviewee 9 further stated, "really it is collaboration and working together" and "it [integrated STEM] takes a lot of people coming together and working together to provide the opportunities for the kids." Interviewee 11 saw the way to create integrated STEM as having "basic grade level teams where they would get together and they would call them professional development communities or professional leadership teams." He further extended this thought to include "PLC's (professional learning communities) should expand well beyond any given content area." Interviewee 12 said, "you do some STEM education where you're going to be teaming and having someone going to co-teach." Interviewee 12 spoke about this collaboration idea related to staffing changes when she said, "I think team teaching is your strongest." Finally, she said to create integrated STEM we "have to be very comfortable in our content, and be willing to work in a team situation to make it come alive for our students. To conclude, Interviewee 13 stated, "it [integrated STEM] takes partnerships and collaboration, you need people to advise you."

Nearly all the Interviewees mentioned collaboration in numerous situations as they responded. The phenomenon of collaboration was closely intertwined with several other identified integrated STEM phenomena and it can be argued that subject integration/project-based learning/design-based education and authentic/relevant/real-world experiences for students can only be achieved in collaborative environments, since these phenomena are connected via other identified phenomena. Collaboration is prevalent in the interview responses and its interconnected nature with the other identified integrated STEM phenomena makes a strong case that it is indeed a key implementation factor for integrated STEM.

Phenomenon 8: Willingness. The phenomenon willingness of teachers to participate in integrated STEM was evident throughout the entire interview but primarily in interview question 1 where respondents spoke about their perceptions of integrated STEM. Ten of 13 Interviewees spoke about the importance of willingness of teachers to participate as critical to integrated STEM education. This phenomenon was related to other phenomena by the Interviewees including collaboration, time, subject integration/project-based learning/design-based education, and professional development.

The phenomenon of willingness of teachers was closely related to the phenomenon of collaboration. Four respondents specifically spoke about teachers being willing participants in cohorts, or on teams. Interviewee 1 stated, “It [integrated STEM] starts with a cohort of willing teachers. Interviewee 3 agreed. She said, “you have teachers that are willing to work together instead of individually on their independent things.” Interviewee 3 further stated, “it is very important for people to be knowledgeable about one area but then be willing to work as a team member with people knowledgeable in other subject areas.” Interviewee 12 believed that, “teachers have to be very comfortable in our content and be willing to work in a team situation to make it come alive for our students.” She further said that the teaching of integrated STEM would be done by “a team of folks. Math, science, technology, CTE folks, it could be any combination.” Interviewee 13 summed up these comments. She said, “You have to have teachers who are willing to work with other teachers…you have to have the teachers with a broad range of experiences who are willing to be involved.” Finally, “we need the willingness of all teachers to be a part of it [integrated STEM].” This concept of a cohort, team, or collaboration of teachers also was prevalent when analyzing question 2, and likely is a critical implementation factor for the integrated STEM classroom.

The relationship between willingness of teachers and time is evident in the comments from these participants. Interviewee 4 said, “I think the teachers have to be willing to put the hours in, especially the first couple of years we set it up.” Interviewee 7 stated this about willing teachers, “it [creation of integrated STEM] is really based on dedicated teachers that are willing to put in time to try to create something that isn't really out there right now…or to learn what's out there.”

There were multiple general comments about the willingness of teachers to be involved with and participate in integrated STEM that further strengthen willingness as a phenomenon. Two respondents spoke about the willingness of teachers to go beyond their current area of specialization. Interviewee 1 thought, “it [integrated STEM] starts with teachers who are willing to go beyond just their topic…with teachers willing to go outside of their area.” Teachers need a “willingness to explore and to go off on tangents when they present themselves.” Finally, Interviewee 1 thought, “it [integrated STEM] starts with having willing teachers, and that doesn't mean teachers who know everything about technology or mathematics or science or engineering.” Interviewee 2 supported this idea. He said, “you have to be willing to investigate some content that may not be part of your core.” Interviewee 2 further believed that teachers need “a level of expertise, or being willing to cross pollinate with some other teachers, or possibly even co-teach.”

Three respondents said that teachers must be willing to change. Interviewee 2 said this when asked about who would teach integrated STEM.

> Some people are very set in ‘I know what I know’, and going beyond that is tough, and some are willing to accept and adopt any sort of new changes. I think you can't limit yourself to, ‘here's a certain teacher’. I think it is an attitude more than just what you teach.

Interview 9 implied that integrated STEM teachers must be willing to change when she said, “it [integrated STEM] starts with the teacher. It's a totally different mindset. It's a totally different paradigm shift the way of teaching.”

Three respondents stated that teachers must be willing to try integrated STEM. Interviewee 1 said this of an integrated STEM teacher. “I think you need those people who are willing to try, willing to learn, and willing to be the guide of the class.” He further implied that an integrated STEM teacher must be willing to try integrated STEM, when he said an integrated STEM teacher is “someone who is willing to learn, someone who is willing to push themselves, and someone who is willing to become the expert I think is just as viable. So an excited person.” Interviewee 4 saw an integrated STEM teacher someone who is “not afraid to try teaching it. You have to be willing...” She further said that an integrated STEM teacher needs “a willingness to change and a willingness to try something.” Interviewee 10 implied that a teacher needed to try integrated STEM when he said an integrated STEM teacher is “an informed, enthusiastic, innovative educator.” He further said, “you can't have somebody in there who...I don't want to say is not learning it themselves...but who is not vested in it.” An integrated STEM teacher is “any teacher with a passion to truly want to engage.”

One respondent talked about teachers being willing to give up “turf”. Interviewee 6 stated that, “I think it takes willingness to give up turf” when he spoke about how to create integrated STEM.

While different Interviewees spoke about willingness related to teachers in different conceptual ways, it can be argued that there is significant overlap. If as a teacher you are willing to try integrated STEM, would you not have to change? Will you not have to develop other expertise? Will you not have to dedicate time to the initiative? Finally, is it out of the realm of possibility that you would have to collaborate with other teachers? From the perspective of this study, all these different references to willing teachers are considered as the same, which appears to be an interview phenomenon and a critical implementation factor.

The phenomenon of willingness of teachers is also connected to the phenomena of subject integration/project-based learning/design-based education and professional development. If a teacher is going to work in an integrated STEM environment, logically they are going to have to understand and have training in those types of environments. Subject integration/project-based learning/design-based education are the backbone pedagogical methods for integrated STEM, and professional development would provide the necessary training. Specific evidence related to these links can be found in the subject integration/project-based learning/design-based education and professional development phenomena that are developed in the structural implementation phenomena section.

The phenomenon of willing teachers with the desire to participate in integrated STEM was evident throughout the interviews. Willingness of teachers is closely related to several other identified phenomena by the connecting threads of the identified phenomena related to integrated STEM. By the number and type of connections, it can be clearly argued that willingness of teachers to participate in integrated STEM is a key implementation factor for integrated STEM education.

Phenomenon 9: Authentic/relevant/meaningful experiences. The phenomenon of authentic/relevant/meaningful experiences was evident in many interviews in several different places. It was also a focus in interview question 4 related to assessment of integrated STEM. Ten of 13 Interviewees spoke about the importance of authentic/relevant/meaningful experiences in various ways, as being important to integrated STEM education. This phenomenon was closely related to assessment, professional development, and outside support by people and businesses.

The relationship between authentic/relevant/meaningful experiences and assessment can be seen in the following comments by the participants. Interviewee 3 discussed the competency that students need to display related to integrated STEM when she said,

> The best assessment strategies would probably be ones that allowed for students to show some level of reasoning, or logic, or approach, so either one-on-one discussions with students, or maybe some virtual interactive thing where they are manipulating things, and saying why they are doing what they are doing.

She further stated that students should "be able to argue from evidence or use modeling, mathematical modeling, or physical modeling of things, or software modeling to demonstrate knowledge" and "you have to have very fluid ways for them to demonstrate or discuss their approaches and thoughts." Interviewee 5 agreed and clearly stated, "It [assessment] is definitely a movement to more of a competency-based model." He went on to say that assessment would be "competency-based models or authentic assessments such as portfolios. Performance assessments, moving beyond the traditional as we think of a test, but definitely competency-based." Interviewee 8 said, assessment needs to be like "real-world environments...On the job training." He elaborated on what assessment should look like when he said,

> The types of assessments that we need to be more invested in are product based, project-based, outcome-based. Show me what you know. Demonstrate what we have been talking about for the last three weeks. Build me something. Create me something. Change something. Adapt something. Envision something. Develop a philosophy. Give me something that demonstrates integrated higher-order thinking skills on your part as a student.

Interviewee 10 said that the assessment needs to be,

> Something that you can explain. Something that you can present. Something that you can demonstrate that does what it is supposed to do…Shows its function, so to me it doesn't have to be an assessment outside of the project itself. I think the type of assessment; that would be vital.

Interviewee 11 said that assessments need to ask, "can kids ask very appropriate pointed questions and can they employ didactic content from one area into another, without being taught specifically to do that." Students need to "look at the appropriate use of technology to solve bigger types of problems in science or in engineering, but use science and engineering content and synthesize information from math and science to create some new sort of idea for a problem that they're trying to solve." Further, assessments need to have “a focus on higher level thinking and an earnest attempt to find good ways to measure critical thinking through the implementation and integration of didactic content from the different STEM areas.” Interviewee 13 said that integrated STEM needs “authentic assessment with teachers asking why…you have to have authentic assessment all the time.”

It can be argued that both project-based assessments and portfolio-based assessments fit as authentic and competency based models for assessment. In fact, several of the Interviewees used project-based or portfolio-based models in their description of authentic, competency-based assessments. Ultimately, the assessments of integrated STEM are going to be non-traditional, where students create a product that demonstrates their skills in a real life authentic setting.

While the following comments are general in nature, it is important to note that authentic/relevant/meaningful experiences are deemed necessary for students when working in integrated STEM environments. Interviewee 2 believed that integrated STEM is “a much more real world and rich educational experience.” Interviewee 3 saw integrated STEM, as “when they are in their math class, the math is relevant to what they're working on.” Interview 4 saw “meaningful experiences” as a key component. Interviewee 5 believed, “a key component of integrated STEM is authenticity.” Interviewee 9 says using integrated STEM, students “apply knowledge and solve real-world relevant problems.”

The phenomenon of authentic/relevant/meaningful experiences is also closely connected to the phenomena of professional development and outside support by people and businesses. Logically, for teachers to understand and create integrated STEM environments for students, they must be trained in these types of environments. The training must come from somewhere, so outside support by people and businesses would be important. There is also concrete evidence supporting these logical arguments, which are detailed in the professional development and outside support phenomena that are included in the implications for research questions section.

Authentic/relevant/meaningful experiences for both teachers and students, surfaced throughout the interviews. Authentic/relevant/meaningful experiences are closely related to many other phenomena through the connecting web of the identified phenomena related to integrated STEM. With the nature and number of these connections, and the number of Interviewees that spoke to and advocated for authentic/relevant/meaningful experiences for both teachers and students, it logically can be concluded that authentic/relevant/meaningful experiences is a key implementation factor for integrated STEM education.

Phenomenon 10: Leadership. The phenomenon of leadership related to integrated STEM surfaced in most of the interviews, and throughout the entire interview. Leadership was prevalent in the interview, as all respondents mentioned leadership in various ways. Leadership was found in all four interview questions when respondents spoke about their perceptions of integrated STEM education, the creation of integrated STEM, the implementation of integrated STEM, and the assessment of integrated STEM.

This phenomenon was related to collaboration, professional development, and outside support by people and businesses. The following comments demonstrate these connections. While these comments are not grouped specifically by their relationships to other phenomena, as you read the comments by the participants, it is obvious that leadership is highly connected to numerous other identified phenomena related to integrated STEM.

All participants (13 of 13) in the interviews specifically stated some form of leadership as being necessary for successful integrated STEM education. From the literature, leadership, specifically school administrators, were cited as a key support structure for integrated STEM education. While the participants of the study did discuss the need for strong school leadership, their thoughts on the leadership related to integrated STEM education was far broader in scope. They include such ideas as leadership by teachers, shared leadership, student leadership, and leadership by outside experts.

School leadership can be defined in many ways. For the purpose of the results, the researcher has combined comments about school leadership from anyone directly attached to the school, except teachers and students. This includes building and district level administrators, curriculum specialists, and school board members. Interviewee 1 believed that you must "have an administration that is willing to put trust in the teacher, and teachers that are willing to put trust in the students" and further, that "you have an administration that is allowing this [integrated STEM] to take place." Interviewee 3 says that, "the administrator has to buy in." In addition to facilitate curriculum and teaching, "the administration actually gives the team, of the different subject area matters, planning time to talk about things, to talk about the students that are in all those classes." When developing an integrated STEM curriculum, Interviewee 4 believed that you must,

> Talk to the administration and go forward from there. So from a teacher's perspective, if you have the passion for it, go for it, and find people that will

> support you. From an administrative position, see teachers that are passionate and want something like this [integrated STEM] and just talk to them and see what they're willing to do.

Interviewee 4 agreed with Interviewee 3 when she said, “If I am an administrator in a building, I would want to allow that time for my teachers to work together on a new program such as this [integrated STEM].”

Interviewee 5 said for implementation of integrated STEM, “you may need an instructional coach...Someone who's able to coach and to provide that support in terms of improvement of instruction.” Interviewee 6 thought that there “needs to be a STEM curriculum director who oversaw those departments and has some sort of control over it.” He further reiterated, “Whether it is someone designated as the STEM leader of the school where they lead an interdisciplinary committee, or better they have a designated curriculum director who is the STEM curriculum director.” Interviewee 8 believed a “collaborative effort is going to be necessary on this [integrated STEM], with good administrators and good leaders at the top.” Interviewee 10 believed that to implement integrated STEM, “administration, curriculum, and professional development, those three things are needed.” He further believed that STEM certification is needed and “that [certification] can be done with the support of the administration in that building, or maybe the school district and the other teachers to provide a course.”

Interviewee 11 believed that staffing would require, “educational leaders in integrated STEM who have a lot of the abilities and knowledge that I have been talking about.” He elaborated teachers need to be, “fully degreed in two or more of the subject areas, or have at least a very good concept of the crossover of how all those really are used, from one field to the next." He also believed that integrated STEM requires "educational leaders who have the ability to very specifically guide teachers in that process."

Leadership by teachers, students, and outside the school, was also mentioned as important to integrated STEM. Interviewee 2 felt teachers need to have leadership experiences. He, as a practicing high school teacher, felt he has "enough experience either formally or informally with engineering and mathematics that I feel pretty comfortable in either leading something or finding out the information I need." Interviewee 6 thought, "it [integrated STEM] needs some sort of faculty specialist in STEM, with a vision for it. Interviewee 7 strongly believed that "it [integrated STEM] takes leadership from students that are interested in pursuing STEM activities." He further stated that the creation of integrated STEM "takes leadership, I think from both the teacher's perspective and the student's perspective as well." Interview 9 believes when professional development is needed, you need to "find community leaders, to kind of help out with that training, so that you're on top of it." Interview 12 stated "[It would be the] Nebraska Association of Teachers of Mathematics [for math]. It would be NETA for technology. It would be NATS for science. I think all of those leadership groups would be the ones who would help disseminate and support the idea of STEM integration."

Possibly the best way to sum up the leadership needs for integrated STEM is through shared leadership. Eight of the 13 interviews spoke to the shared leadership needs of integrated STEM. Interviewee 2 said, "It [integrated STEM] takes a lot of cooperation on the part of all the participants. The students. The teachers. The administration. The parents." Interviewee 4 stated, "The teachers, the teacher's organizations, and the administration have to be on the same page and have to make sure that their goals are all the same." Interviewee 5 believed that "it [the leader] is someone taking the lead and saying let's think differently on how we view STEM, and let's think differently on how we communicated to are teachers and our students." Interviewee 6 spoke about the importance of leadership when he stated,

> If you don't have any person to develop a STEM course, or an engineering course, or a computer science course, and it counts for university entry requirements and moves from an elective to a required [course], one of the options for required courses, then who does that. Who leads that conversation?

Interviewee 7 believed that integrated STEM takes "leadership, I think from both the teacher's perspective and the student's perspective as well." He further stated this about shared leadership,

> I think you have to have leadership in the school from the adult side and from the student side. From the adult side, you'll see that leadership, possibly you'll see that leadership in the administration and in some cases where the administrator did see the importance of STEM experiences for their students."

Interviewee 8, Interviewee 12, and Interviewee 13 spoke about shared leadership in term of vision and collaboration. Interviewee 8 stated, "I think we need practical visionaries...Practical visionaries...What I mean by that are people who can lead and demonstrate." Interviewee 12 says to implement integrated STEM it "takes a champion." Interviewee 13 summed up leadership related to integrated STEM this way. "It [integrated STEM] takes partnerships and collaboration, you need people to advise you…the partnership has to go outside the school doors. You have to reach out into the community. Your school board definitely has to be a part of that creative team as well."

The phenomenon of leadership being essential to integrated STEM resounded across all the interviews. Each Interviewee respondent put a unique spin on exactly who and how the leadership must be applied, nevertheless it appears leadership is an important aspect of integrated STEM.

From the preponderance of comments related to leadership by the Interviewees, it is apparent that leadership is essential to integrated STEM education. As the participants stated, integrated STEM takes leadership in many forms and aspects. It takes leadership from teachers, school officials, people outside the school, and students. That leadership must be present in professional development and the classroom. As with any change, leadership is crucial to its success. Leadership was found in the literature as being important to integrated STEM, and leadership was one of the support structures for integrated STEM in the conceptual framework of the study. It was not a surprise that leadership was identified as a key implementation factor for integrated STEM.

Phenomenon 6 (continued): Outside support by people. The phenomenon of outside support, by people and organizations, for integrated STEM surfaced in most of the interviews and throughout the entire interview. Outside support was prevalent in the interview as 10 out of 13 respondents mentioned outside support in various ways. This phenomenon was related to leadership, collaboration, and authentic/relevant/real-world experiences by the Interviewees.

The relationship between outside support by people, businesses, and leadership can be found in the following Interviewee comments. While the comments do not specifically mention leadership, leadership by people is implied by the respondents.

Interviewee 9 believed that,

> The educational reform that's going on right now needs to include and incorporate all of the STEM experts that are out there, whether it's business or universities, or informal science organizations like the zoo that has the experts, the researchers that are working in STEM education.

Interview 11 thought schools need "better working partnerships with teacher training institutions" for integrated STEM staffing. Interviewee 12 mentioned, "I think making a connection with your community college" is important for integrated STEM. Interviewee 13 echoed that sentiment, when she said integrated STEM could benefit from "involving some of the community colleges to bring that expertise into your school."

Seven of the 13 respondents said that expertise related to integrated STEM could be found in the world of business and industry. Ultimately, they thought educational support, by providing expertise, was also seen as a way that business and industry can help schools with integrated STEM. Interviewee 2 thought that integrated STEM could benefit from "pulling people from local business to give some insight." Interviewee 4 said students need "opportunities to get involved with career focused individuals outside of the classroom. It might be…going on field trips or it might be meeting with people in their industry, that they are possibly interested in." Interviewee 5 stated that for integrated STEM it "is really critically important to…I think just [have] access to experts." He wondered if you are the teacher and,

> you know if I am not the expert in a scientific area, but I want to be able to utilize that, who can I reach out to in my community? Who can I partnership with from a business and industry perspective? Businesses can possibly fill that role.

Interviewee 9 says “they [schools] have to open up the doors and really let the experts, but there needs to be an understanding from some of the experts out in the field, some of the researchers, some of the other organizations, for example like the zoo that come in.” She further stated that schools cannot “be afraid to ask others to come in and kind of help out.” Interviewee 10 said this of business expertise,

> The community resources once again, would be professionals who can not only come to the class, we're not talking about show and tell, we're not talking about career day, but you truly assist and help that educator with projects and so on to also help expose the students to professionals, working professionals. Then also, to get those students out to community and that's also in a sense how those students can see their part in the community.

Finally, Interviewee 13 said this of business and industry expertise, “along with that business and industry partnership, they can also bring in people who have expertise, that are not always available to a school and likewise they become your partner if you need equipment of any kind.”

The relationship between outside support by people and businesses can be seen in the respondents’ comments that saw collaboration between outside entities as important for successful integrated STEM in schools. Interviewee 4 felt that “it [integrated STEM] may be more of an internship, where they work more in collaboration with an organization or business in the community.” Interviewee 8 said, “It [integrated STEM] is going to have be embraced by the community." Interviewee 9 said, "the big picture of integrated STEM education is to bring in all the different components and players and everybody have an open mind and working together on educating our youth." She further stated that, "the educational reform that's going on right now needs to include and incorporate all of the STEM experts that are out there, whether it's business or universities or informal science organizations like the zoo that has the experts, the researchers that are working in STEM education." Interviewee 13 believed that "it's so important to have the business and industry and the people in your community involved, because they can help you see and you can help them see how you are training in working with kids to fill their needs within the community, with jobs and quality workers and that type of stuff." She further stated that, "it [integrated STEM] takes partnerships and collaboration, and you need people to advise you. The partnership has to go outside the school doors."

The relationship between outside support by people, businesses, and authentic/relevant/real-world experiences can be found in the words of the Interviewees. Interviewee 2 mentioned "students taking field trips, to see real world applications and experiences" is important to integrated STEM. Interview 12 stated, "we can throw in business to try to help us figure out what the real world is asking for," [schools can] "team up with maybe local businesses that would be interested," and "get the business people that talk about STEM careers and for education."

The prevalence of outside support for integrated STEM can be seen in the interviews. Outside support takes on two facets by helping with the structural as well as the interpersonal implementation of integrated STEM. This phenomenon, as with the other phenomena identified from the interviews is intertwined with all the other phenomena. The interconnectedness, which has been outlined in this chapter, related to the synthesis of data demonstrated their importance to integrated STEM. On this basis, the data indicates that these phenomena appear to be critical for integrated STEM. If one phenomenon is missing it is like removing a critical part from a complex machine. It may function, but definitely not as it was designed or as efficiently. The ten identified phenomena: subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, outside support (from and by businesses and industry), leadership, collaboration, willingness, and authentic/meaningful/relevant experiences for participants are critical for integrated STEM as identified in the interviews.

Additional Implementation Considerations

One idea on which the participants reached consensus, but did not rise to the level of a phenomenon, is that staffing changes were not necessary to implement integrated STEM education. The respondents did not feel that you needed to fire and rehire different staff. Rather, they felt that through the use of leadership, outside support, professional development, collaboration, authentic/relevant/real-world experiences, and willingness, any teacher could become a competent integrated STEM teacher; particularly current STEM discipline teachers. They did feel that it might be necessary to hire a specialty teacher in some cases.

The samplings of comments from the interviews below emphasize these thoughts by the Interviewees. Five respondents said that the creation of integrated STEM would require no staffing changes. Interviewee 1 said, “I don't know that there is. I think anybody could do it. I don't think that it takes a well trained individual to come in and they are the only ones who can do this." Interviewee 3 stated, "I don't think there has to be any change in staffing." Interviewee 5 agreed and said, "I don't know that you need any changes in staffing." Interviewee 8 believed, "I don't know that we need huge staffing changes." Interviewee 13 spoke to staffing changes in this way. She said, "if you have dedicated teachers who are willing to work towards a common goal, and committed teachers who want to do that, you wouldn't have to change your staff." While these respondents said that no staffing changes are necessary to create integrated STEM, they did not mention whether training or retraining is required. It does seem likely that some training for current staff would be needed.

Seven of the respondents believed that training or retraining of people, or augmenting the staff with some specialty personnel is necessary to create integrated STEM. Interviewee 1 said, "I think that you do need a couple of specialty trained people." Interviewee 2 stated,

> I think you can train the teachers that you have got, but it is going to take some time and willingness on the part of those people because, for all intents and purposes, starting an endorsement in other areas, or touching on at least having a level of expertise, or being willing to cross pollinate with some other teachers, or possibly even co-teach, takes training.

Interviewee 7 said that schools "looking at hiring people with the needed background is certainly important, or training people." Interviewee 10 stated, "I would say that you would almost have to repurpose, and I know that sounds bad, but repurposing some educators in a sense of providing them the opportunity to obtain training." Interviewee

13 believed that, “if you have a deficit of a knowledge base in your staff, you would definitely want to recruit that person [with the requisite training].”

Interviewee 11 spoke about the necessary knowledge that teachers of integrated STEM needed, which implied that training might need to occur. He said integrated STEM needs people who are,

> Either fully degreed in two or more of the subject areas, or have at least a very good concept of the crossover, of how all those really are used from one field to the next. So to have some knowledge in engineering for a math teacher, would be extremely important.

Interviewee 9 discussed the experiences that an integrated STEM teacher needed to have which also implied training of existing staff. She said,

> Those teachers that have that real world experience or that experience outside of the classroom, not going right from college into a classroom, tend to be able to build activities with lessons, ask questions, facilitate, have the kids lead the conversation. I don't know if that's because of their experiences that they are bringing into the classroom, and that they have been out, and they're able to use relevant examples.

The affirmation by the Interviewees that the current teaching workforce was sufficient for integrated STEM to take place, should be comforting to schools and school leaders that are considering taking on or creating an integrated STEM program. If the teaching workforce had to be changed to implement a program like integrated STEM, it simply would not be possible to implement integrated STEM. The respondents felt that with training, leadership, and a willingness on the part of teachers to be part of such an initiative, integrated STEM could be successful. It is interesting that in the eyes of the Interviewees, the things necessary to help teachers become integrated STEM teachers (leadership, outside support, professional development, collaboration, authentic/relevant/real-world experiences, and willingness) are the very phenomena that were identified in the interviews as key implementation factors. This fact not only strengthens the importance the phenomena that were identified related to integrated STEM, it also helped validate the inclusion of the information related to integrated STEM not requiring staffing changes in the results from the interview analysis.

An additional phenomenon was found in the analysis of the interviews that had relevance to the creation and implementation of an integrated STEM program. The phenomenon of dissension brought some important discussions to the forefront that need to be considered for the creation and implementation of integrated STEM programs.

Phenomenon 11: Dissent/concerns for schools. The final phenomenon developed in the data analysis of the interviews was related to dissent among the Interviewees. There were four major areas of dissent that must be addressed. The reason for this is related to the fact that if the thirteen interview participants from this study could not come to consensus, it is likely that other practitioners would have similar concerns and disagreement. Schools should be aware of these areas of dissent when creating and implementing an integrated STEM curriculum. They could pose potential stumbling blocks, which would need to be addressed. The primary areas of dissent present in the interviews were: 1) elective vs. core class, 2) certification, 3) standardized testing, and 4) cost.

The first area that the respondents disagreed on was whether integrated STEM is an elective or a core class. Twelve of the Interviewees spoke to this topic with almost an even split between them. Three respondents felt that integrated STEM is a core class, four felt that it is an elective, and five respondents felt that integrated STEM is somewhere in between. Interviewee 3 said, “I think it's a core course…integrated STEM is just separate core courses working together for a common goal.” Interviewee 4 is an integrated STEM teacher in a large metropolitan school district. This is what she said about integrated STEM being an elective vs. core class.

> We decided to make ours a replacement for the first two years for core classes, and then as they get into their junior and senior year it becomes an elective. That way...Ideally I think it would be an elective all the way through, but for staffing and for funding within the school, it is much more practical to make it a replacement course for one of the standard classes that they would have to take as a freshman or sophomore, or at least by the time they graduate from high school.

Interviewee 6 stated that integrated STEM is a “core class.”

Interviewee 2 saw integrated STEM differently. He said that, “I can see upper divisions being an elective. Something akin to nationwide contests and challenges. I do see that you could really expand and take the top tiers as an elective.” Interviewee 9 stated,

> I see it [integrated STEM] more as an elective. I see it more as a career exploration pathway, with STEM introducing children who have an interest in science, technology, engineering, and math, to give them opportunities to explore all the options.

Interviewee 10 said, “I would say elective,” when asked about integrated STEM. Interviewee 1 stated,

> I think that STEM is a core concept that works best in an elective setting. I think that electives have the freedom to explore ideas rather than to teach specific topics. Core classes teach the STEM foundations, but electives get to put them to practical uses.

Some other Interviewees see integrated STEM as something different from an elective or a core class. Interviewee 5 said, “I think it [integrated STEM] is everywhere. If we're talking true integration.” He went on to say that, “I think the most important thing is that it's intentional. I think that's a key word.” Interviewee 6 stated, “It [integrated STEM] needs to be an evolution of the curriculum structure of schools. It needs to cross disciplines.” Interviewee 7 said, “I think it [integrated STEM] would be integrating, within the courses and then maybe doing something with school-based projects, possibly something like that.” Interviewee 8 saw integrated STEM completely differently. He said, “No it's a track. It's large chunks of time spent with multiple team teachers in an incubator of creativity utilizing science, technology, engineering, and math.” Interviewee 12 believed,

> Right now, it doesn't fit very well. Again, if it fits in curriculum-wise you would see some of it in science, some of it in mathematics, and you would see technology to probably support the effort, and you would see it in CTE actually. Industrial technology would be a good idea for an area that would model a STEM application. So there are bits and pieces, but it isn't a package; let's put it that way.

Another area of disagreement was related to certification of teachers of integrated STEM. Seven of the respondents stated that certification is not needed for integrated STEM teachers. Interviewee 3 said, “I don't think the educator with a STEM certificate or a STEM degree would have a deep enough knowledge in any one of the areas to excel.” Interviewee 4 believed, “I don't know if it [certification] is necessarily a requirement in my eyes.” Interviewee 5 emphatically stated, “I don't think we need a certification on STEM.” Interviewee 7 said, “I don't know if there would be a general STEM certification, and what that would involve, and whether somebody could conceivably do all of that in 4 years.” Interviewee 8 believed,

> Certification, it could be a specialty area but I don't want it to be. We could get a specialist certification in STEM education. That's fine, I don't have a problem with it. I would rather see a dedication to the philosophy than a certification necessarily in order to be a STEM teacher.

Interviewee 9 said this when discussing the topic, “certifications, that one I kind of have mixed feelings about that with certifications.” Interviewee 12 stated this when discussing certification. “Don't touch it. I do not see, I don't know, I do not see a STEM certification.”

Two respondents saw certain STEM disciplines needing a certification that currently does not exist. Interviewee 6 said, “Computer science and engineering desperately need their own certification.” Interviewee 11 stated, “I would like to see engineering education certification.”

Several respondents had answers regarding certification that were between 'yes, it is necessary', and 'no, it is not necessary'. Interviewee 1 called the certification area of integrated STEM "grey". He said,

> I think this is where it gets grey, because I don't know that a STEM class fits one certification. I don't think that you need to necessarily have a math certified person, and a science certified person, and so on down the line.

Interviewee 2 skirted the issue of STEM certification when he stated, "I don't believe that we have an actual STEM certification right now." Interviewee 10 believed that "certification, that is something that would be accepted by the state" and it could be a "secondary certification, not a whole degree in a sense." Interviewee 13 took a different approach to certification than most states have for educators. She said,

> I think that we also need to go and look at certification pieces, so that if we become certified like at a community college or at a college and we have a piece of certification, that [certification] can be added onto our state certification certificates and reflect the STEM area that we have an emphasis in.

Another area of dissent among the interview participants is whether integrated STEM would help or hinder the standardized testing culture found in education. Seven respondents believe that integrated STEM cannot be assessed through standardized testing. Interviewee 1 discussed the difficulty with standardized tests and what integrated STEM looks like when he said,

> Again, I think that the end result of STEM project or products would be sort of a portfolio of work. I think that is hard to fit into bubbles. I think that it's hard to demonstrate on a multiple-choice test.

Interviewee 1 also mentioned that for standardized testing to work for integrated STEM, it would have to be modified.

> I think multiple choice tests and standardized tests can change, and I think you can still ask problem solving questions that require the same skill set that we currently test for, but I don't think the answer is the same.

Interviewee 2 said this about standardized testing, “unless carefully crafted, it [integrated STEM] could be detrimental to standardized testing because it is not looking at the ideas in isolation. It is looking at the big picture.” Interviewee 5 said, “if you want to assess STEM instruction for integrated STEM or whatever you're calling it, then it probably does not fit very well within the current state assessment process.” Interviewee 7 agreed. He stated, “I think, standardized testing assumes a content base and I think in integrated STEM, really good integrated STEM, you're not going to know what the content is.” Interviewee 9 said, “I have no idea how you're going to do that, [standardized testing] if you're going to go in the direction that I’m thinking.” Interviewee 10 agreed and said this about standardized testing, “I don't see it happening and I would not be a proponent of it because that is not STEM.” Interviewee 11 stated this about standardized testing, “I don't think it does.”

Four respondents feel that standardized testing results would not be hindered by integrated STEM. Interviewee 6 was the strongest proponent. He stated, “I personally believe that the standardized tests are just fine. The curriculum is what needs to change.” Interviewee 6 further stated, “The standardized tests, I think, are fine. I think it is not time to change the test, it is changing the instruction.” To conclude, Interviewee 6 said, “If a math teacher says they're not going to learn how to do this on a standardized test, the research is showing the opposite in a lot of ways." Interviewee 13 believed, "it [standardized testing] can happen in a STEM class. The teachers just have to be cognizant of it." Interviewee 3 initially said standardized testing and integrated STEM would not be compatible. However, on reflection she said,

> Actually, that's not true because there is a chance if it's done well and the teachers point out what the concepts are that they are learning, if a student then takes traditional standardized tests they might go, 'oh yeah, yep, I know how to do linear equations' or 'I remember how a voltmeter is set up to read', or whatever it is.

Interviewee 8 stated this, "I think there is room for both [integrated STEM and standardized testing]. I think we need both."

Another area of contention is the cost of an integrated STEM program. Not all Interviewees spoke to this topic, but those who did were emphatic in their opinions. Three respondents think that integrated STEM can be done for very little expense. Interviewee 8 stated, "it [integrated STEM] doesn't have to be high and expensive things, but it should be collaborative, large environments that have access to certainly plenty of technology. It doesn't have to be off the hook or expensive." Interviewee 10 agreed when he said, "it can be done for little or nothing." Interviewee 1 felt that integrated STEM would not have to be expensive. He said,

> Again, most facilities would work…Equipment and software licensure. I think most of this is free. I don't think that there is a lot of expensive stuff that needs to be bought. I think that a lot of stuff exists that allows you to explore. I don't think that there is one technology, or one piece of software that is the STEM

> learning software. I think you go out and find what is available which accomplishes the task that you have already defined and not the other way around.

Interviewee 4 is an integrated STEM teacher in a large metropolitan high school and she disagreed. She said, “It [integrated STEM] costs. It is an expensive thing to do.” This school got a large grant to establish their integrated STEM program, which has teachers co-teach a STEM class that replaces core curriculum.

The areas of dissent between the Interviewees related to cost, certification, standardized testing, and core class vs. elective class are worth noting. These are exactly the types of discussions that must be conducted, and where compromise must be identified if integrated STEM is going to gain traction in public schools. Knowing the areas of agreement provides common ground for possible integrated STEM implementations, and knowing the areas of disagreement can drive discussions that make integrated STEM better if handled correctly.

Tactical Definition of Integrated STEM. The study’s research questions were specifically designed so that phenomena important to any implementation of integrated STEM were identified. A specific definition of STEM education is not included as a study outcome because a single definition of STEM education might be inappropriate. The difficulty with a definition of STEM education is that there is little agreement in the literature or among experts about STEM education.

With that being said, a tactical or operational definition of integrated STEM education might serve as a place to begin discussions in local environments attempting to create and implement integrated STEM programs. The study asked the respondents to define integrated STEM education. These definitions are presented in Chapter 4. The respondent definitions were further combined with some of the identified phenomena from the study to create a tactical definition of integrated STEM education. This definition should not be considered the only definition of integrated STEM education. However, in the context of the data from this study, it does serve to aggregate many of the phenomena the respondents felt were critical to integrated STEM education. The following definition is the result.

> *Integrated STEM education involves the purposeful integration of science, technology, engineering, and mathematics as well as other subject areas through project-based learning experiences for students that require the application of knowledge to solve authentic, real-world problems in collaborative environments.*

Conclusion

This chapter focused on the synthesis of data that was presented in Chapter 4: Results. The synthesis was completed using the technique that Creswell outlined for layering phenomena from qualitative data (Creswell, 2015, p. 251). Using these techniques, 10 phenomena were identified in which the Interviewees found consensus. The 10 phenomena were then further grouped into two classes of implementation phenomena: structural and interpersonal. The structural implementation phenomena included: subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, and outside support (from businesses and industry). The interpersonal implementation phenomena included: leadership, collaboration, willingness, authentic/meaningful/relevant experiences for participants, and outside support (from people in business and industry).

When considering these phenomena related to the research questions, their strong interconnected nature made it impossible and undesirable to attempt to separate them into the key components and critical implementation factors from the two research questions. The following rationale was given for this decision. It can be argued that these phenomena are indeed critical components because if any one of them were missing, integrated STEM, as envisioned by the Interviewees, would be greatly diminished. It can also be argued that these phenomena are also implementation factors, because you cannot implement integrated STEM without the identified phenomena being present. The interconnectedness of the phenomena and the fact that they are all necessary for integrated STEM, as well as being necessary for implementation of integrated STEM, makes the identified phenomena both critical components and implementation factors. Therefore, the synthesis of data proceeded as if they are in fact the same thing.

Chapter 6: Discussion and Implications will include a discussion on what the phenomena identified from the study mean to current educational practices. How these phenomena are related to the conceptual framework and the literature will be explored. Finally, the implications of the study related to possible further research will be considered.

Chapter 6: Discussion and Implications

As discussed earlier, there is a rise in interest related to providing students with learning that makes connections across STEM disciplines; however, there is little research and/or consensus on what integrated STEM means and how to create integrated STEM offerings for student learning (Brown, et al., 2011; Householder & Hailey, 2012; NAE, 2014). Householder & Hailey (2012) state that there is a need for clarity in the outcomes that may be expected and the arrangement of developmental sequences related to integrated STEM, and that there are few organized efforts that include engineering experiences in high school STEM courses. According to the National Academies of Engineering and National Research Council report, *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*, there is little research on how to best conduct integrated STEM, or what factors make the integration of STEM subjects increase student learning, interest, retention, achievement, or other outcomes (NAE, 2014). This study attempted to address these needs identified in the literature, by answering the following research questions. First, what were the critical components of an integrated STEM definition? Second, what critical factors were necessary for an integrated STEM definition's implementation?

Research Questions Addressed

Earlier in Chapter 5, the interconnected nature of the identified phenomena was demonstrated through the synthesis of the analyzed data. The researcher argued that these phenomena are indeed critical components of integrated STEM, because if any one of them were missing, integrated STEM as envisioned by the Interviewees would be greatly diminished. The researcher also argued that these phenomena are implementation factors, because you cannot implement integrated STEM without the identified phenomena being present. The interconnectedness of the phenomena and the fact that the data showed they are all necessary for integrated STEM as well as being necessary for implementation of integrated STEM, made the identified phenomena both critical components and implementation factors. Therefore, it was impossible and redundant to attempt to separate the phenomena into critical components and implementation factors.

Identified critical components/implementation factors for integrated STEM. Through the interview process, the analysis and synthesis identified 10 phenomena that can be considered both a critical component and key implementation factor for integrated STEM. These 10 phenomena were further grouped into two classes: structural implementation phenomena, and interpersonal implementation phenomena.

Structural implementation phenomena

- Subject integration/project-based learning/design-based education
- Non-traditional assessment
- STEM content
- Time
- Professional development
- Outside support (from businesses and industry).

Interpersonal implementation phenomena

- Leadership
- Collaboration
- Willingness
- Authentic/meaningful/relevant experiences for participants
- Outside support (from people in business and industry).

The structural implementation phenomena were deemed structural, not because they are structures (even though some of them are), but because these phenomena represent things that must be in place either from the schools or outside influences. The interpersonal implementation phenomena were considered interpersonal, because they all are something that people (teachers, students, outside experts) all do, or in which they participate. These phenomena are more connected to the people involved in the integrated STEM process, where the structural phenomena are more about needs for integrated STEM.

The interconnectedness of these phenomena is shown in figure 17 which can be found in Chapter 5. This graphic showed, and is further detailed in the analysis that followed that integrated STEM appears to be more like a tapestry or a spider web than just a random listing of components or implementation factors. If any one of these phenomena were removed, the data showed that integrated STEM would be diminished.

The identified phenomena work in concert to produce something that is more than the sum of its parts. This is an important consideration for measuring the performance of existing integrated STEM programs, or when attempting to begin a new program. The nature of integrated STEM from the perspective of the data, was that integrated STEM is truly integrated. Not only does it incorporate the integration of multiple disciplines as content, it incorporates multiple structural and interpersonal aspects as part of that process. This in turn makes integrated STEM very complex.

The real question is can you create and implement integrated STEM without all of the phenomena identified in the research study? When speaking to the Interviewees, the nearly universal responses related to these phenomena made a strong argument that they must all be included. The literature tends to agree, and details to that effect can be found in the next section. A primary difference between the identified phenomena in the literature and the identified phenomena in the research study, was that the phenomena identified in the study were much more highly interconnected than the literature appears to indicate. The literature tends to list phenomena that are important to integrated STEM, but does not necessarily explore the interconnectedness between them.

Relationship to Literature

In the literature, research identified many essential components for the successful implementation of integrated STEM education. <u>Effective STEM instruction</u> was identified in research as a critical for student achievement. This type of instruction utilizes student's interests and experiences. It identifies and builds on their prior knowledge, and gives them educational experiences that engage them in STEM coursework and sustains their interest (Herschbach, 2011; National Academy of Engineering, 2014; National Research Council, 2011).

This incorporates two phenomena found in the interviews: authentic/relevant/real world experiences and the professional development, which is required for teachers to be effective STEM instructors.

The National Research Council report, *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics* (2011), identified another critical component of integrated STEM education, which is <u>adequate instructional time.</u> The NRC report states that the current No Child Left Behind legislation has changed the time allotted for science, technology, engineering, mathematics teaching, and learning in the K–12 curriculums. Elementary schools are focusing more on mathematics and English because these are tested annually, at the expense of losing time for science, technology, and engineering education. This decrease in educational time for science education is a problem, because research indicates that interest in science careers develops in elementary school (National Research Council, 2011).

The relationship to this study is that time was identified universally by the Interviewees, as essential to integrated STEM. The Interviewees spoke directly to instructional time when discussing longer class periods, as well as providing students time to think and process. The Interviewees also spoke about time for teachers to work, collaborate, and learn, which directly affects the teacher's ability to instruct quality integrated STEM. Time, from the standpoint of the study, is definitely important to integrated STEM for multiple uses and from multiple perspectives.

Equal access to high-quality STEM learning opportunities was cited as another critical component for integrated STEM education in the literature. These learning opportunities must have an inclusive STEM mission, where goals are stated clearly to prepare students for STEM careers, to support students from minority and underrepresented population groups, and to have an emphasis on recruiting students from these underrepresented population groups (DeJarnette, 2012; National Research Council, 2011; Peters-Burton et al., 2014; Stone, 2011).

Equal access to high-quality STEM learning opportunities, just like providing effective STEM instruction, relates to the study-identified phenomenon of authentic/relevant/real world experiences for students. Providing these types of experiences for students will help prepare students for STEM careers and help with motivation and recruiting.

Another component related to integrated STEM education found within the literature is having real world partnerships, research opportunities, and internships. In literature, identified STEM schools provide extensive research opportunities for students.

These opportunities allow students to connect with businesses, industry, and the world of work via internships, mentorships, and projects, both within the school day and outside the school day/school year. These research experiences provide hands-on experience for students and have the possibility of increasing interest in STEM career fields (Ejiwale, 2012; Peters-Burton et al., 2014; Pfeiffer, et al., 2010; Scott, 2012).

The importance of this phenomenon was clearly defined in the Interviewees when speaking about outside support from structures and from people. The Interviewees discussed exactly these types of experiences for students of integrated STEM. The Interviewees went one step further when they thought outside support for resources and expertise related to instruction was essential for integrated STEM education. For there to be successful integrated STEM, there is evidence that outside support is needed.

Collaboration between teachers of all disciplines was seen as a critical integrated STEM component. Teachers from all disciplines should meet to analyze lesson plans and student work, to improve future learning (Peters-Burton et al., 2014). STEM education requires collaboration, since teachers have not been trained in all STEM curricular areas. The time allocated to teacher training needs to be dedicated and collaborative (Brown et al., 2011; Peters-Burton, et al., 2014; Sanders, 2009; Scott, 2012).

Collaboration was a universal phenomenon that surfaced in the interviews as being important for integrated STEM. The cited evidence from literature confirms that collaboration is important. The Interviewees again went further when discussing the collaborative nature of integrated STEM from the students' perspective. The data and literature showed that collaboration's many facets are essential to integrated STEM.

Professional development/teacher support was another key component of integrated STEM education identified in the literature. According to the National Academy of Engineering, (2014) very few teacher education programs are preparing prospective teachers with appropriate knowledge in more than one STEM curricular area. Rockland, et al., (2010) claimed that to increase the presence of engineering in the K–12 classroom, pre-service teachers must be exposed to training on engineering concepts, and how to integrate those concepts into the classroom. Professional development of teachers allow them to become more comfortable with their own knowledge of STEM, and as teachers learn more about math and science they become more comfortable teaching STEM (Nadelson, Seifert, Moll, & Coats, 2012). The implementation of integrated STEM education in all educational settings will require additional content and pedagogical knowledge beyond which teachers currently are trained, therefore schools currently attempting to have an integrated STEM curriculum must provide professional development for its teachers and leaders (Nadelson et al., 2012; National Academy of Engineering, 2014; National Research Council, 2011; Rockland et al., 2010; Scott, 2012; Sterns et al., 2012).

Professional development was clearly identified by the participants as important to integrated STEM, particularly the type of experiences cited in the literature. The data from the study, as well as the literature, highlighted the phenomenon that teachers need experience with more than one discipline in integrated environments. Professional development is one way to gain those experiences and is therefore essential to the success of integrated STEM.

The idea of better assessments for integrated STEM is also present in the literature. The National Research Council report, *Successful K-12 STEM Education:*

Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics (2011), identified a supportive system of assessment and accountability as important for integrated STEM. The report states that the current push by governmental oversight agencies toward standardized testing limits the teacher's ability to teach using techniques that are known to increase learning of mathematical and science content and practices (National Research Council, 2011).

The Interviewees spoke about the non-traditional nature of integrated STEM. Some Interviewees felt that integrated STEM would not hinder standardized testing. However, the types of non-traditional assessments that were mentioned in the data were often not standardized. The Interviewees did not mention a supportive system of assessment, but the types of assessments which were discussed, would support integrated STEM education. This would effectively create a supportive system of assessment. Ultimately, the data and literature demonstrated the importance of assessment, which will likely be non-traditional for integrated STEM.

The next area in the literature that has connections to phenomena generated in the interviews was using engineering design and problem-based learning as a mechanism for integrated STEM education. Project-based learning and problem-based learning is not exactly the same thing, but are often used interchangeably. Engineering design and engineering design challenges in the classroom expand on traditional problem-based learning which is a highly researched instructional technique (Rockland, et al., 2010). Strobel & van Barneveld (2009) performed a qualitative synthesizing meta-analyses of problem-based learning, and determined that problem-based learning is significantly more effective than traditional instruction to train competent and skilled practitioners, and to promote long-term retention of knowledge and skills acquired during the learning experience or training session. Inquiry learning, problem-based learning, and project-based learning, are teaching methods that are proposed for use in engineering education (Prince & Felder, 2006).

The Interviewees specifically stated project-based learning needed to be part of an integrated STEM environment. These statements regarding project-based learning made up one third of the subject integration/project-based learning/design-based education phenomenon that was found in the data from the interview. These three pedagogical methods were grouped into one phenomenon because they are the primary instructional methods from the study's conceptual framework.

The above literature discusses engineering design and problem-based learning as well as project-based learning. These concepts together make sense, because project-based learning is made up of smaller problems, that must be addressed though some kind of process. In integrated STEM, the engineering design process can be the driving force to address the problems that make up the larger projects. The amount of literature related to problem-based and project-based learning and the consensus of the Interviewees related to project-based learning makes it an important factor for integrated STEM implementation.

Another area in the literature that has connections to phenomena generated in the interviews was subject integration, which is also part of the conceptual framework of the study. In the article *The STEM Initiative – Constraints and Challenges,* Dennis Herschbach (2011) discusses STEM as a curriculum concept. Herschbach states that there are two types of curriculums: correlated and broad field. In a correlated curriculum, each course retains the identity of each subject and is offered separately. In a broad field curriculum, all courses are integrated together with each course losing its own identity (Herschbach, 2011). Math and science tend to be correlated in nature, where technology and engineering tend to be broad field in nature. The broad field curriculums of engineering and technology are a very good way to organize engineering and technology instruction because they are interdisciplinary. Using this model, instruction is built around the integrated use of knowledge from engineering and technology, with supporting knowledge drawn from the correlated fields of science and mathematics (Herschbach, 2011).

The National Academy of Engineering report, *Engineering in K-12 education: Understanding the status and improving the prospects* (2009) identified a symbiotic relationship between mathematics, science, and engineering, where engineers use mathematics and science in their work, and mathematicians and scientists use the results from engineering in their work. The committee that authored this report found that due to this symbiotic relationship, engineering could be the vehicle for the development of integrated STEM education (National Academy of Engineering, 2009). Rockland, et al., (2010) believe that the engineering design process can provide a context that supports teachers in teaching scientific inquiry to students, because scientific inquiry and engineering design are parallel processes with both having similar problem solving characteristics. Kimmel, Carpinelli, & Rockland (2007) argue that when engineering and science are taught together, they extend and reinforce each other. The integration of engineering principles into science instruction, presented through problem-solving inquiry/discovery pedagogy, can stimulate students as well as enable them to recognize links between their lessons and tasks performed by engineers in the real world (Harwood & Rudnistsky, 2005).

The Interviewees all discussed the integrated nature of integrated STEM. Several respondents mentioned that integration is sometimes claimed, but when what is actually happening in the classroom is analyzed, integration is not occurring. They all felt that subject integration is critical for integrated STEM to occur, and the literature appears to support those feelings. Because of the consensus of Interviewee opinions related to subject integration, the amount of literature surrounding the importance of subject integration, and the fact that subject integration made up one of the instructional delivery models of the conceptual framework of the study, subject integration can be considered critically important for integrated STEM.

Some other areas in the literature that are cited as important for integrated STEM were not found in the comments of the Interviewees. First, the literature stated, high quality integrated STEM educational settings utilize varied technology. Integrated STEM institutions use a wide variety of instructional technology like computers, graphing calculators, calculator-based laboratories, and other digital data instruments to deliver inquiry based lessons, engage in research, and to produce and present projects. The use of technology has the potential to change the interactions and relationships between students, teachers, and the knowledge that teachers are trying to convey (Peters-Burton, et al., 2014; Scott, 2012).

The Interviewees did mention some specific technology that integrated STEM environments could use. However, as stated earlier, most of the ideas that the respondents spoke about were conceptual rather than “things.” This does not mean that varied technology is not important, rather that the Interviewees did not address specific technologies and did not reach a consensus on that matter.

Second, a clear and understandable set of standards and curriculum where there are strong course offerings in all STEM areas is important for integrated STEM. Engineering and technology are explicitly and intentionally integrated into STEM and non-STEM subjects. Setting rigorous standards and aligning the curriculum to those standards can show gains in student achievement (Brown, 2012; National Research Council, 2011; Peters-Burton, et al., 2014).

In today's educational climate, standards and curriculum are very important. The Interviewees did discuss standards and found much more agreement related to national standards than they did related to state standards. However, there is disagreement among the Interviewees related to standards and curriculum, and whether integrated STEM is a core class vs. elective class. The national standards in the eyes of the participants were much broader and process-based than state standards. This might be why they feel that integrated STEM would fit national standards better than state standards. The issue of curriculum and how integrated STEM fits into schools is a more difficult topic.

Third, teachers with a high capacity to teach their discipline is a key component of integrated STEM education that is identified by many researchers. Teachers must teach in ways that inspire all students, and increase their understanding of STEM content and practices (National Research Council, 2011; Scott, 2012). Teachers must have advanced STEM content knowledge and/or practical experience in STEM career fields and they must be well prepared (Brewer & Goldhaber, 2000; Ejiwale, 2012; Monk & King, 1994; Peters-Burton et al., 2014; Rowan, Chiang, & Miller, 1997).

While the Interviewees did not specifically mention high capacity teachers, it could be implied in their conversations regarding professional development. They stated that teachers must be willing, excited, and well trained. These are likely traits of high capacity teachers. The fact that the Interviewees did not state integrated STEM teachers needed to have a high capacity to teach, does not discount the literature. Rather, the questions in the interview might not have been asked in such a way as to elicit this type of response.

The literature aligns well with the findings of the study, which is a confirmation of the findings. There were some phenomena identified in the interviews on which the literature is not as clear. The concept of willingness was prevalent in the Interviewee responses. The participants overwhelmingly thought that willing teachers (and to a certain extent, willing students) are essential for successful integrated STEM. This might be a characteristic that could be included in the high capacity teachers component from the literature. Regardless, this is something that the data from the study shows is important to integrated STEM.

The participants spoke at depth about non-traditional assessment for integrated STEM. While the literature touches briefly on the need for a supportive assessment system, the Interviewees were much more specific about the nature of integrated STEM assessment. The Interviewees also put emphasis on authentic/meaningful/relevant experiences for participants. Again, the literature touches on this phenomenon when it cites real world partnerships, research opportunities, and internships, as important to integrated STEM. However, the Interviewees were much more specific about the nature of those experiences.

The final phenomenon that the respondents considered very important to integrated STEM is leadership. The literature does speak to leadership related to integrated STEM, which is also a support structure from the conceptual framework. However, the Interviewees were much broader in their discussion of the type of leadership, and from whom the leadership needs to originate than the literature.

How Results Relate to Conceptual Framework

The results of the study in terms of the phenomena generated through the interviews, which are both key components and implementation factors, align well with the conceptual framework of the study. The subject integration/project-based learning/design-based education phenomenon was identified by the Interviewees as the primary instructional mechanism for integrated STEM. This matches the three pedagogical methods outlined by Pitt (2009) that forms one leg of the conceptual framework. The second leg of the conceptual framework was STEM content, which was also either explicitly stated or implied by the Interviewees as being important to integrated STEM education. The third leg of the conceptual framework was the support structures identified in the literature as important to integrated STEM. Two of the six support structures were clearly identified in the interviews as phenomena: collaboration and professional development. A third support structure of the conceptual framework, administrators, was greatly expanded upon within the interviews, in the leadership phenomenon. The respondents did mention school leaders. However, they saw leadership as much more than just school leaders. Leadership from multiple aspects and multiple perspectives were identified in the interviews as important to integrated STEM. The other three conceptual framework support structures: counselors, libraries, and the arts curriculum, were not mentioned by any of the Interviewees. This does not discount them as important to integrated STEM. Rather, it means that in the course of the interview they were not mentioned. The Interviewees also included supporting elements for integrated STEM that were not included in the conceptual framework. These include: non-traditional assessment, time, outside support, willingness, and authentic/meaningful/relevant experiences for participants.

The fact that the Interviewees' responses matched the conceptual framework validates its construction. The additional phenomena (supporting elements) that were found, provide additional information related to integrated STEM.

Implications for Future Research

The implications for future research are numerous. One area of consideration is to explore the interconnectedness of the phenomena identified in the interviews. Is one phenomenon more important than another is? Are all the phenomena necessary, or can one or more be left out to determine the distilled minimum amount of key components/implementation factors for integrated STEM? Are some of the connections between the phenomena more important than others? This has implications for implementation, because if some connections are more important, leaders and practitioners need to be aware of it, and concentrate effort on building that connection versus another.

Another area for further research is to explore the value each phenomenon specifically contributes to integrated STEM, and to further identify the specific characteristics of the phenomenon. This would involve an in depth look at a single phenomenon using quantitative and qualitative methods to see how a particular phenomenon relates to integrated STEM, as well as specifically what that phenomenon represents. For instance, is one particular area of leadership important or is one aspect of outside support more important than another is? If you have limited resources, this type of research could help optimize the impact of your resources.

A third area to consider for future research is to analyze existing STEM implementations in the context of the identified phenomena, to see if the study's phenomena are present. This research study can serve as a gauge for the quality of a STEM education curriculum and suggest ways to improve STEM education by incorporating phenomena that were identified as important, but which might not be present.

Conclusion

The study utilized a semi-structured interview approach to identify phenomena that are critical components and key implementation factors related to integrated STEM education. Thirteen expert practitioners were identified and interviewed. The interviews were transcribed and analyzed for content in three different ways, by person, by interview question, and across interviews using exploratory data analysis methods.

Ten phenomena that were considered both critical components and key implementation factors were identified. The 10 phenomena were further grouped into two classes: structural implementation phenomena and interpersonal implementation phenomena. The structural implementation phenomena were: subject integration/project-based learning/design-based education, non-traditional assessment, STEM content, time, professional development, and outside support (from businesses and industry). The interpersonal implementation phenomena include: leadership, collaboration, willingness, authentic/meaningful/relevant experiences for participants, and outside support (from people in business and industry).

These phenomena were looked at related to the literature and identified evidence for them being important to integrated STEM was presented. The phenomena were also discussed in relation to the conceptual framework of the study. Although not all parts of the conceptual framework were found in the interviews, the identified phenomena not only matched the conceptual framework very well, but also enhanced it. Implications for further research were explored which include the possibility of looking at the interconnectedness of the phenomena, what each phenomenon contributes to integrated STEM, and analyzing current STEM implementations to see if they incorporate the identified phenomena. The possibility of improving STEM instruction by incorporating one of the identified phenomena if it were found lacking, is also a possible future research opportunity.

The study affirmed what other research has said about integrated STEM. It also highlighted the interconnected nature of the components that make up integrated STEM. The interconnected nature of the components that are important for integrated STEM found in the study had not been evident in the literature. Not only did the study identify phenomena essential to integrated STEM, it demonstrated that all the phenomena are important and if any are lacking, integrated STEM education is diminished. This underscores the importance of understanding and making these connections in integrated STEM environments.

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