University of South Carolina

Scholar Commons

Spring 2020

Program Evaluation of a Middle School Stem/Steam Program

Warren Richard Wintrode

Follow this and additional works at: https://scholarcommons.sc.edu/etd

Part of the Educational Administration and Supervision Commons

www.manaraa.com

PROGRAM EVALUATION OF A MIDDLE SCHOOL STEM/STEAM PROGRAM

by

Warren Richard Wintrode

Bachelor of Science in Computer Science
United States Military Academy, 1985

Master of Education
University of South Carolina, 2006

_____

Submitted in Partial Fulfillment of the Requirements

For the Degree of Doctor of Philosophy in

Education Administration

College of Education

University of South Carolina

2020

Accepted by:

Susan C. Bon, Major Professor

Edward Cox, Committee Member

Peter Moyi, Committee Member

Michael Seaman, Committee Member

Cheryl L. Addy, Vice Provost and Dean of Graduate Studies

ACKNOWLEDGEMENTS

ABSTRACT

Beginning with the Obama administration's "Educate to Innovate" campaign in 2009, integrated science, technology, engineering, and math (STEM) programs have flourished in our nation's schools. Designed to increase the number of STEM professionals in the workforce and contribute to the United States' continued viability in the global economy, these programs promote inquiry-based, technology-driven learning in collaborative, cross-curricular projects. Some schools have added art, and liberal arts, to the curriculum, making them STEAM programs. Middle schools are a popular home for STEM and STEAM programs, serving as the connective tissue in the K-12 STEM/STEAM "pipeline." To date, there have been relatively few program evaluations of STEM/STEAM programs in the literature on these programs. The purpose of this study was to conduct a program evaluation of a middle school program. This program evaluation examined the role of student interest, student self-efficacy, and teacher confidence in the success of a middle school STEAM program. The methodology of the study was a pragmatic, mixed methods program evaluation. The data collection instruments included an interview with the school principal, focus groups with the school's teachers, and surveys of all teachers and all students. The results of the evaluation indicated that faithfully implemented over the long-term, a school-wide STEAM program may contribute to student interest in STEAM professions, student self-efficacy, teachers' confidence in their instructional capacity, and student academic achievement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AYP...Adequate Yearly Progress

CIPP ....Context, Inputs, Process, and Products

DDE .... Deliberative-Democratic Evaluation

DE .... Department of Education

E3 ....Enrichment Experiences in Education

ESEA... Elementary and Secondary Education Act

GTT.. Gateway to Technology

HHS..Health and Human Services

I3 .... Investing in Innovation

IEP... Individualized Education Plan

Joint Committee .... Joint Committee for Standards for Educational Evaluation

NSF .... National Science Foundation

PBL .... Problem-based Learning

PLTW...Project Lead the Way

STEAM ....Science, Technology, Engineering, Arts, and Mathematics

STEM...Science, Technology, Engineering, and Mathematics

UDL ....Universal Design for Learning

UFE... Utilization-focused Evaluation

VEE...Values-engage educative case study model

CHAPTER 1

INTRODUCTION

Introduction

In a presentation on the science, technology, engineering, and mathematics (STEM) program implementation process, the Southern Regional Education Board (SREB, 2017) compared the problem-based learning (PBL) process of the STEM educational model with what it described as "Edutainment." STEM problem-based learning is inquiry-based and open-ended rather than teacher directed and highly structured. In PBL, there may be many solutions while in a teacher-directed project there is likely one best answer. In a highly structured project, the solution is the end state of the project, while in PBL the process is the launching pad for exploration, collaboration, and communication. The SREB described the goal of an "Edutainment" project as fun, but the goal of a PBL project is engagement. This distinction between the collaboration and inquiry-focus of problem-based learning and the highly structured, teacher-centered projects we find in many of our classrooms is intriguing and worth exploring.

Statement of the Problem/Research Questions

There are numerous STEM programs in the country, dedicated to training the next generation of STEM professionals. These programs often integrate art, and liberal arts, into their program of study, transforming them into STEAM schools. To date, there have been relatively few program evaluations of middle school STEM/STEAM programs, exploring the distinction between "Edutainment" and true project-based

1

learning. Therefore, it is worthwhile to conduct an evaluation of a STEM/STEAM

program in a middle school, to determine and measure the factors that indicate program

effectiveness.

Research points to three attributes in a STEM/STEAM program that predict

program effectiveness. The first attribute is student engagement in the learning and

interest in STEM and STEAM professions (Milner, Horan, & Tracey, 2014; Reiss &

Mujtaba, 2017; Sjaastad, 2011). The second attribute research emphasizes in

STEM/STEAM program effectiveness is the development of student self-efficacy

(Sithole et al., 2017; Olivarez, 2012; Sanders, 2009). Student self-efficacy is the

perception of students that they can master STEM concepts and skills and persevere

through the challenges of a STEM educational program. The third attribute is teacher

self-efficacy. Teacher self-efficacy is teachers' confidence in their ability to provide

rigorous and engaging instruction using the engineering design process to guide the

students in their tasks (Lesseig, Slavit, Nelson, & Seidel, 2016; Ferrara-Genao, 2015; van

den Kieboom, McNew-Birren, Eckman, & Silver-Thorn, 2013). A thorough evaluation

of a middle school STEM/STEAM program will contain valid and reliable measures of

the state of these three attributes in the middle school program. The following research

questions guided this assessment of the selected middle school STEM/STEAM program.

2

1. What is the STEAM program's impact on student interest in STEM/STEAM professions?

2. How has participation in the STEAM program influenced the self-efficacy of students in STEAM knowledge and skills, with a focus on females and minorities involved in the program?

3. How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students?

4. What is the STEAM program's influence on student achievement?

Purpose

The purpose of this dissertation is to examine the components of STEM educational programs and use this knowledge to conduct a program evaluation of a middle school program. In this instance, the examination involves a STEM program that includes art, and liberal arts, as a component of the program, transforming it into a STEAM program. In evaluating a middle school program, the evaluator worked with the school faculty and administration to assess program effectiveness and make recommendations for program improvement. Additionally, this program evaluation of a middle school STEAM program may contribute to the literature of evaluation of STEM and STEAM programs in its exploration of student interest and self-efficacy. Specifically, this program evaluation will be one of the first uses of the STEM Common Measurement System (Saxton et al., 2014) as a framework for organizing an evaluation of a STEM/STEAM school and will contribute to its legitimacy if it proves viable.

A middle school program is the object of this study because middle school is the connective tissue in the K-12 STEM education "pipeline." This pipeline refers to the

3

various paths students choose as they pursue STEM courses from kindergarten through the end of high school (Gonzalez & Kuenzi, 2012). Middle school is the first instance in which career education is seriously explored, and students begin to map out their choices in education and future profession. In 2010, the President's Council on Science and Technology (PCAST) recommended to the president several goals in STEM education, among them the establishment of 1000 STEM-related K-12 schools by 2021 (Executive Office of the President: PCAST, 2010). The distribution of schools was 200 high schools and 800 middle schools. This weighting in favor of middle schools was intentional. It reflects the understanding that if we want to grow our STEM workforce to remain economically competitive, it will occur through our recruiting and education processes. To do this, we need to engage our youth when they are beginning to explore their future. This occurs in middle school.

Rationale for the Study

To meet the challenges of recruiting, training, and producing STEM/STEAM professionals for our workforce, there is a need for further inquiry into evaluating STEM/STEAM education programs. To date, the country is making gains in the construction of STEM/STEAM schools at the middle and high school levels. There are numerous, overlapping models for STEM/STEAM instruction. The model which middle schools use in South Carolina is the Advanced Career STEM model sponsored by the Southern Regional Education Board (SREB, 2017). Higher education programs, such as the UTeach program at the University of Texas Austin (Perez & Romero, 2014), are providing teacher education programs for science and math teachers. Other programs (van den Kieboom, McNew-Birran, Eckman, & Silver-Thorn, 2013; Sanders, 2009)

4

prepare integrated STEM teachers. There is considerable research on student interest, persistence, and self-efficacy in the K-12 "pipeline," and in higher education, particularly regarding female and minority students.

One shortfall in STEM/STEAM inquiry is in evaluation of STEM/STEAM educational programs. To date, there have been few evaluations of middle school STEM/STEAM program effectiveness. In the research for this study, three middle school STEM/STEAM program evaluations emerged in the literature. There may be more, but they are not prominent. In 2008, researchers from the University of Akron (Lam, Doverspike, Zhao, Zhe, & Menzemer) conducted a post-positivist, quantitative methods program evaluation of a year-long, STEM program for local middle school students with individualized education plans (IEP). In 2015, Ferrara-Genao, a graduate student from the University of Southern California, conducted a constructivist, values-focused evaluation of three middle school STEM programs using qualitative methods. Recently, Nakamoto and Bojorquez (2017), researchers from WestEd, conducted a quantitative methods program evaluation of four Clark County, Nevada middle schools engaged in STEM programs. This inquiry should add to the understanding of student interest in STEM/STEAM fields, student self-efficacy, and teacher self-efficacy in a STEM/STEAM program.

<div align="center">

Research Context/Background

</div>

Context for the STEM/STEAM model

The context for the science, technology, engineering, and mathematics (STEM) model at a middle school begins with the STEM initiative within the United States. STEM education emerged in the second half of the 20th Century, in response to

the Soviet launch of the Sputnik rocket in 1957 and the subsequent race for space between the United States and the Soviet Union (Wissehr, Concannon, & Barrow, 2011). Galvanized by the Soviet space program, the United States government passed the National Defense Education Act of 1958, which recognized the need for an increased workforce with science, technological, engineering, and mathematics skills (H. Res. 13247, 1958). They challenged the educational system to produce more scientists, technicians, engineers, and mathematicians. This was the most recent evolution of STEM education in the United States. STEM education reemerged in 2007 and 2008, when the administrations of both President Bush and President Obama cited a shortage of STEM professionals in the country, and the corresponding need to promote education in technical fields.

In 2009, President Obama announced an "Educate to Innovate" campaign designed to promote STEM literacy, improve science and math instruction, and increase opportunities for female and minority students in STEM fields (Office of the Press Secretary, The White House, 2009). In 2010, the President's Council on Science and Technology (PCAST) convened to
generate STEM policy for the Obama administration. The PCAST report to the president (Executive Office of the President: PCAST, 2010) made numerous recommendations, including the increase of STEM educators by 100,000 by 2021, and the establishment of 1000 STEM-focused schools (200 high school and 800 middle school) by 2021. This increase in STEM educators refers to teacher training programs in our universities; however, another facet of teacher preparation is the professional development in STEM

curriculum, instruction, and assessment for teachers in schools that are implementing a STEM program.

In this current resurgence of STEM, the educational emphasis has been on inquiry-based, cross-curricular learning using a variety of media for presentation (SREB, 2017; Burgstahler, 2012).   In this model of STEM education, students use the engineering design process to analyze and solve complex problems with no simple solution. In some instances, schools have included art, and liberal arts, in the STEM model, transforming it into a science, technology, engineering, arts, and mathematics, or STEAM, school. This research explored STEAM education at the middle school level.

Inputs in the STEM/STEAM model

The STEM/STEAM model is an integrated, cross-curricular instructional model encompassing science, technology, engineering, arts (and liberal arts), and mathematics. The instruction is problem-based, and requires the students to research, collaborate, and communicate the results of their efforts in multiple media (SREB, 2017; Burgstahler, 2012). In contrast to traditional, teacher-centered instruction, the STEM/STEAM model is inquiry-based, student-centered, and technology-driven (Parker, Stylinski, Bonney, Schillaci, & McAuliffe, 2015; Quigley, Herro, & Jamil, 2017). The teachers serve as facilitators rather than instructors. This requires committed teachers, who continually strive to improve their pedagogy through ongoing professional development and personal effort. The model requires ample supports for students, both academic and interpersonal. Career education is also a component of the STEM/STEAM model, as are extracurricular activities such as field trips and clubs.

The primary input to a middle school STEM/STEAM model is the actual STEM/STEAM program itself. In this instance, middle school STEM/STEAM programs in South Carolina adhere to the Advanced Career guidelines of the Southern Regional Education Board (2017). The funding for the middle school program is another important input to the model (Ferrara-Genao, 2015). Some middle schools obtain a grant for the program. However, grants expire, so schools need to renew them or seek other funding sources. Traditional funding comes from school and district funds. Other inputs to the model include initial teacher training in STEM/STEAM education, school partners in the STEM/STEAM program, parent and community support, and school district oversight and assistance.

Process for the STEM/STEAM model

The process for the model begins with STEM/STEAM implementation within the school. The driving component of a STEM/STEAM program is a rigorous, interdisciplinary academic component, which requires students to follow the engineering design process: define the problem, plan solutions, make a model, test the model, then reflect and redesign (SREB, 2017). This process requires the students to exercise their critical thinking, collaboration, and communication (both verbal and written) skills. The program also consists of ongoing professional development for the teachers, and the requirement to include a STEM/STEAM component regularly in all classes. Students receive regular exposure to STEM/STEAM careers and the professionals who perform them (Angle et al., 2016). There should be frequent STEM/STEAM-focused excursions, and the students should conduct some of their projects within the local community. STEM/STEAM schools also sponsor STEM/STEAM-related extracurricular

8

activities, such as a math club or a science fair, and they routinely offer after-school tutoring in math and science (Nakamoto & Bojorquez, 2017).

Short-term outcomes of the STEM/STEAM process

The goals, or outcomes, of the STEM/STEAM process fall into short-term and long-term categories. In the education setting, short-term goals typically carry a school through the end of the school year. Generally, the teachers and administration establish short-term goals, often in concert with parents and students. In program evaluation terms, this group represents the stakeholders (Mertens & Wilson, 2012). Short-term goals most often focus on academics and school climate and reflect school report card statistics. Long-term goals generally last for a three- to five-year period, the duration of a school's strategic plan. Long-term goals also focus on academics and school climate and require progressive improvement in these areas. Both these types of goals establish the educational priorities of a school and should guide all programmatic and instructional decisions that educators make within a school.

In a STEM/STEAM program, the short-term goals begin with student interest in STEM/STEAM fields, potentially pursuing further study in science, technology, engineering, or math, and entering a technical profession. The other short-term outcome for students is their self-efficacy in STEM/STEAM knowledge and skills. In this context, self-efficacy is a student's confidence in their ability to study and master STEM subject matter, to take on complex challenges with no easily discernible solution, and to eventually become a STEM/STEAM professional. A student's self-efficacy is a result of the student-centered, problem-based STEM educational process, and student supports,

9

such as tutoring, collaborative learning communities, mentoring, and extracurricular activities (SREB, 2017).

Self-efficacy manifests itself in student persistence in completing STEM/STEAM projects and surpassing teacher expectations. Additional characteristics of self-efficacy generated in a STEM/STEAM program include critical thinking, technological competence, collaboration, initiative, and communication, all characteristics found in South Carolina's Profile of the 21st Century graduate (South Carolina Education Oversight Committee, 2017). For teachers, the potential short-term outcome is their confidence in teaching complex, cross-curricular subject matter in a manner that is the antithesis of traditional instructional pedagogy. Being the students' facilitator, not their instructor, is not an easy transition for many teachers, who thrive on the traditional, direct instructional model.

Long-term outcomes of the STEM/STEAM process

Long-term outcomes of the program include an increase in STEM/STEAM-related education at the high school, college, and beyond, and a corresponding increase of graduating students entering the STEM/STEAM workforce (America Competes Act, 2007; STEM Education Coordination Act, 2009; Executive Office of the White House, PCAST, 2010). Academically, students should improve their performance on standardized measures, such as the SAT, ACT, Workkeys, and ASVAB. Figure 1.1 contains a graphical depiction of a STEM/STEAM program at a middle school.
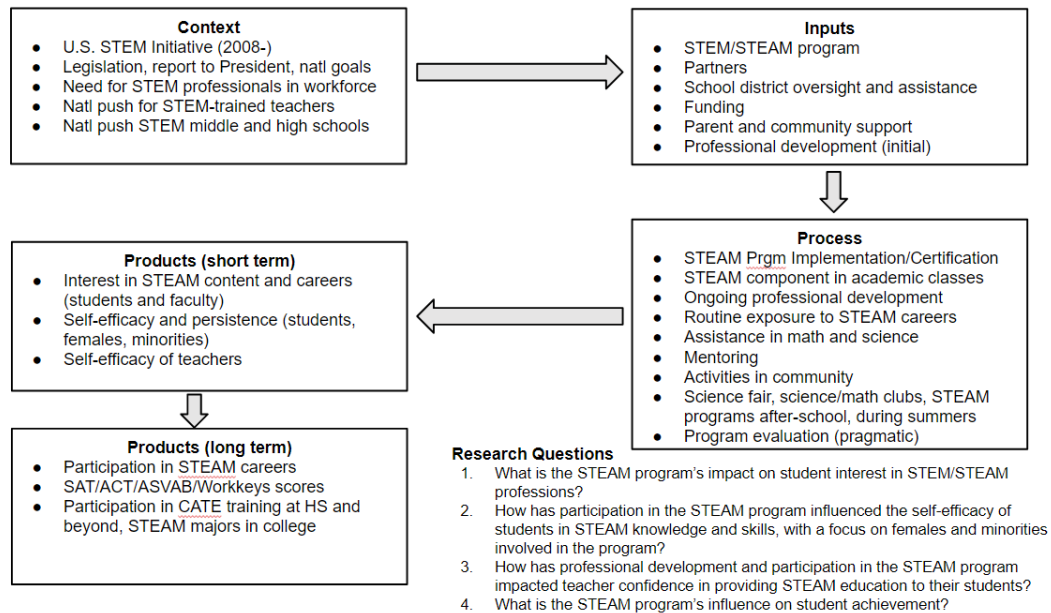
Figure 1.1. Components of a middle school STEM/STEAM program (CIPPP).

Researcher Perspective

I have been an educator for over 20 years, in the classroom, as a curriculum coordinator for my school district, and as an administrator. The target school for the program evaluation is a sister school in my school district, one of two STEM/STEAM middle schools in the district. I have no formal relationship with the school. A math teacher by trade, I am a product of traditional, teacher-centered instructional pedagogy. Although I had heard of integrated science, technology, engineering, and mathematics (STEM) education previously, I became familiar with it in 2016, when I applied for a position as principal of a STEM middle school. Although I did not receive the position, I became intrigued with STEM education and its potential for revolutionizing technologically focused education. My bias might be that I am hesitant to commit to student-centered, problem-based instruction until I see it in action. I have little

experience with students willingly accepting challenges and taking charge of their education. While pessimistic, I remain hopeful that my bias will be proven false.

Methodology

To answer the research questions posed above, the methodology (a research paradigm for gathering information) and method (a technique) for research should yield meaningful answers regarding students' interest in STEM/STEAM and their self-efficacy in content knowledge and skills (Mertens & Wilson, 2012). To examine student interest, student efficacy, teacher efficacy, and academic achievement in a middle school STEM/STEAM program, a pragmatic, mixed-methods approach is the most appropriate program evaluation approach (Mertens & Wilson, 2012). The researcher collected data for this study through a student survey, a teacher survey, focus groups with the teachers, an interview with the principal, and school report cards depicting academic performance and student body composition. The conceptual model for the program will be the context-inputs-process-products (CIPP) paradigm (Mertens & Wilson, 2012). Although there are other models to conceptualize the program, the CIPP model enables one to visualize a process for inputting students into the STEM/STEAM "pipeline," processing them with knowledge, skills, and confidence, and passing them out of the "pipeline" into follow-on education and STEM/STEAM careers.

Participants and Study Site

During this inquiry, the focus of data collection was the students, teachers, and administrators within a STEM/STEAM middle school. In program evaluation terms, these are the stakeholders (Mertens & Wilson, 2012). The selected middle school had been conducting an integrated science, technology, engineering, arts, and mathematics

12

(STEAM) program for several years. At this stage of program implementation as a

STEAM school, the school is either going to internalize its identification as a STEAM

magnet school, or it is going to continue as a STEAM school in name only.

Definitions of Program Evaluation Terms

Table 1.1. *Definitions of Program Evaluation Terms*

Term(s)	Definition
Constructivist evaluation	A constructivist evaluation is a qualitative or mixed methods evaluation, often in case study form, that focuses on determining the values of a program (Mertens & Wilson, 2012).
Culture	The culture of an organization or group is its shared set of beliefs, behaviors, values, and goals (Merriam-Webster online dictionary, n.d.).
Diversity	Diversity refers to the inclusion of various types of people, for instance people of different races, religions, or cultures, in the program being evaluated (Merriam-Webster online dictionary, n.d.).
Evaluand	An evaluand is the object of evaluation in a program evaluation (Mertens & Wilson, 2012).
Merit	The merit of an object refers to its quality, either intrinsic or with respect to a criterion (Mertens & Wilson, 2012).
Methodology	Methodology is the approach chosen to gather "information about what would be known" (Mertens & Wilson, 2012, p. 36).
Mythopoesis	Mythopoesis refers to "the making of myths" (Merriam-Webster online dictionary, n.d.). In policy making, it involves the narrative developed to convince the target audience of the legitimacy and utility of a policy.

(continued)

Term(s)	Definition
Paradigm	In program evaluation, a paradigm is the set "of philosophical assumptions, and theories of evaluation, programs, and social science" (Mertens & Wilson, 2012, p. 34.).
Persistence	Persistence in STEM refers to continuing a STEM educational program despite challenges and adversity.
Post-positivistic evaluation	A post-positivistic evaluation is one that uses quantitative methodology to discern the state of the program (Mertens & Wilson, 2012).
Pragmatic evaluation	Pragmatic evaluations seek to improve the usefulness and cost-effective of a program and are typically mixed methods (Mertens & Wilson, 2012).
Program evaluation	The Joint Committee on Standards for Educational Evaluation (Joint Committee) defined an evaluation to be "the systematic investigation of the worth or merit of an object" (1994, p.3)
Science, Technology, Engineering, and Math (STEM)	For the purposes of this paper, STEM education refers to integrated, cross-curricular instructional programs. Common elements of STEM education programs include inquiry-based learning, student-centered instruction, and relevant, hands-on learning experiences.
Science, Technology, Engineering, Arts, and Math (STEAM)	STEAM education is STEM education that includes artistic expression, and liberal arts, as integrated parts of the whole program.
Self-efficacy	Confidence in one's knowledge, skills, and ability to overcome challenges.
Stakeholders	Stakeholders are "individuals or groups that may be involved or affected by a program evaluation" (Joint Committee, 1994, p. 3).
STEM education "pipeline"	The STEM education "pipeline" refers to the various pathways of STEM courses from "from kindergarten to 12th grade" (Gonzalez & Kuenzi, 2012, p. 19).

(continued)

14

Term(s)	Definition
Worth	The worth of an evaluand is its value within the context of the evaluation (Mertens & Wilson, 2012).

Conclusion

This first chapter established the context and conceptual model for a STEM/STEAM program in a middle school. It also introduced the rationale for conducting a study of STEM/STEAM programs, a problem statement, research questions, and research methodology. In this instance, the methodology is a program evaluation of a middle school STEAM program. The next chapter is a literature review of STEM and STEAM programs, focusing on the recruitment of students into STEM/STEAM education programs and professions, and the development of student self-efficacy and perseverance. The literature review will also explore teacher preparation programs, and the inclusion of minorities and women in STEM/STEAM programs and professions. It will conclude with an exploration of program evaluations of STEM/STEAM programs preparatory to establishing a program evaluation as the methodology for this study.

15

CHAPTER 2

LITERATURE REVIEW

Introduction

Chapter 1 is the explanation and justification for conducting a program evaluation of a Science, Technology, Engineering, Arts, and Mathematics (STEAM) program at a middle school. As noted, a STEAM program is a hybrid of a Science, Technology, Engineering, and Mathematics (STEM) program. There are four research questions that emerged from the literature review. These questions are best answered using a systematic, outcomes-focused study; specifically, by using a program evaluation. These research questions not only reflect the researcher's personal and professional interest in STEM and STEAM programs, but they reside in the framework of scholarly research that examines the topic. This chapter contains a review of the literature and explanation of the relationship between the research questions and the literature, establishing why the research questions are feasible and appropriate. Given the current attention on STEM and STEAM programs, as well as a significant financial investment in these programs, this study is especially timely.

This literature review seeks to first establish a foundation for the proposed program evaluation. To understand the historical roots of STEM/STEAM, we begin by exploring the research literature documenting the genesis and rise of the current trend in integrated science, technological, engineering, and math education in the country. Additionally, the literature review includes research on the drive to generate

more STEM teachers, STEM schools, and STEM professionals. This growth of STEM professionals, teachers, and schools corresponds with the creation and implementation of STEM/STEAM programs in the middle school.

Following the background of the current STEM and STEAM renaissance in the country is an examination of the literature concerning the recruitment of students into STEM/STEAM education programs, and their retention in the programs once begun. Students become interested in STEM/STEAM education by exposure to relevant, engaging educational experiences, and student-centered, problem-based instruction (Milner, Horan, & Tracey, 2014; Reiss & Mujtaba, 2017; Sjaastad, 2011). They develop persistence, or grit (Duckworth, 2016), remaining in STEM/STEAM educational programs, when they are provided educational, emotional, and social supports, and mentoring.   When students develop an interest in STEM/STEAM education and the persistence to stay the course, they eventually become the STEM/STEAM "pipeline" of professionals joining the STEM/STEAM workforce.

Because of the student-centric, inquiry-based nature of the STEM/STEAM classroom, teaching in this environment can be a challenge. Building teacher self-efficacy, the confidence to facilitate the project-based learning integral to STEM and STEAM programs (Lesseig, Slavit, Nelson, & Seidel, 2016; Ferrara-Genao, 2015; van den Kieboom, McNew-Birren, Eckman, & Silver-Thorn, 2013), begins with professional education. The literature on professional development programs documents teacher certification programs for prospective teachers of science, technology, engineering, or math in our K-12 schools. The literature also describes summer workshops and intermittent professional development during the school year for current teachers engaged

17

in initiating and sustaining a STEM/STEAM program within their schools. The literature associates these professional development programs with the self-efficacy of the teachers necessary to facilitate meaningful and enriching STEM/STEAM learning.

To implement successfully, a STEM/STEAM program requires resource capacity (Ferrara-Genao, 2015), a sound curriculum, and effective instructional practices. The research literature explores these common measures of successful implementation of STEM and STEAM programs (Saxton et al., 2014, p. 30). The literature review also examines the addition of arts – performance art, creative art, and liberal arts – to the STEM program, transforming it into a STEAM program. All these elements found in the literature of successful STEM and STEAM programs - resource capacity, project-based curriculum, instructional best practices, and the inclusion of art and liberal arts – will inform the program evaluation of a middle school STEAM program.

One of the major themes found in the literature of STEM is the recruitment and sustainment of female and minority students into underrepresented STEM fields. These fields, including engineering, computer science, and physics, traditionally have low participation of female and minority students, both in the educational programs and in the professions (Cheryan, Ziegler, Montoya, & Jiang, 2017). The literature review discusses the characteristics of these educational programs, which are frequently adversarial to female and minority students, and what actions educators can take to encourage participation, promote self-efficacy, and build persistence. The inclusion of female and minority students in STEM professions is a stated goal of President Obama's "Educate to Innovate" campaign (Office of the Press Secretary, The White House,

18

2009). Consequently, supporting females and minorities in STEM/STEAM studies should be a conscious goal of a middle school STEM/STEAM program.

To develop a thorough and insightful program evaluation of a STEAM middle school, the literature review assesses the literature on the different paradigms of program evaluation. Following an assessment of the post-positivist, pragmatic, constructivist, and transformative forms of program evaluation, the review compares the various paradigms, introducing the concept of "methodological pluralism" suggested by Lawrence and Huffman (2006), and establishing the STEM Common Measurement System (Saxton et al., 2014) as a tool to organize the program evaluation.

The synthesis of the literature review begins with a brief restatement of the research on STEM/STEAM education, and how it relates to STEM/STEAM programs at the middle school level. Specifically, the literature emphasizes the elements of STEM/STEAM educational programs that should factor in the program evaluation of the middle school. These elements include student interest in STEM/STEAM, student self-efficacy, STEM/STEAM instructional components, student supports, and teacher efficacy.   The core of these elements are student interest, student self-efficacy, and teacher self-efficacy. These three elements of STEM/STEAM programs form the basis for the first three research questions. The fourth research question addresses the initial attraction of a STEM/STEAM program in potentially elevating student achievement, particularly in math and science.

This thorough review of the literature on STEM/STEAM programs and program evaluation introduces the subject of the methodology for the program evaluation, and its connection to the literature and best practices of STEM/STEAM education. Proposing a

www.manaraa.com

pragmatic, mixed-methods case study, the researcher worked with the middle school faculty to determine the best way to implement the evaluation and receive results that are meaningful for them and their students.

The Background of STEM/STEAM in the United States

In recognition of a rising need within the United States to educate and train greater numbers of scientists, engineers, mathematicians, and technologically proficient workers, the 110th Congress passed H.R. 2272, better known as the America Competes Act (2007). This legislation directed the Office of Science Technology Policy (OSTP) to determine the state of science, technology, engineering, and math (STEM) within the various government agencies (America Competes Act, 2007). This legislation, later reinforced by the STEM Education Coordination Act of 2009, gave direction to numerous federal agencies, including the National Science Foundation (NSF), the Department of Education, the National Aeronautics and Space Administration (NASA), The Department of Energy, the National Institute of Science and Technology (NIST), and the National Oceanic and Atmospheric Agency (NOAA). These pieces of legislation, under Presidents Bush and Obama respectively, authorized the OSTP to establish a committee to coordinate activities and programs of all federal agencies engaged in STEM education, develop a five-year strategic plan for STEM education, and maintain an inventory of federally sponsored STEM education programs. The legislation also authorized grant programs and teacher preparation programs and encouraged innovation in business enterprises. The purpose of the strategic plan is to establish annual and long-term goals, to publish common metrics among the multiple agencies engaged in STEM education, and to describe the various methods for each agency engaged in development

20

of STEM education programs (America Competes Act, 2007; STEM Education Coordination Act, 2009).   In 2015, the 115th Congress updated the definition of STEM education to include computer science and its various disciplines (H.Res. 1120, 2015).

In 2010, the President's Council of Advisors on Science and Technology (PCAST) produced a report to the president that summarized their findings in two conclusions (Executive Office of the President: PCAST, 2010). First, to improve STEM education, we must focus on the preparation of our students and their inspiration to pursue STEM careers. Second, historically the United States government has not had an integrated strategy, nor enough leadership, to pursue STEM education in the K-12 setting. The council also published seven recommendations, which included goals for recruiting and training 100,000 STEM educators by 2021, the recognition of the top 5% of STEM teachers as a STEM master teacher corps, and the creation of 1000 STEM-focused schools (200 high schools and 800 middle schools) by 2021.

In an interview with Popular Science near the end of his presidency, President Obama praised the STEM achievements of his administration, including the graduation of 25,000 more undergraduate-level engineers per year, the training of half of the 100,000 STEM-trained teachers by 2021, and over $1 billion in private investment in STEM education (Ransom, 2015). The end state for this increase in trained STEM professionals, STEM-trained teachers, and funding for STEM education is to keep the United States economically competitive in the world. To increase the STEM workforce and grow our economy begins with STEM education.

In a 2010 editorial, Bybee addressed the failure of recent STEM revivals, and his hope that the next decade can witness a rebirth of STEM education. He identified the

21

United States race to space with the Soviet Union in the late 1950s and 1960s as the first instance in which the United States successfully expanded the STEM workforce through its education programs. Since then, Bybee stated that attempts to revive STEM education have failed. His purpose in the editorial was to promote the current rebirth of STEM education and emphasize why it is important in our current economic conditions. He explained that true STEM education includes science and math, but also cannot neglect technology and engineering. He also emphasized that since engineering involves problem solving and innovation, it should be at the heart of STEM efforts, particularly before college. In current STEM programs in the K-12 "pipeline," the engineering design process is the methodology students use to research, design, develop, and review their projects (SREB, 2017).

One significant point Bybee (2010) made in his editorial is that the reauthorized Elementary and Secondary Education Act (ESEA) has unintentionally sidelined science education by not making science achievement a significant factor in determining Adequate Yearly Progress (AYP). This has created a disconnect (cognitive dissonance) between what we state as our priority – a STEM-educated citizenry – and what our measures of effectiveness indicate to be our priority. This disconnect continues today. Recently, the South Carolina legislature sent its proposal for school report cards to the Department of Education. In the proposal, South Carolina public schools will measure academic achievement and growth solely by student math and English Language Arts scores on standardized tests. This proposal complied with the 2015 reauthorization of the Elementary and Secondary Education Act, which requires states to measure academic achievement and growth based solely on reading and math test results (Every

Student Succeeds Act, 2015). Bybee wrote his editorial in 2010, with the hope that this disconnect between what we say we want and what we measure would be resolved. It has not.

According to a 2012 Congressional Research Service report (Gonzalez & Kuenzi), STEM education in the United States is in a flux, with conflicting reports of success and failure. For instance, between 2005 and 2012, Congress authorized four inventories of STEM programs, two by the Government Accounting Office (GAO), one by the Academic Competitiveness Council, (ACC), and one by the National Science and Technology Council (NSTC). These reports differed in the number of federal agencies they reported involved in STEM education, from the 105 agencies the ACC found in 2007, to the 252 "distinct investments" (Gonzalez & Kuenzi, 2012, p. 3) in STEM education the NSTC reported in 2012. Similarly, the amount of funding for federal STEM programs varied from $2.8 billion to $3.4 billion in these inventories. These funding figures fluctuated throughout this period, and varied in each year, depending on the source of the funding estimate. These discrepancies in number of programs and funding occurred in the various inventories because of "a lack of a common definition of what constitutes a STEM education program or activity" (Gonzalez & Kuenzi, p. 3). In his article on creating a vision for STEM in the country, Bybee (2010) asserted that defining what STEM education entails – its programs, policies, and curriculum – is the number one priority. This Congressional report affirms that conclusion, emphasizing governance concerns due to duplication of effort, lack of coordination among the federal agencies pursuing STEM education, the lack of a clear definition of STEM and the absence of a strategic plan.

During the period 2005-2012, the National Science Foundation (NSF), the Department of Education (DE), and Health and Human Services (HHS) received approximately 80% of federal funding for STEM education (Gonzalez & Kuenzi, 2012). The largest federal programs for STEM education were in these three agencies. First, in 2012, HHS awarded $274 million in institutional research grants through the Ruth L. Kirschstein National Research Service Awards. Second, the NSF awarded $198 million in graduate research fellowships. Third, the Department of Education awarded $150 million to state programs to improve student mathematics and science performance. These three programs, while receiving the greatest amount of funding for STEM education, also represented K-12 teacher training and graduate fellowships, which are the two major areas receiving federal funding.

In STEM performance, the Congressional report portrayed conflicting data (Gonzalez & Kuenzi, 2012). Between 1990 and 2011, U.S. K-12 student performance in science and math achievement increased; however, the achievement gaps between majority and minority remained. Similarly, although U.S. science and math achievement increased, U.S. students underperformed their first world international counterparts in math and science achievement. However, this may be a result of universal participation on achievement tests in the United States versus selective participation abroad. Minority and female participation in STEM undergraduate programs increased in the 1990's and 2000's, yet so has the foreign student enrollment in U.S. universities and the foreign student completion of U.S. doctoral programs. Additionally, the U.S. was not the leader in undergraduate STEM degrees, falling behind China and the European Union. It is within this conflicting picture of STEM education, that we examine a middle school

program conducting an integrated science, technology, engineering, arts, and mathematics (STEAM) curriculum.

Next, we will review the literature on recruiting students into the STEM/STEAM workforce. Specifically, we will focus on efforts to build student interest in STEM/STEAM education and professions.

<div align="center">**Recruiting Students into STEM/STEAM Professions**</div>

The primary goal of STEM education programs is the recruitment of students into the STEM workforce. This begins with engaging the interest of students to entice them into the STEM education "pipeline," and continues with developing student self-efficacy. Both these elements, interest, and self-efficacy, are the twin requirements for increasing the number of students who enter STEM/STEAM educational programs, persist in their studies, and graduate to become professionals in a STEM field. In this section, we examine programs that encourage students to engage in STEM/STEAM studies in high school and post-secondary studies and attempt to confirm the importance of interest and self-efficacy in STEM recruitment.

In a quasi-experimental study, Banerjee (2017) examined longitudinal data from the British national population database regarding the experience of informal STEM activities and the follow-on pursuit of STEM majors/careers. His research focus was to determine whether informal experiences with STEM education (field trips, STEM expert visits, hands-on activities) increased the inclusion of underrepresented groups in STEM majors and careers. His research group was the 2007 cohort of 11 to 16-year-old students in English secondary schools. Specifically, he asked, "Do young people sparsely represented in STEM courses such as those from a lower socioeconomic class and black

ethnic minority engage better with STEM subjects because of actively participating in these activities?" (Banerjee, 2017, p.202). He found that there is no conclusive evidence to support the contention that informal activities persuade students to pursue STEM education and professions.

This is significant because it apparently contradicts much of the literature on recruitment into STEM education and STEM careers. Banerjee (2017) acknowledges that his research does not establish causation for the findings and recommends further research. A potential avenue for further research would be to explore the difference between intensive, protracted STEM experiences, and the brief, informal activities described here. If brief, informal activities do not generate enduring student interest in STEM training and STEM careers, will more extensive, engaging experiences with STEM research and careers spark student interest in STEM?

In contrast to the previous focus on brief, interesting STEM experiences, in 2011 the computer science, biology, and biomedical informatics programs at the University of Pittsburgh established an 8-week summer outreach program for high school students interested in biomedical informatics (Dutta-Moscato, Gopalakrishnan, Lotze, & Becich, 2014). This protracted STEM educational opportunity included active research opportunities and mentoring of the students to create awareness and stimulate interest in informatics. The program developers attempted to distinguish their program from similar programs by providing "a mentored, hands-on primary research experience" (Dutta-Moscato et al., 2014, para. 2). The students worked in current research with a faculty mentor and presented their findings at the end of the program to the faculty and fellow

students. The intent of the program was to create a pipeline of the best and brightest high school students into the informatics program at the University of Pittsburgh.

The program developers tracked participation in the program over a five-year period in which it grew from three students to 56 students and changed its focus from attracting local participants to becoming an international academy. The significant component of the program was the inclusion of the students in current, viable research occurring at the university. This required extensive coordination and support from the participating colleges in the university but indicated the potential to create a healthy pipeline of applicants into the informatics program. Additionally, this participation in current, viable research demonstrated the dual capability to generate interest among the student participants in the field of informatics and build their sense of confidence in their ability to pursue and accomplish a program of study in informatics.

In the Bridging the Valley (BTV) program, a group of STEM departments from four universities in the Virginia Shenandoah Valley worked with the National Science Foundation to implement programs for recruiting and retaining STEM majors to their undergraduate programs (Kolvoord et al., 2016). The prominent aspects of the BTV program were summer workshops for prospective STEM majors, and collaborative learning communities on the college campuses during the school year. The inclusion of the collaborative learning communities distinguished the BTV program from the informatics summer workshops at the University of Pittsburgh because these communities targeted student self-efficacy and persistence. Additional components of the BTV program included assistance in identifying internships and employment, and faculty development, particularly in student-centered pedagogy and mentoring skills. In

this two-faceted approach, the intent of the summer workshops was to interest the students in STEM education, while the learning communities provided the assistance and support to enable the students to develop self-confidence and persistence.

The group conducted a pragmatic, mixed methods program evaluation of the summer bridge workshops and the collaborative learning communities. They analyzed data from student surveys, interviews with project leaders, focus groups, and pre- and post-assessment results from mathematics classes. The survey findings, collected over a four-year period, indicated student perceptions of self-efficacy, ability to persist in the academic program, and optimism of a future in a STEM profession were positively influenced by the program. Statistically, student enrollment in STEM majors at the participating universities increased over 50% from 2008 to 2013 (Kolvoord et al., 2016). Similarly, STEM retention in major increased for participants in the summer workshops and participants in the learning communities over the same period.

The BTV program operated because of a grant from the National Science Foundation. The researchers identified numerous institutional benefits of the program, including inter-university collaboration, flexibility in implementing the learning communities, and institutional commitment. It would be interesting to learn whether the collaboration and commitment of the participating colleges to a resource-intensive program continued after the grant lapsed. Additionally, this program, which combined activities to stimulate student engagement in STEM with activities to provide student academic, emotional, and social supports, is an example of a program that combined recruitment and retention initiatives. It would be worth an attempt at replication at other campuses and STEM education programs.

28

In a quantitative study of factors that determine interest and self-efficacy in STEM subject matter, Milner, Horan, and Tracey (2014) conducted two surveys with a volunteer 400-student sample at a Southwestern university. The first survey addressed student interest and self-efficacy in STEM career activities, while the second addressed interest and self-efficacy in STEM career titles. What statistical analysis of the surveys showed with reliability was that among the students who displayed an interest and self-efficacy in STEM subjects, that interest was broadly spread across the STEM subjects rather than on one specific field in STEM. This was also true for interest and self-efficacy towards STEM occupations.

This past year, Reiss and Mujtaba (2017) assessed two United Kingdom (UK) projects, the ASPIRES (named for student aspirations) project, and the Understanding Participation Rates in Post-16 Math and Physics (UPMAP) project. The purpose of these two projects was to determine why fewer UK students are choosing STEM educational programs and STEM professions. The results from both the ASPIRES and the UPMAP programs indicated that fewer students were choosing STEM educational programs and STEM professions; however, there are several factors that have a correlation with selecting a STEM pathway. Among the factors that positively influence selecting a STEM pathway are encouragement from parents and teachers, a sense that a STEM career is viable and beneficial, a demonstrated ability in a STEM field, and strong instruction in STEM education.

Following their analysis of the ASPIRES and UPMAP programs, Reiss and Mujtaba (2017) proposed and defended a series of propositions to embed STEM careers education within the STEM education program. The propositions included an emphasis

on student choice in career education, stressing the accessibility, availability, and usefulness of STEM careers rather than their importance. They also recommended that significant adults (parents and teachers) discuss STEM education and careers with students to encourage them. What is significant about this assessment of interest and self-efficacy in STEM, and the corresponding propositions for embedding STEM careers education in STEM education, is that it can be accomplished without launching a high dollar, technology-heavy recruitment program. If we teach our children of the accessibility, the availability, and the usefulness of STEM careers, while we are teaching those students the subject matter, we will have the opportunity to improve recruiting and retention in these fields. Naturally, this conclusion needs further research and validation, but it is worth exploring as we examine our options for growing the STEM workforce.

In a quantitative analysis of survey results from 25 of 26 Norwegian universities engaged in STEM education, Sjaastad (2012) examined influences on student choices of STEM education and STEM careers. He specifically attempted to identify sources of inspiration for the students now participating in STEM education pathways. The primary source of inspiration for these students was a significant adult, a parent or teacher, who influenced the student to pursue STEM education. The author categorized these sources of inspiration as "definers" (p. 1615). These definers serve several purposes for the prospective STEM students. First, they help students define the accessibility, the utility, and the purpose of STEM careers. And second, they model STEM-related careers, and facilitate student participation in activities that allow students to understand opportunities in STEM education and STEM professions. What is significant about this study is that it quantifies the influence of interpersonal relations in influencing students to choose STEM

30

education and STEM careers. Just as Reiss and Mujtaba (2017) emphasized STEM careers education on an interpersonal level, Sjaastad (2012) emphasized the importance of interpersonal relations with our "definers" to persuade students to follow the STEM pathway.

With the funding from a National Science Foundation grant, Subotnik, Tai, Rickoff, and Almarode (2009) began a three-year study of specialized STEM high schools. The purpose of their study was to determine if the participants in specialized STEM schools were more likely to enter STEM educational programs and STEM professions than their peers in public high schools. The research team also sought to identify those STEM educational practices more likely to result in the retention of students in the STEM educational "pipeline." They based their study on Bloom and Sosniak's (1985) theoretical framework, the talent development model. This theoretical framework is three-fold, beginning with recruitment and inspiration, followed by STEM education, and completed by mentoring, polishing, and staging for success.

In a separate article comparing self-efficacy of undergraduates who completed specialized STEM high schools with their peers from traditional high schools, Almarode et al. (2014) found that completers of specialized high schools were more than twice as likely to complete STEM undergraduate programs. While this certainly promotes the construction of specialized high schools and magnet schools, these schools require significant funding that is not always available. However, the initial research of the NSF group (Subotnik et al., 2009) does provide suggestions for the promotion of STEM in traditional public education. These practices include STEM skill development characterized by relevance, hands-on engagement, and effective pedagogical practices.

31

Additionally, schools can emphasize the importance and persistence of STEM-related products and practices in the workplace. They can also champion interpersonal relations with positive role models (teachers and parents) and peers who share their interest in STEM-related subjects.

Throughout the research on recruitment, several themes emerge. Establishing interest in STEM education and STEM careers begins with relevant, hands-on, educational experiences in the field. It can be fostered by mentoring and personal connections with STEM professionals, particularly parents and teachers. Persistence in a STEM educational pathway depends on student self-efficacy. Again, personal connections, in the form of mentoring, tutoring, and collaboration with peers, contribute to self-efficacy, enabling students to develop mental resilience and a belief in one's ability.

Once students become engaged in the STEM educational "pipeline" they require competent educators to provide the inquiry-based, student-centered, technology-driven instructional model. The next section discusses teacher preparation programs for pre-service teacher candidates, and professional development for in-service educators. These initiatives prepare teachers to provide STEM instruction in a student-centric, process-driven educational model.

Teacher Preparation

As discussed, one of the recommendations of President Obama's Council of Advisors in Science and Technology was the training of 100,000 STEM teachers by 2021 (Executive Office of the President: PCAST, 2010). This training refers to the pre-service training of teachers at university education programs. STEM teacher training at

universities occurs in content-specific programs, such as science or mathematics, or in programs designed to prepare teachers to teach integrated STEM curriculum to their students. Another form of training is the professional development in STEM implementation and best practices delivered to teachers in the field teaching a STEM subject, or in a STEM program. This section begins with a review of professional development programs for serving teachers, then transitions to pre-service, university teacher education programs. It will also review integrated STEM teacher programs, and isolated STEM discipline programs.

Professional Development

There are numerous programs offering professional development to serving teachers. One such program is the Enrichment Experiences in Engineering (E3) program at Texas A&M, a four-week summer enrichment program for high school STEM teachers, to indoctrinate them in engineering practices and instruction (Page, Lewis, Autenrieth, & Butler-Purry, 2013). The intent of the program is to prepare these teachers to return to their schools and integrate engineering practices into their core instruction. The proposed outcomes of the program are an increase in the professional knowledge of the teachers in the program, and an increased exposure of the teachers' students to the engineering profession and practices.

The researchers (Page et al., 2013) conducted a mixed methods evaluation of the program, conducting surveys of the participating teachers, and analyzing the narrative comments attached to the surveys. In the surveys, the teachers indicated a positive gain in professional development, a willingness to implement engineering practices in their classrooms, and the intention to promote the engineering fields to their students. It would

33

be worthwhile to follow up with the participating teachers and their students to determine the extent to which the teachers integrated engineering practices in their classrooms, and the impact of exposure to the engineering fields on their students.

In another case study of a teacher's workshop, Avery and Reeve (2013) discussed the results of their qualitative study of workshops conducted by the National Center for Engineering and Technology Education (NCETE). NCETE designed and conducted five 8-hour long workshops during the summer to build capacity of in-service teachers in the engineering design process, and best practices for teaching the process. In their study, conducted two years after the 2006 workshops, Avery and Reeve followed up with four of the seven participants of the workshops, conducting interviews, analysis of teacher documents, and classroom observations. For various reasons, the other three participants in the NCETE training were unavailable for the study. Their purpose was to determine the influence of the program on teachers' integration of the engineering design process in their instructional practices, challenges to the implementation, and the benefits of integrating the engineering design process in STEM instruction.

Based on their analysis of data, Avery and Reeve (2013) determined that, despite challenges faced in implementation, the engineering design workshops had a beneficial impact on classroom instruction, student engagement, and teacher knowledge and skills. It is significant that in their reflections, the teachers involved in the workshops indicated a need for further professional development on instructional practices, curriculum development, and assessment/project development. This indicates that regardless of when the teachers receive professional development on STEM curriculum

34

and instructional practices, professional development should continue throughout the teachers' tenure as a teacher of STEM subject matter.

Preservice Training

Pre-service training refers to the teacher education programs sponsored by colleges and universities for potential K-12 STEM teachers. Traditionally, teacher education programs contain content-specific courses, in areas such as mathematics, biology, history, or literature, and teacher preparation courses. The teacher preparation courses contain generic instruction on instructional practices, classroom management, and assessment. These programs may combine content and pedagogy in a course, such as a course in secondary math instruction, but this integration of content and instruction is usually reserved for a capstone semester each education student spends in a local classroom. This semester, referred to as student teaching, scaffolds the student teacher from classroom observation through planning, instruction, and assessment of students in an active school.

In pre-service programs for STEM teachers, the implementing colleges and universities eliminate, or greatly reduce, this separation of content and pedagogy. Students in these programs spend a significant portion of their program learning to teach STEM subjects in the classroom. These programs either train teachers to become teachers in integrated K-12 STEM programs, or they focus on training science or math teachers in best practices in instruction and assessment.

Integrated STEM teacher training programs. STEM education programs implement an instructional approach in which the students work together using the engineering design process to research, analyze, solve, and communicate solutions to

open-ended problems that span multiple content areas (SREB, 2017). In this paradigm, the teacher becomes a facilitator for the student work groups less interested in content area instruction than in guiding the students through the engineering design process. This section of the literature review discusses teacher education programs that prepare teachers to teach in schools with integrated STEM curriculum. While students in these programs may earn a certification in a single content area, such as high school science or middle school mathematics, the purpose of integrated STEM teacher training is participation in STEM education programs.

In their article, Burrows and Slater (2015) discussed a theoretical framework for preparing STEM teachers for the field that focuses on teaching STEM content as integrated cross-curricular material. In this framework, the providers merge the STEM fields together instead of teaching each academic component in isolation. Burrows and Slater referred to their conceptual model of integrated STEM instruction as iSTEM. The iSTEM model partners with the Next Generation Science Standards (NGSS), adopted in 2013. In the NGSS model, there are three dimensions: practices, cross-cutting concepts, and disciplinary core ideas. These correlate to the scientific and engineering practices found in STEM, the synergy gained by integrating the multiple disciplines, and the core principles of the individual fields.

The iSTEM framework (Burrows & Slater, 2015) is a circular, tiered model with single disciplines at the outer circle, combining disciplines as it moves inward. The inner circle of the framework is continuous STEM integration. Figure 2.1 illustrates the model.

Level Four: Constant STEM Integration

Level Three: Engineering Projects

Level Two: Multiple Disciplines

Level One: Discipline plus Mathematics*

Level Zero: Single Discipline
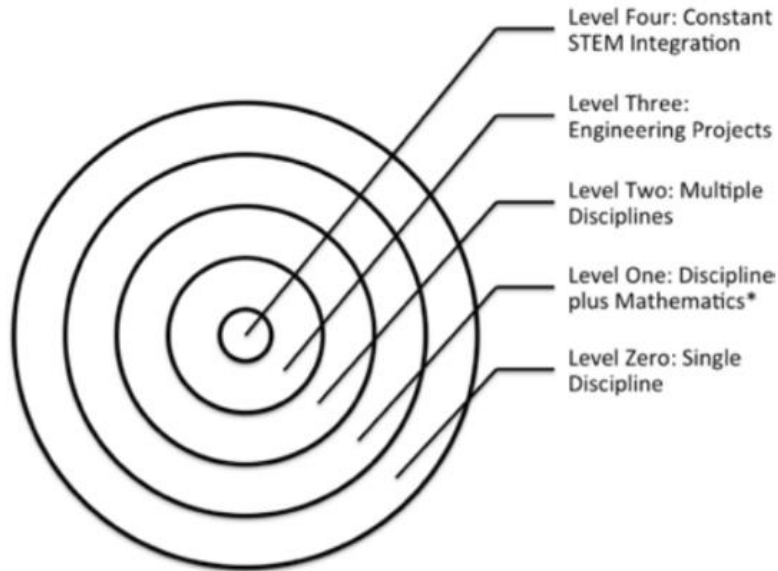
Figure 2.1 iSTEM framework of tiered integration of STEM disciplines (Burrows & Slater, 2015, p. 324)

In a qualitative case study of the Robert Noyce Teacher Scholarship, van den Kieboom et al. (2013) described the integrated STEM teacher preparation program at Marquette University. The underlying tenets of the program were integrated content knowledge, instructional practices, and content-specific teaching knowledge and skill. The program accomplished this by immersing teacher candidates in a series of cooperative teaching experiences. Through the analysis of participant reflections on their experiences in the program, the authors assessed the effectiveness of the program. The authors acknowledged that they do not have the data to make confident conjectures about replication of the program, the ability to scale the program to access larger numbers of participants, nor the ability to recruit sufficient numbers to a scaled program to meet the needs of STEM teachers in the U.S. These are valid concerns. Additionally, program implementers might consider the ability to provide student supports, such as academic assistance, mentoring, and placement services, which are components of currently successful STEM teacher preparation programs.

In his article, Sanders (2009) described the integrated STEM teacher preparation program at Virginia Tech. The Virginia Tech program focused on "purposeful design and inquiry" (p. 21). The project-based learning in the program requires the integration of science, math, and engineering into the solution of the problem, rather than the isolated application of each field in turn. The program's tenets come from cognitive learning theory, which depicts learning as constructed knowledge. In this model, constructing meaning requires motivation and social interaction. Additionally, all learning should be contextual and relevant. The outcome of this STEM educational model is the technological literacy of the student, grounded in an integrated knowledge of STEM disciplines.

Integrated pre-service teacher preparation programs rely on relevant, hands-on instructional experiences involving the integration of all the STEM disciplines. They also provide the teacher candidate with thorough content area knowledge, and instruction on best practices for teaching all subjects. The next teacher preparation programs are those in which the teachers achieve certification in a single STEM discipline.

Isolated STEM teacher preparation programs. Traditionally, teacher education programs prepare students to become teachers of a single content area, usually combining content area knowledge and instructional practices toward the completion of the certification program. In isolated STEM teacher preparation programs, students also earn a single certification, typically in science or math. However, these programs immerse the students in the content area instruction of their discipline throughout the program, often including multiple rotations in classrooms as active teachers (King,

Lancaster, Defrance, & Cleveland, 2013; Schuster et al., 2012; Perez & Romero, 2014). This section illustrates these programs.

According to King et al. (2013), the teacher preparation curriculum developed by the Woodrow Wilson Teacher Fellowship program among six Michigan universities focuses on preparing subject matter experts in one of the STEM fields to become classroom teachers. This 15-month program is for students who have received their degree in one of the STEM disciplines. Each course in the program requires what the program developers describe as a "rotation" (p. 709) in an active classroom as a teacher candidate. These rotations include emphasis on classroom management, integrating curriculum, instruction, assessment, diversity, and discipline-specific literacy. The rotations conclude with student reflection on their experience and a plan for going forward.

The core of the instructional model the teacher-candidates learn in the Woodrow Wilson Teacher Fellowship program is the universal design for learning (UDL). The UDL framework is an instructional model used by special educators that emphasizes using multiple means of presentation, multiple types of activities and engagement practices, and multiple strategies for instruction (Burgstahler, 2012). It has been adopted by numerous STEM programs (Lam, Doverspike, Zhao, Zhe, & Menzemer, 2008; Basham & Marino, 2013) and its characteristics are a staple of STEM education programs. Additional characteristics of the fellowship program include classroom management, student engagement and love for the discipline, and developing student-centered classrooms that utilize technology, hands-on activities, and cross-disciplinary learning. What is significant about the Woodrow Wilson Fellowship Program (King et

39

al., 2013) is the inclusion of the rotations in actual classrooms during each course in the program. Essentially, the teacher-candidates practice their craft in a focused manner as they learn it.

In their article on STEM teacher certification, Schuster et al. (2012) discussed the hybrid STEM teacher certification program that they have created at the University of Indiana, in cooperation with the Woodrow Wilson Fellowship program. In the spectrum of teacher certification, most STEM certification programs either require full participation in an on-site, university-based program, or alternative certification through the state. The program at the University of Indiana consists of elements of both certification routes and lies in the middle of the spectrum. There are four facets to this hybrid program.

First, STEM discipline majors can work together with a cooperating teacher in a school setting in a mentor-mentee relationship, the teacher candidate eventually transitioning into the role of teacher. Second, induction STEM teachers can access university resources during their first year in the classroom. Third, new STEM teachers can participate in ongoing professional development through the university during their initial years in teaching. Fourth, induction teachers continue to work with their mentor teachers to plan lessons and co-teach.

Schuster and his fellow researchers (2012) acknowledged that they do not have longitudinal data indicating the retention of participants in the hybrid certification process. However, the concept of providing ongoing supports to STEM majors is one which has proven to be effective in the persistence of female and minority students in the STEM pipeline (Museus & Liverman, 2010; Museus, Palmer, Davis, & Maramba,

2011). It is worth collecting data on retention in the profession, self-efficacy, and persistence of the participants in this hybrid program to see whether it merits continuance.

The UTeach program at the University of Texas (UT) Austin is a nationally recognized STEM teacher preparation program (Perez & Romero, 2014). Because of its recognition and demonstrated effectiveness in preparing teachers who practice STEM principles and receive positive results with students, it has become an education program which other universities replicate. In their review of replication of the UTeach program as a strategic initiative, Perez and Romero (2014) discussed the process and its implications for producing significant quantities of STEM teachers in a short period of time. This growth in the number of STEM-trained teachers follows the guidance from the America Competes Act (2007) and the Obama administration's "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009).

Perez and Romero (2014) addressed a trend in out-of-area teachers assigned to teach STEM classes, emphasizing the nationwide shortage of STEM teachers. In a National Center for Educational Statistics report, Hill and Gruber (2011, p.14) presented statistics for teachers' certification in their main area of assignment during the 2007-2008 school year. The statistics indicated that 27.5% of math teachers had not majored in mathematics, while 16% of science teachers had not majored in science. In response to this shortage of STEM teachers trained in their discipline, the UTeach program is a four-year program that awards a teaching degree in a STEM discipline, and a degree in that STEM discipline. The program combines active recruitment of STEM majors, institutional and community support, dedicated master teachers, hands-on, relevant, field

41

experiences in the STEM disciplines, instruction in best teaching practices, and extensive student supports, including mentoring, internships, and scholarships.

As of 2016, 44 universities in 21 states were replicating the UTeach curriculum (Backes, Goldhaber, Cade, Sullivan, & Dodson, 2016). In their quantitative evaluation of the UTeach program, Backes et al. (2016) found that the students of UTeach-trained teachers performed significantly better statistically on end of course tests than students of teachers trained in other educational programs. Additionally, the students of UTeach graduates learned more content knowledge in high school math (4 months more knowledge) and high school science (5.7 months more knowledge) than students not taught by UTeach graduates (Backes et al., 2016). Students of UTeach graduates from schools other than the UT Austin performed slightly worse than students of UT Austin graduates; however, students learning from UTeach graduates at any university performed better overall than their counterparts.

What is significant about the UTeach program is the success that it has had in replication of the curriculum. The principles that the UTeach program has implemented to sustain this success are a "clear articulation of program elements … comprehensive planning with qualified sites, intensive implementation support, and ongoing evaluations of progress" (Perez & Romero, 2014, p. 26). If the UT Austin community can continue this success in replication, then the program has the possibility of becoming a framework for STEM teacher preparation programs nationwide. Currently, there are numerous teacher preparation programs in the country, and most share many of the same elements. However, there is no consistent, national standard for STEM teacher preparation. The UTeach program has the potential to become this national standard.

In all the professional development and teacher certification programs, there is a common element. All training programs for STEM teachers contain abundant opportunities to participate in relevant, hands-on activities in STEM disciplines. These opportunities for building interest and self-efficacy occur in teacher workshops, in pre-service teacher classrooms, and in field experiences in actual classrooms. Other elements found in many of the programs include reflection on learning experiences, student supports, and instruction in the content knowledge of the STEM disciplines, the engineering design process, and effective pedagogy. All the elements found in effective teacher training programs can be found in actual STEM/STEAM classrooms. Implementation of the elements of effective STEM/STEAM instruction in K-12 is the topic of the next section.

STEM/STEAM Implementation

The implementation of an integrated program of science, technology, engineering, and mathematics (STEM) education within a school or school system is a resource intensive endeavor that requires the commitment of administration, faculty, students, and the community. In this section, we will discuss the resources required for STEM implementation, the characteristics of STEM education, and the addition of arts, both traditional art and liberal arts, to STEM programs, making them STEAM programs. From a resource's perspective, STEM programs require enough funding to adequately initiate and sustain them. They also require suitable curriculum, adjustments to school scheduling, and the space and equipment to implement relevant, hands-on, resource-intensive activities. As noted in the previous section, the teachers who implement STEM programs require intensive ongoing professional development.

43

The characteristics of a STEM curriculum include inquiry-based, student-centered instruction that has the students working on relevant, engaging, technology-driven activities and projects. These activities, focused on the solutions to real-world problems, require the students to collaborate with each other and communicate their results, verbally and in writing, to their audience. STEAM programs add the arts, traditional and liberal, to the STEM curriculum, either as an integrated, equivalent discipline with the other disciplines, or as a valuable addition, useful for the creativity and communication inherent in the arts.

Traditional STEM Program Implementation

STEM education is not new. As Bybee (2010) noted in his editorial on the renaissance of STEM education, the most recent iteration of STEM education occurred in the 1960s when the United States needed scientists and engineers to support the race to space with the Soviet Union. This national recommitment to producing scientists, engineers, mathematicians, and computer scientists formalized in the America Competes Act (2007) and the Obama Administration's "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009) provides a new twist to an old formula. In the past, STEM education was stove piped by discipline. Students learned science, math, and engineering in their respective classrooms, with little cross-over between disciplines. In the current revival of STEM education, the emphasis, at least in the K-12 programs, is on integrated STEM education, in which cross-curricular, project-based learning is the norm. This framework for STEM education begins with a shared definition of STEM education, and a vision for STEM implementation.

Overarching vision for STEM implementation. In his article on a vision for STEM implementation, Bybee (2010) proposed a 10-year action plan for STEM definition, development, construction of national, state, and local platforms, and sustainment. According to Bybee, this vision can be implemented in five steps, beginning with the definition of "STEM," in terms of "policies, programs, and practices" in the educational arena (Bybee, 2010, p. 30). The second step is the increased use and integration of technology in the implementation of curriculum. The third step is the increased recognition of the engineering design process in educational programs.

The fourth step is the integration of STEM curriculum and instruction with 21st century skills. In South Carolina, 21st century skills are enumerated in the "Profile of the South Carolina Graduate," published by the South Carolina Education Oversight Committee (2017). These skills include creativity and innovation, critical thinking and problem solving, collaboration, communication, technology use, and learning how to learn. The profile also elaborates the desired characteristics of its graduates, notably including perseverance. One characteristic that continually emerges in the research on STEM implementation is persistence or perseverance. Students in STEM programs, particularly students from underrepresented populations, must develop the fortitude, or "grit," to persevere in the face of adversity (Duckworth, 2016). Developing grit is intrinsic to the development of self-efficacy, which is a goal for STEM/STEAM program implementation.

The fifth step in establishing the vision for STEM is the development of STEM curriculum (Bybee, 2010). This involves clarifying the purpose for STEM, identifying the challenges to STEM implementation, and establishing the contexts for STEM in the

45

real world. The development of the actual curriculum will occur over a 10-year period of initiation, implementation, and sustainment, supported by continuous self-evaluation and adaptation.

The significance of Bybee's (2010) vision for STEM implementation by 2020 is that it provides an overarching set of strategies for creating national, state, and local STEM programs that have a common definition and operational terms. House Resolution 1709, the STEM Education Coordination Act of 2009, directed the Office of Science and Technology Policy (OSTP) to develop of a 5-year strategic plan for STEM education. It also directed the OSTP to coordinate all federal agencies and activities involving STEM education. Although his vision spanned a 10-year period, Bybee (2010) established a framework for building and coordinating a national STEM infrastructure that meets the OSTP's requirement for developing a national STEM strategy. With a common definition of STEM education, and a shared vision for implementation, educators can begin assembling the components of a STEM program.

Components of a STEM program. Within the overarching framework for STEM education lie the components for program implementation. This begins with the method, or pedagogy, for STEM instruction. In an article on Integrative STEM education (I-STEM ED), Wells (2016) proposed the use of the engineering design process and student-centered, relevant instructional practices. The vehicle for I-STEM ED is the PIRPOSAL model, which stands for problem identification, ideation, research, potential solutions, optimization, solution evaluation, alterations, and learned outcomes. I-STEM ED is a potentially effective, but untested, vehicle for implementing STEM education in schools. What is significant about the model is its purposeful integration of the different

STEM disciplines. This cross-curricular integration is a hallmark of STEM programs and an important factor in implementing a student-centered, relevant, and technologically driven education program.

McNally (2012) opened a reflective essay on improving science literacy among our middle and high school students by questioning whether we should focus our efforts on our high achievers or spread our efforts to all students. After some discussion, he settled on the approach that we need to change our instructional approaches to science instruction for all students, as early as middle school, so that the students can make an informed decision whether science intrigues them. He outlined a set of guidelines for developing and implementing science instruction that engages our youth.

These guidelines include linking new information to prior knowledge, making instruction relevant by establishing context, and using multiple representations to communicate information to the students. Using multiple representations and multiple media to communicate information is also a hallmark of the universal design for learning (UDL), a framework developed for special education but often cited by STEM education programs (Burgstahler, 2012). McNally (2012) also advocated applying recently learned scientific knowledge in new and relevant contexts, and engaging students in the construction of arguments and explanations. As stated, the guidelines McNally outlined intuitively make sense, and form many of the characteristics found in STEM education programs. It would be interesting to put them to the test as a conceptual framework in actual science classrooms to see if they can make the transition from theoretical construct to practical application.

In a qualitative case study of successful STEM implementation in three California middle schools, Ferrara-Genao (2015) discussed the key factors to successful implementation of a STEM program from a principal's perspective. Her method was to conduct extensive interviews with three middle school principals and classroom observations of nine STEM classrooms in the three schools. All three schools implemented the Project Lead the Way (PLTW) curriculum. In her interviews and observations, she found factors common to all three of the STEM programs.

In each of the schools, the principals and faculty were firmly committed to STEM education for all students in their schools. The author characterized the principals as "transformational," emphasizing their program knowledge, passion, and ability to inspire their stakeholders (Ferrara-Genao, 2015, p. 128). Additionally, the faculty in each of the schools recognized the need for continuous professional development in STEM implementation.

From a logistical perspective, all three principals recognized the importance of gaining support from the community, marketing their program extensively. Similarly, all three principals identified program funding as an ongoing issue (Ferrara-Genao, 2015). Essentially, when the principals secured a funding source, they were already seeking their next source. In this matter, all the principals recognized the importance of a supportive school district and the necessity of thrift. In terms of curriculum, each principal supported a national curriculum; however, none of their programs were similar. Each school tailored its program to the needs of its student body, the strengths and interests of its faculty, and the personality of the community in which the school resided.

While researching STEAM schools, Herro and Quigley (2016) found three different models for STEM or STEAM implementation. These models included: a school based on the STEM or STEAM paradigm, a school in which STEM/STEAM lessons were inserted in a traditional school model, and a third setting in which schools participated in STEAM-based activities. Similarly, in her research Ferrara-Genao (2015) observed differing structures for implementation. However, regardless of the model for STEM or STEAM implementation, each school used collaboration, project-based learning, and extensive application of technology. The instructional strategies in each school were evident of pedagogy common to STEM programs, involving inquiry-based learning and student-centered classrooms. The projects the students worked on were alike in their relevance and the interest they sparked within the students.

In each of these STEM programs, common components included the engineering design process, project-based learning, relevant assignments, and extensive application of technology. Students collaborated and communicated their results in a variety of media. These programs required extensive and ongoing professional development of faculty, and support from the community and the school district. The end state of this approach to education is students who are passionate about STEM disciplines, and who develop a sense of self-efficacy in STEM course work. Self-efficacy derives from student competence in STEM subject matter, and perseverance in the face of intellectually challenging subject matter and potentially adverse educational climates.

Persistence. One of the components of student self-efficacy is developing persistence. Students in the K-12 STEM "pipeline" must develop the wherewithal to pursue and successfully complete STEM courses in middle and high

49

schools. Unfortunately, there is little research at developing student resilience at the middle and high school. However, there is research on developing student resilience at the undergraduate and graduate level.

Most college programs with a high degree of follow-on employment in lucrative professions have large student participation and completion. STEM majors do not follow this trend, with low numbers of entrants and a high percentage of dropouts, particularly among women and underrepresented minorities (Sithole et al., 2017). A contributing factor to this continuing shortage of STEM entrants and completers is incoming freshmen who struggle with mathematics. Continued low performance in science and math of our K-12 students supports this conjecture.

Sithole et al. (2017) discussed the factors contributing to low entrance rates and high attrition in STEM programs at the undergraduate level in an extensive review of STEM literature. To recruit STEM majors and assist in developing resilience, Sithole et al. recommended orientation programs for students entering STEM programs, and early warning systems to alert the colleges of students in danger of dropping a STEM program.

Sithole et al. (2017) also recommended faculty professional development and extensive faculty interaction with students in their programs. Essentially, college professors need to become educators who engage their students in and out of the classrooms, as tutors, role models, and mentors. This is particularly important in the retention of females and underrepresented minorities. In their research on faculty mentoring of minorities, Griffin, Perez, Holmes, and Mayo (2010) stressed the

importance of professors serving as role models and mentors for their students to help them develop self-efficacy and resilience.

Finally, Sithole et al. (2017) recommended developing campus outreach programs to attract high school students to STEM programs and establishing learning communities for them to get the academic and social supports they will need to persist in a STEM program. In their summer outreach program with Ohio high school students, Zhe, Doverspike, Zhao, Lam, and Menzemer (2010) exemplified the relevant, inquiry-based, technology-driven, student-centered learning designed to spark interest in potential STEM majors.

In order to spark interest among prospective students, Sithole et al. (2017) emphasized that an array of changes was necessary in universities to attract and retain STEM majors. College professors must transition from their traditional roles as academics focused solely on research, to become educators who engage their students with relevant, hands-on projects, and student-centered instruction. This engagement must occur within the classroom, and outside of the classroom, as the universities establish the supports needed to help their students develop persistence and self-efficacy. Extrapolating this focus on retention from college STEM programs to K-12 STEM programs, K-12 STEM programs must also develop the supports – academic, emotional, and social – to grow and retain the future STEM professionals in their care. These changes must occur in our curriculum, in our pedagogy, and in our approach to engaging our students, both within and outside of the classroom.

Academic achievement. One of the expected results of the implementation of a STEM curriculum is student improvement in science and math achievement. McDonald

(2016) indicated that the empirical studies of STEM education and its correlation with academic achievement have had mixed results. What is interesting about this finding is that it provides a shortsighted reason to not implement a STEM program. In short, the considerable costs incurred in the implementation of a STEM program may overwhelm the commitment of a faculty if the academic achievement of the students is uncertain. What is overlooked with this observation is the long-term goal of a STEM program. This long-term goal is the increase in the workforce of scientists, computer scientists, engineers of all flavors, and mathematicians inspired by their participation in STEM curriculum. This will occur through student interest and engagement in STEM content, their sense of self-confidence in their ability to master the material, and their resilience. Actual academic achievement may or may not play a role in this process.

Fortunately, the studies do indicate that students who engage in inquiry-based learning and the scientific method generally have a greater motivation and interest in science. Additionally, McDonald (2016) noted the teacher's role in STEM education. While the academic achievement of students in STEM programs is not guaranteed, teachers who do successfully implement a STEM curriculum do have a positive influence on student achievement. Improving student engagement in integrated STEM programs can reverse a downward trend in student enrollment in math and science education.

According to McDonald (2016), and the other proponents of STEM education, the best pedagogical practices for STEM education include problem-based learning, argumentation and reasoning, digital learning, and computer programming and robotics. In terms of student supports, teacher academic assistance and mentoring

influence student competence, positive outlook, self-efficacy, and resilience. Finally, ongoing faculty professional development is critical in developing the skills to implement and sustain a STEM curriculum. These elements also factor in the success of STEM programs that integrate art, and liberal arts, in their cross-curricular endeavors.

STEAM Program Implementation

In recent years, there has been a trend in STEM education to add arts, both traditional art and liberal arts, to the curriculum, creating a STEAM program. This hybrid of the STEM curriculum presents its own challenges, and hopefully, benefits. The next portion of this section addresses STEAM program implementation.

In a theoretical paper, English (2017) proposed the integration of arts into STEM education, making a STEAM model. This is a relatively recent adaptation of traditional STEM education, without significant research and supporting assessment data, but early data is promising. In English's proposal, he maintained the equitable representation of all the disciplines, including arts, in the curriculum. The challenges for this new curriculum are numerous; however, the insertion of arts within the STEM arena adds creativity to the structure of these fields. It also creates opportunities for engaging underrepresented populations, such as female and minority students, who have shied away from the discipline and structure of science, technology, engineering, and mathematics. In a sense, STEAM softens the hard edges of the STEM fields.

As noted, adding the arts to integrated STEM programs is a relatively new twist on the cross-curricular model of education, effectively creating a STEAM paradigm. Realizing there is little data to support this trend in education, Herro and Quigley (2016) conducted a multi-year, mixed methods program evaluation of 14 middle

schools in the southeastern United States that are implementing STEAM programs. After analyzing the data from the programs, the authors focused on three teachers, conducting an intensive, qualitative case study.

From the data of the 14 programs, Herro and Quigley (2016) determined that teachers found mixing disciplines - transdisciplinary - to be difficult; however, using the problem-based approach and facilitative technologies eased this difficulty. Additionally, the teachers realized that inserting the arts into a STEM program required the expertise and involvement of arts and liberal arts teachers. The participating teachers also stated that an intensive one-week professional development prior to implementing the STEAM program was insufficient. Initial and ongoing professional development is necessary to provide teachers a base set of skills, and then to continue honing them as they continue through the life of the program.

When they focused on three teachers implementing STEAM education, Herro and Quigley (2016) studied three different versions of STEAM: a school based on the STEAM paradigm, a school in which STEAM lessons were inserted in a traditional school model, and a third setting in which the school participated in STEAM-based activities. Based on teacher reflections, Herro and Quigley found that while schools are still transitioning from traditional educational models to the STEAM educational model, it is best to mix traditional educational practices (direct instruction, guided practice, checks for understanding, and so forth) with the problem-based learning of the inquiry-model. In all the cases, the teachers attempted to promote collaboration and hands-on, relevant, technologically enhanced projects. However, these efforts were modified by the

realities of traditional standards and curriculum, class schedules, and high-stakes standardized testing.

One of the primary purposes for the inclusion of arts in STEM is to make STEM more attractive to female and minority students. Female and minority students are under-represented in several of the STEM disciplines, including physics, engineering, and computer science (Cheryan et al., 2017). In a theoretical paper, Quigley, Herro, and Jamil (2017) proposed a theoretical framework for the inclusion of liberal arts in a STEM program. Their proposal creates an organic, integrated STEAM model, in which the arts embed within the whole, an equal partner with science, technology, engineering, and math. This is a new direction for the STEAM model, contrary to the prevalent view in which arts are simply an add-on to the STEM curriculum.

Quigley et al. (2017) proposed two components to their conceptual model. The components are instructional content and learning context. The instructional content of STEAM involves problem-based instruction with discipline integration. The instructional content of the model requires problem-solving skills, which exercise the cognitive, interactional, and creative abilities of the students. The learning context contains three facets, beginning with instructional strategies that encompass inquiry, multiple domains, and technology integration. The second facet of the learning context is assessment practices that require authentic alignment of standards, data driven instruments, student reflection, and adjustment of the instruments based on data. The third facet of the learning context is equitable participation, which encourages student choice, recognition of student diversity, and relevance of the learning context.

As research on the integrated STEAM model continues, it will be worthwhile to learn of STEAM programs that have successfully implemented this version of the integrated STEAM model. At this stage, an integrated STEAM framework is a theoretical construct. As STEAM grows and adapts, it will be interesting to see if this framework of STEAM education perseveres or is replaced by other models.

In an article on the debate over adding the arts to the STEM educational paradigm, Jolly (2014) acknowledged there is opposition from both engineers and artists. Engineers do not deny that art, and the liberal arts, belong in STEM endeavors, at least incidentally. However, they have concerns that the inclusion of arts and liberal arts in STEM education might dilute the technical aspects of STEM. Similarly, proponents of the arts understand that while the arts may sometimes use technology and engineering, including arts in the STEM disciplines devalues the primacy of the arts and liberal arts.

While acknowledging the debate, Jolly (2016) proposed that art, and liberal arts, does have a role in STEM education. The arts contribute to the design of STEM projects and the creativity required to develop "out-of-the-box" solutions to problems with no straight-forward solutions. Additionally, in the communication aspect of STEM projects, the liberal and performing arts are a natural fit. Writing, speaking, and presenting are all components of a project proposal.

In terms of STEAM models, Jolly (2017) did not propose an integrated model in which the arts are an equal partner in the program. Unlike Quigley et al. (2017), who proposed a model in which the arts education serves as an equal and active partner with the STEM disciplines, Jolly's approach (2017) is more a STEM-plus-arts model. As STEAM programs attempt to gain credibility and collect evidence of their impact on

56

student learning and participation in further STEM education and STEM professions, it will be interesting to discover which model prevails.

STEM and STEAM programs require vision, starting with a common definition and common understanding of what STEM/STEAM entails (Bybee, 2010). Following the establishment of a common definition, STEM/STEAM programs require an integrated, interdisciplinary curriculum that emphasizes inquiry-based learning, and hands-on, relevant, technology-intensive activities. STEM/STEAM programs should include student supports, academic, social, and emotional. Additionally, STEM/STEAM programs need focused leaders and dedicated faculty (Ferrara-Genao, 2015), and their professional development must be ongoing. Finally, STEM/STEAM programs require initial and continuing funding, and support from outside agencies, including the school district.

Having established recruiting and implementation practices for STEM/STEAM programs, the next section addresses the inclusion of female and minority students in STEM/STEAM programs. The inclusion of female and minority students in STEM is a goal of the "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009), and an implied goal of all K-12 STEM/STEAM programs. Developing and nurturing student resilience is a critical factor in these efforts to recruit, educate, and retain these underrepresented populations.

Underrepresented Participation in STEM/STEAM

Two populations that are under-represented in the fields of science, technology, engineering, and math are females and ethnic minorities. The addition of these populations to the STEM professional workforce is an implicit goal of STEM

programs. In its 2009 "Educate to Innovate" campaign, the Obama administration acknowledged this deficiency. Specifically, the official press release included in its three overarching priorities the expansion of "STEM education and career opportunities for underrepresented groups, including female and minority students" (Office of the Press Secretary, The White House, 2009, para. 6). This will occur only through the deliberate recruitment of these populations and their inclusion in STEM programs at K-12, undergraduate, and graduate levels. This section discusses successful efforts at the recruitment and inclusion of female and minority students in STEM programs, and in individual science, technology, engineering, or math programs.

Females in STEM/STEAM

A decade after the kick start into STEM education inspired by the America Competes Act (2007) and the Obama administration's "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009), females in STEM fields remain underrepresented in some fields, and paid less than males across the board. Buffington, Cerf, Jones, and Weinburg (2016) found discrepancies in employment and pay for females in their 10-year, quantitative study of four universities with federally funded research grants in STEM fields. Studying the records of the research grants, 2010 census data, and W-2 records of employees, Buffington et al. concluded that women earn 31% less than men in science, but 11% less when controlling for field of study and funding source. Women were also more inclined to participate in certain STEM fields than others, achieving parity with men in biological sciences, mathematics, statistics, and chemistry, but falling behind in physics, computer science, and engineering (Cheryan et

al., 2017). A final finding of the study was that women graduating STEM programs have a greater inclination to enter academia than industry.

Statistics from the National Women's Law Center (National Coalition for Women and Girls in Education, 2008, p. 22) indicated that females represent less than 10% in vocational fields, such as heating, ventilation, and air conditioning (HVAC), welding, electricity, plumbing, and automotive. In contrast, females make up over 85% of participants in cosmetology, childcare, and health-related fields. Significantly, these male-dominated fields have higher wages than traditionally female fields of employment.

In a review of literature for the period 2007-2017, Blackburn (2017) discussed recruitment, retention, and barriers for females entering the STEM fields in higher education. This review also explored stereotypes, biases, campus culture, classroom experiences, self-efficacy, and sense of belonging of females in STEM education programs.

The factors contributing to the shortage of females in STEM education included social pressures, inadequate structure to support female recruitment and participation in STEM programs, and early education experiences that either failed to inspire girls or actively repressed them. As the author (Blackburn, 2017) discussed recruitment efforts, she also noted that few higher educational programs make a retention effort once females have entered their program. This is significant because it shines a spotlight on an aspect of female participation in STEM programs that is not addressed frequently in the literature, nor in the actual practice of the STEM programs. It suggests that efforts at attracting females, minorities, and the handicapped should not only focus on the recruitment of

these groups, but that focus should shift to retention of female recruits throughout the educational programs and into the STEM workforce.

In her discussion of the challenge's females face once they have entered STEM educational programs, Blackburn (2017) cited stereotypes in which females are portrayed as weak in math and science, and ingrained biases against females in technical fields. Barriers to females in STEM programs include campus cultures that are described as "chilly" (p. 243). Within the classroom, females have experiences that trivialize or exclude them. For example, it is difficult to be the only female in a large engineering classroom governed by a professor with little previous work experience with female colleagues and little inclination to accommodate the single woman in the room.

These barriers to female participation and persistence in STEM higher educational programs also lead to lower self-efficacy (Blackburn, 2017; Cheryan, Ziegler, Montoya, & Jiang, 2017) and lower sense of belonging in the field. Additionally, as females leave these programs to enter the workforce, they face a marketplace that is not fully aware of the presence of females in the various STEM fields and may not be prepared to target them as prospective employees. Essentially, women may find fewer opportunities simply because employers are unaware of this untapped resource.

In their review of literature, Cheryan et al. (2017) sought to distinguish between the cultures of the various STEM fields, instead of treating the entirety of STEM as a single culture. This is significant because much of the discussion about gender differences in STEM treats STEM as a single culture with comparable treatment of females across the board. This is not the case. The authors compared rates of program

participation between individual fields and found significant differences in the percentage of females in each field.

In their study, Cheryan et al. (2017) compared gender differences in six of the largest STEM fields, including biology, computer science, engineering (all fields), mathematics and statistics, chemistry, and physics. In biology, mathematics, statistics, and chemistry, there is close to gender parity. In computer science, engineering, and physics, females are a clear minority, with participation hovering around 20% (Cheryan et al., 2017, p. 3). In a statistical study for the Department of Commerce, Beede et al. (2011) confirmed this disparity in gender participation in the STEM fields. This underrepresentation begins before college, carries through undergraduate and graduate programs, and proceeds into the workforce.

As they compared the STEM fields with gender parity to those in which females are a clear minority, Cheryan et al. (2017) found three factors. First, in computer science, physics, and engineering there is a strong masculine culture, or system of beliefs and behavior. Essentially, the stereotypes of computer scientists, physicists, and engineers are predominantly male.   Second, females have significantly less early childhood and adolescent experience in these fields. And third, as a gender, females in these fields have less self-efficacy, or self-confidence in their abilities than males in these fields.

What is interesting, and disheartening, is the way these factors form a cycle, each factor contributing to the next in a self-perpetuating spiral. It is difficult to discern whether the masculine culture leads to females having less early experience in STEM disciplines, which in turn leads to less self-efficacy, or whether the cycle begins at one of the other factors. Nevertheless, it is one goal of STEM education to break this cycle and

facilitate the entry of more females into the underrepresented fields. This would create significant growth in the size of STEM educational programs, and eventually, an increase in the STEM workforce.

Tsui (2009) explored the reasons for the underrepresentation of females in the various fields of engineering and identified potential strategies to achieve parity. According to a 2008 statistical study submitted to the National Science Foundation (Tsui et al., 2008), females represented 20% of the graduates in engineering programs. While this is an increase from the past, it still indicated that females are a largely untapped resource in the fields of engineering. Because the topic involves the perceptions of the stakeholders, Tsui elected to conduct a qualitative study using interviews and focus groups,

To control for variability, Tsui chose the field of mechanical engineering to conduct her study. She and other researchers conducted 110 interviews, and 25 focus groups (Tsui, 2009) at six undergraduate programs that had a relatively high population of female participants. The researchers interviewed faculty, administration, and students in the programs, and conducted single gender focus groups with female and male students in the programs. Their findings indicated that these mechanical engineering programs had extensive outreach programs in high schools. Undergraduates within the mechanical engineering programs proved to be successful recruiters when involved in the outreach efforts. An important component of these outreach programs was the clarification of the scope of mechanical engineering, and its benefits to society produced by mechanical engineering.

What is significant about this study (Tsui, 2009) is the potential to increase recruitment of females into male-dominated fields, such as mechanical engineering. The factors which increased female participation in these programs included outreach programs, undergraduate participation in outreach, and the deliberate effort to educate the target audience about the scope and benefits of the field. Future research and similar efforts by other engineering programs in these and other schools will prove whether these factors of success are replicable in other venues.

Toglia (2013) explored the state of gender participation in traditionally male career and technology education (CTE) and STEM programs in a statistical analysis of existing research. His research indicated that females had not achieved gender parity in STEM fields. Similarly, Walters and McNeely (2010) examined the potential to enforce Title IX of the Educational Amendments of 1972 for the prevention of exclusion or discrimination in the academic workforce. Traditionally, Title IX has been cited to invoke equal treatment for females in sports programs; however, both sets of authors emphasize that the language in Title IX prohibits discrimination in educational programs. The United States Justice Department's website explains that Title IX "prohibits discrimination based on sex in any federally funded education program" (2015). Unfortunately, in practice, equity based on sex in educational programs has not occurred.

Toglia (2013) concluded his statistical analysis with suggestions from the research to promote female participation in CTE and STEM programs. He suggested the exploration of STEM professions with all students, and equal treatment of male and female students by teachers, counselors, parents, and coaches. This means the adult role

63

models for our children must identify their biases and consciously seek to eliminate them. Toglia also suggested highlighting female examples of success in traditionally male-dominated fields, assertiveness training for females, and working with employers to hire highly qualified STEM graduates, regardless of gender. Assertiveness training for females might combat what Cheryan et al. (2017) perceived as a lack of self-efficacy of females in STEM programs, such as engineering, physics, and computer science.

Although Toglia (2013) started out by emphasizing the implications of Title IX in leveling the field for gender equity in CTE and STEM programs, he concluded with suggestions to increase female participation in these programs. He does not follow up with suggestions or examples of leveraging Title IX to increase female participation in CTE and STEM programs, nor does he indicate whether Title IX has been invoked to achieve gender equity. These avenues are worthy of further research and examination.

In the studies on female participation in STEM, research has identified existing biases and stereotypes as contributing factors to the disparity in female participation in certain STEM fields (Cheryan et al., 2017). As a gender, females have fewer experiences with STEM content earlier in life, and subsequently develop lower self-efficacy than their male counterparts. A solution to the disparities in participation between men and women in certain STEM fields is the deliberate recruitment of females into underrepresented programs (Tsui, 2009), and conscious efforts to level the academic environment for men and women in STEM classrooms.

Minorities in STEM programs and professions face many of the same challenges that females face, and other challenges specific to their ethnic group. These groups also represent a targeted population for STEM recruitment and retention efforts.

Minorities in STEM/STEAM

Minorities refer to underrepresented groups within a larger population. In STEM education and STEM professions, ethnic populations, those with black, Hispanic, Asian, or other ethnically different factors, are minorities. This section examines the causes for this underrepresentation, and successful strategies for eliminating barriers to the inclusion of ethnic minorities in STEM education programs and STEM professions. Because there is little research on efforts at recruitment and resilience of minorities in the K-12 STEM "pipeline," the research will explore these efforts in universities, and as available, in K-12 STEM programs.

Museus and Liverman (2010) conducted a qualitative empirical study of three successful undergraduate STEM programs, seeking to identify the environmental factors, policies, and practices that have made them successful in retaining and graduating minority STEM students. They collected data with face-to-face interviews of students, professors, and administrators, and through artifact analysis. In these three successful institutions, there was repeated evidence of three components. First, these institutions had a positive, supportive culture that promotes networking and targeted support, and accepts institutional responsibility for their academic program. Second, these institutions had strong, and redundant, academic, and interpersonal support systems for the students. And third, these institutions each had a challenging and rewarding academic program, characterized by collaboration, relevance, and consistent engagement between students and teachers. The outcomes of a healthy campus and classroom climate are a sense of belonging to the community of the school, persistence in the STEM programs, and attainment of STEM degrees.

65

What is significant about Museus and Liverman's study (2010) was that it clearly delineated the factors in a school culture and classroom environment that contribute to minority persistence and completion of a STEM program. These factors are evident in all successful STEM programs, regardless of the composition of the student body; however, they are doubly important when implemented with a group that has numerous institutional and societal barriers to success.

In a national report on the state of ethnic minorities in STEM education, Museus, Palmer, Davis, and Maramba (2011) conducted a thorough assessment of the factors contributing to lower rates of success for minorities at the K-12 and collegiate levels. They also identified the factors which contribute to success in persistence and completion of STEM programs at both these levels. This report is significant, because in a political and economic environment that promotes STEM education and increased participation in the STEM workforce, minority participation in STEM education programs and STEM professions still has not achieved parity in all STEM professions.

In the K-12 educational pipeline, there are frequent discrepancies in funding of schools with predominantly minority students (Museus et al, 2011). In many traditional minority schools, there is a shortage of highly qualified teachers, a system that "disproportionately" places high numbers of minority students in remedial classes, and fewer opportunities for Advanced Placement classes. Additionally, in these schools, racial stereotypes lower teacher expectations of minority students, and institutional cultures fail to foster academic and supportive cultures.

In contrast, K-12 schools with high proportions of minority students that achieve success in STEM education exhibit parental support for the students and the school,

relevant and challenging curriculum, access to Advanced Placement classes, and the availability of bilingual education (Museus et al., 2011). Additionally, these schools expose their students early to STEM experiences, a rigorous and challenging STEM curriculum, and have "STEM opportunity and support programs" (p. viii). This builds the self-efficacy of the minority students, which is vital in building resilience and completion of STEM programs. To fill this gap, Museus et al. (2011) recommended funding high minority schools equitably, attracting highly qualified teachers, increasing Advanced Placement courses, limiting remedial tracks, and providing bilingual education.

In higher education, positive campus culture, classroom climate, and student supports (economic, academic, and social) promote student self-efficacy in STEM, resilience, and program completion. Additionally, successful programs fund outreach programs like those Tsui (2009) described to recruit females into engineering programs. The authors (Museus et al, 2011) concluded their discussion of STEM in higher education by encouraging research on the various experiences of minority students in STEM education programs, and inquiries to determine effective methods for minority retention and completion of STEM programs.

Two of the recurring themes in the literature on minority students in STEM programs at the undergraduate and graduate level are the encouragement of minority students to attempt a STEM program of study and developing the persistence to continue in the program to graduation. Teachers as role models and mentors for prospective STEM scholars is not a new phenomenon; however, for minority students who may feel isolated, or academically unprepared to meet the rigors of a STEM program, role models

67

and mentors of the same color or ethnic background are impactful. In their mixed methods study of STEM professors of color, Griffin et al. (2010) attempted to identify the characteristics of professors of color who have achieved professional success, and the methods these professors employed to mentor their minority students.

The research group (Griffin et al., 2010) accessed the survey results from 320 surveys of STEM teachers of color collected by the Higher Education Research Institute (HERI) at UCLA to identify trends in experiences, campus and classroom climate, and mentoring characteristics. They refined these trends by conducting and analyzing 28 interviews with professors of color at two predominantly white universities.

In their interviews, the professors reported themes frequently emphasized in the literature on STEM education, including family encouragement, personal drive, and passion for the subject (Griffin et al., 2010). One factor that emerged as significantly important was the previous experiences these professors had with their own mentors and role models. These experiences enabled the professors to complete their programs of study, even in adversity, and fashioned the type of mentors they became for their students as faculty members. In the role of mentor, these professionals reached out to their students, encouraged them, advised them, and pushed them to complete their programs.

In her research on grit, Angela Duckworth (2016) had this say about student success, "In the Chicago public school system, a supportive teacher made it more likely that students would graduate" (p. 31). Duckworth defined grit as "the combination of passion and perseverance" (p. 25). In the same way, what these professors of color are providing for their students in their mentoring relationships is a crash course in grit. They provide encouragement, guidance, inspiration, and serve as role models for

perseverance and following one's passion. When discussing STEM education for female and minority students, persistence is a topic that recurs frequently. To complete STEM education programs in circumstances that are challenging, often adverse, these students will need to develop and demonstrate passion and perseverance. As I work with a faculty to design a program evaluation for a middle school STEM program, we will need to determine whether the program is engaging all students, including females and minority students, and whether the program is providing the mentoring and supports necessary to assist the students build self-efficacy and resilience. Although difficult to immediately quantify, these components of the STEM program may prove to be the most important in predicting student long term success.

STEM/STEAM Program Evaluation

In what has become the governing document for educational evaluation, the Joint Committee defined an evaluation to be "the systematic investigation of the worth or merit of an object" (1994, p. 3). As explained by the Joint Committee, the object of the evaluation is a program. Consistent with this definition, a STEM/STEAM program evaluation is a systematic investigation of the merit of a school STEM/STEAM program. The research questions will be used to guide this systematic inspection of the STEM/STEAM program at a middle school and will facilitate the focus on describing factors that promote student interest and self-efficacy, inclusion of females and minorities, and teacher efficacy. The product of the evaluation will be a targeted indication whether these factors are present and effective in the STEM/STEAM program. Additionally, this evaluation will lead to recommendations regarding what the middle school can do going forward to improve.

In their text on program evaluation, Mertens and Wilson (2012) defined program

evaluation in numerous contexts, including an applied social research context definition,

a political context definition, and an international development definition. However, the

practical definition they discussed involves determining the merit of a program, or its

intrinsic value (p.6). In the context of the program, the merit of the program establishes

its worth. Mertens and Wilson also described the four major paradigms of program

evaluation: post-positivist, pragmatic, constructivist, and transformative. Table 2.1

elaborates these four paradigms of program evaluation.

Table 2.1. *Paradigms, Branches, and Defining Characteristics of Program Evaluation*
(Mertens & Wilson, 2012, p. 41)

Paradigms	Branches	Defining Characteristics
Post-positivist	Quantitative Methods, Data Driven	The post-positivist paradigm focuses on quantitative methods, analysis of data, and the merit/worth of the evaluand established by the data. The evaluator is an objective observer.
Pragmatic	Utility, Mixed Methods	The pragmatic paradigm finds merit and worth in the usefulness of the evaluand. It advocates mixed methods (quantitative/qualitative). The evaluator and stakeholders work together to define worth and success of the evaluation.
Constructivist	Values, Qualitative Methods	In the constructivist paradigm, the observers attempt to determine the values and perspectives of the stakeholders. The observers have extensive exposure to the stakeholders, and full interaction with them.
Transformative	Social Justice, Qualitative or Mixed Methods	In this paradigm, the observer attempts to become a change agent, identifying marginalized minorities and attempting to promote human rights and justice. The observer interacts with the stakeholders to further social justice.

70

Each of the paradigms has its unique approach to ethics (axiology), nature of reality (ontology), relationship of the evaluator and stakeholders (epistemology), and methodology (Mertens & Wilson, 2012). The remainder of this section on STEM/STEAM program evaluation will explore the literature of program evaluation using each of the four paradigms to evaluate a STEM/STEAM program. Following this is a comparison of the different types of evaluations, and an assessment of the type of evaluation which will be most useful in the current program evaluation.

Post-positivist Evaluations (quantitative methods, data-driven)

As noted in Table 2.1, a post-positivist program evaluation is a data-driven methodology for evaluating a program using quantitative methods. In this paradigm, the evaluator is an objective observer who collects and analyzes the data from the evaluation using predetermined rubrics for measuring success. Prior to 2006, this paradigm was the primary methodology for program evaluation recognized by the National Science Foundation (Lawrenz & Huffman, 2006). While it is no longer the primary program evaluation methodology dictated by the Foundation, evaluators have used post-positivist program evaluation methods to successfully evaluate STEM/STEAM programs.

Nakamoto and Bojorquez (2017) conducted a quasi-experimental, post-positivist program evaluation of four middle schools in Clark County, Nevada that were implementing Project Lead the Way's (PLTW) Gateway to Technology (GTT) STEM curriculum. They compared the four schools engaged in this STEM program with four matched middle schools not engaged in a STEM curriculum. They collected data from the four middle schools on eight components of STEM implementation centered on

71

teacher professional development, implementation of the GTT curriculum, use of instructional technology, and science and math assistance to the students.

Using a quantitative rubric for each component, Nakamoto and Bojorquez (2017) assessed each component as emerging, moderate, or high implementation. They found that the STEM schools did not have high levels of ongoing professional development or participation in the weekly sessions with STEM professionals. They also found low participation by the students in science and math tutoring. Overall, there was no statistically significant difference between the PLTW schools and the matched schools in science and math achievement.

The significance of this article was Nakamoto and Bojorquez's emphasis on ongoing teacher professional development, and science and math tutoring, as critical elements of a STEM program. Not surprisingly, professional development and student supports repeatedly surface in the literature on STEM/STEAM program evaluations as significant factors in successful STEM implementation.

In 2008, a group of researchers from the University of Akron (Lam, Doverspike, Zhao, Zhe, & Menzemer) conducted a year-long STEM program for middle school students with individualized education plans (IEP). Twenty-six middle school students participated in the program, 11 with IEPs and 15 without IEPs. The inclusion of regular education students was not to provide a control group for the program, rather it was to promote a balance to the educational program. The program consisted of a week-long summer workshop with STEM experiences, and seven weekend experiences throughout the school year. The researchers designed the program using the universal design for learning (UDL).

According to Burgstahler (2012), the UDL incorporates multiple means of representation, multiple activities and means of expression, and multiple methods of engaging the learner. Among the guiding principles of universal design, there is equal access for all, flexibility in use (choice), tolerance for error, attention to diverse learning styles, low physical effort requirements, and attention to spatial requirements of the participants. UDL is widely used in special education programs and was a natural fit for this program.

With the universal design in mind, the researchers ensured the STEM educational experiences in their program included multi-media representations of the material, attention to diverse learning styles, cognitive aids to facilitate retention, relevance of the experiences, and opportunities for collaboration (Lam et al., p. 22). Their evaluation of the program was quasi-experimental, with quantitative methodology. The researchers administered before and after tests of science, math, technology, and engineering knowledge. They also administered surveys to the program participants and their parents. The purpose of the surveys was to identify student inclination to pursue STEM education, and parent satisfaction with the program. The statistical analysis of the tests and surveys indicated statistically significant improvements in student knowledge, and a positive inclination to pursue STEM education and STEM professions. The limitations of the evaluation were its sampling method (convenience), the small sample size (only 17 students participated in the exit surveys), and the lack of a control group, making this a quasi-experimental evaluation.

The significance of the study was its adherence to the principles of universal design. The idea of providing access to all is a powerful concept, opening new markets

for STEM education as we attempt to grow our STEM workforce to meet market demands. STEM fields need to have practitioners from underrepresented populations, females, minorities, and the disabled. This needs to be the rule rather than the exception. The universal design in education is a means to achieve this goal.

What Lam and his partners (2008) did not discuss was the program cost of incorporating UDL principles in the STEM program. The program lasted a week in the summer, and seven weekends throughout the school year, involving the use of university facilities and hundreds of hours of effort from professional STEM educators. Yet the program only accommodated 26 students. The cost-benefit analysis of these types of programs is worth investigating if we are to replicate and fund STEM education programs nationwide that incorporate the principles of universal design and meet the very real demand for STEM professionals in our workforce.

Post-positivist evaluations provide concrete, measurable indicators of program performance. These types of indicators are valuable when comparing student performance on achievement tests, quantifying participation in programs, and assessing participant perception of the program using Likert-style surveys. They enable evaluators to quantify program success, and are useful when justifying program implementation, continuance, or closure. However, quantitative methods are not always practicable, nor do they examine the reasoning processes stakeholders use to arrive at their perceptions.

This in-depth exploration of reasoning and perception can be examined using qualitative instruments such as interviews and focus groups. The pragmatic paradigm uses mixed methods to determine program usefulness. The qualitative methods in pragmatic evaluations assist the evaluator in analyzing stakeholder engagement,

74

perception of self-efficacy, and resilience. These characteristics are quantifiable when measuring program participation and retention, but elusive when attempting to explain how and why stakeholders achieved these characteristics.

Pragmatic Evaluations (mixed methods, utility)

In 2010, a group of researchers from the science and engineering departments at the University of Akron conducted a quasi-experimental evaluation of a ten-week, summer high school STEM program held on campus for local high school students (Jiang, Doverspike, Zhao, Lam, & Menzemer). The study was pragmatic in nature, attempting to determine the utility of the summer program in enticing the students into the science, math, and engineering programs at their university. The sample for the study was a relatively small (n = 33), convenience sample of local high school students. The STEM program design included inquiry-based learning, problem solving, collaboration, multimedia presentation, multiple, hands-on activities, and incorporation of STEM concepts in real world contexts. The students participated in four projects from the fields of "civil engineering, mechanical engineering, electrical engineering and chemical engineering" (p. 62). The team collected demographic data from the group, conducted surveys, held focus groups, and interviewed the participants. According to the results, 100% of the participants intended to attend college and 86% intended to enter a STEM education program (p. 66).

The limitation of this study was its use of a convenience sample. Zhe et al. (2010) gathered a body of students, the majority of whom were white (25 of 33) and more than half were male (18 of 33). Additionally, all the students who could declare their intent to attend college had already indicated they planned to go to college before the project

began. This is not surprising. The major finding of the study was the program's role in bolstering, and perhaps amplifying, the intentions of these college-bound students to attend college and declare for a STEM major. The implication for future program evaluations is to study a demographically different sample to see if the results of sparking interest in further STEM education and STEM professions can be replicated in a setting in which the students' demographics are not predominantly white and male.

Carter (2012) conducted a utilization focused (UFE), pragmatic case study of the University of Missouri's STEM educator resource center. At the time of the report, the resource center, which Carter referred to as the Program, had lost its funding. The program director approached Carter and requested she conduct an evaluation to determine program impact on STEM learning within the state. The resource center provided professional development, student STEM activities, and STEM curriculum materials. The evaluation sought to determine the impact of the professional development, student activities, and curriculum materials on STEM education in the state.

After considering the purpose of the evaluation and its intended use, Carter (2012) chose the mixed methods, pragmatic, case study as her vehicle for the evaluation. She conducted surveys of teachers, students, and program instructors, held focus groups with teachers and program instructors, and conducted interviews with program instructors. Although she acknowledged the limitations of her case study, her findings were that the instruction provided by Program personnel and the Program materials distributed to schools had a positive impact on STEM education within the schools that used the Program services and materials. Additionally, while this was an evaluation of a

STEM resource center, it does provide an example of a rigorous program evaluation of a STEM-related program and has relevance for the middle school STEM program evaluation which is the focus of this research.

In post-positivist evaluations, the evaluator is an objective observer of the program, recording findings and conclusions based on pre-determined measures of success. In assessment terms, the post-positivist evaluation is a summative assessment. In contrast, in pragmatic evaluations, the evaluator develops a relationship with the stakeholders and adjusts the evaluation to meet the needs of the stakeholders. The purpose of the pragmatic evaluation is to determine the usefulness of the program, and guide efforts to improve utility.

Deviating from post-positivist and pragmatic evaluations, the purpose of the constructivist evaluation is to promote certain values, such as the inclusion of minorities and the development of resilience. Constructivist evaluations are characterized by qualitative methods and participation of the evaluation team in the program to promote the program values.

Constructivist Evaluations (qualitative methods, values)

In a multi-year study of an undergraduate research experience program, Boyce (2017) found that exercising patience when implementing a program evaluation was significant, particularly when the express goal of the program was changing culture and promoting diversity. The research program was a three-year program at three universities sponsored by the National Science Foundation's (NSF) Science and Technology Center (STC). The author was a program evaluator for the NSF. The evaluation was a values-engaged educative (VEE) case study model, in which the author analyzed her weekly

77

reflections, program documents, interviews with stakeholders, and peer reviews. The program itself had three explicit goals: quality of program design, contextual power, and advancement of traditionally underrepresented and underserved groups (p. 35). One of the evaluator's responsibilities was to engage in discussions of diversity with the program staff. The VEE evaluation guidelines specified that the evaluators remain respectful and attentive to opinions and cultural perspectives shared by the program staff.

The first key finding of this evaluation was that the emphasis on the inclusion of underrepresented groups was initially opposed by the program staff, despite inclusion being a specific goal of the program and an express mandate from the NSF. This was the result of attempting to change a culture the majority had traditionally dominated. The second finding was that inclusion concepts gradually began to appear in program documents as program administrators changed and the evaluators gained credibility. The conversations between evaluators and program staff eventually became less contentious, as the program staff warmed to idea of diversity.

The importance of patience cannot be understated. Throughout the program life cycle, the evaluators remained respectful and calm as they experienced views of diversity that clashed with their own, and the expressed values of the NSF-sponsored program. However, this was a product of culture, and culture is not something that is quickly changed, particularly a culture with deeply held viewpoints. To facilitate change in an organizational culture, while remaining respectful of the stakeholders within the culture, requires what my father used to call courageous patience. Progress in STEM education is going to involve changing the culture of the many constituencies engaged in STEM education programs. Additionally, the long-term impact of the programs will take

decades to register, as current STEM participants eventually graduate and enter the workforce. This will require patience from the evaluators of STEM programs and attention to incremental changes in STEM programs during longitudinal studies.

In another values-engaged educative (VEE) model for program evaluation, Greene, DeStefano, Burgon, and Hall (2006) proposed a qualitative evaluation model that integrated three facets of STEM education: high quality of scientific content, effective inquiry-based, student-centered instruction, and concern for equity and diversity. According to the authors, this last aspect of the VEE evaluation model is often overlooked and sorely needed. From a statistical viewpoint, this is correct. Female and minority students often find themselves on the outside of STEM programs, yet they constitute a large pool of potential STEM professionals in fields such as physics, engineering, and computer science. While providing high quality content and effective instruction, Greene et al. (2006) proposed that STEM program providers should remain attuned to the cultural, political, and interpersonal characteristics of the participants, and focus on "a commitment to inclusion" (p. 60) and a commitment to "redressing past inequities" (p. 61).

Middle school is the connective tissue in the K-12 STEM "pipeline" (Ferrara-Genao, 2015), connecting elementary and high school STEM efforts. Consequently, it is appropriate to expose middle school students to STEM career fields and the unique aspects of STEM education as early as possible in the "pipeline." Middle school is an opportune time to begin the recruitment process of enticing students into STEM education programs, at the high school and beyond, if we are to meet the goals of increasing STEM professionals begun during the Bush and Obama administrations.

In her qualitative case study of three middle school STEM programs in California, Ferrara-Genao (2015) found the most important factors in effective STEM implementation to be "transformational principals," teachers trained in productive STEM instructional strategies, and a proactive, positive school culture (p. 43). Professional development of teachers in the best instructional practices to teach STEM curriculum, the effective integration of instructional technology, and a fertile school culture are consistent takeaways from the study of STEM programs (Nakamoto & Bojorquez, 2017; Saxton et al., 2014). In fact, each of the principals that Ferrara-Genao interviewed stressed the importance of professional development in the Project Lead the Way (PLTW) STEM curriculum.

Significant in this study was the author's identification of transformational leadership as a key factor in STEM integration. If middle schools are the connective tissue that binds the K-12 educational pipeline, then passionate, informed, and persuasive leaders are the connective tissue that binds together middle school STEM programs. The education models in Project Lead the Way, and the Universal Design for Learning (Burgstahler, 2012), are not traditional educational programs. These non-traditional education models require passionate, purposeful leadership to inspire and facilitate faculties of educators who may lack commitment to the changes in school culture that ensue with a transition to a STEM-focus. The composition of her interviews with the middle school principals will influence the composition of the interview with the school principal. Additionally, Ferrara-Genao observed multiple classrooms implementing PLTW's STEM curriculum. This was her integrity check to ensure the operation of the STEM programs matched the contents of the interviews with school principals.

80

Subsequently, the program evaluation of the target middle school for this dissertation included the observation of classrooms engaged in STEM activities/projects.

By 2005, of 204 existing STEM programs in 13 different federal agencies, only 29% of these programs had performed a program evaluation, not all of them rigorous (Jung, 2014). The goals of these programs are various, but they share several characteristics. Two of the goals evident in most programs are the recruitment of students into STEM educational programs, and the recruitment of candidates into STEM teacher preparation programs. The long-term outcome of these goals is the increase in the workforce of STEM professionals, and subsequent sustainable economic growth.

To investigate the connection between the importance of STEM education in recruiting professionals into the workforce, and improving skills and capacity of workers, Jung (2014) conducted a qualitative evaluation of the Workforce Innovation in Regional Economic Development (WIRED) training program in Southeast Virginia. Between April and August 2011, he conducted interviews of 33 participants in the WIRED program using a snowball sampling methodology to identify participants. Three themes emerged from analysis of these interviews.

First, STEM education is a recruiting program, linking the "talent pipeline" (p. 159) with the workforce. The results from the interviews indicated that STEM education is an important linking element between the education world and the business world. Second, there were benefits from STEM education activities (summer camps) for participants and for local industry. And third, STEM education improved personal capacity and consequently increased regional economic growth.

81

Given the qualitative design and use of snowball sampling, the results of this study may not provide assessment data that is useful for a STEM program evaluation. Further, the study results were not based on random, quantifiable data, and do not support finding a cause and effect relationship or concluding that the WIRED training program increased regional economic capacity. While the participants indicated that the STEM training served as a pipeline for their transition to the workforce, there was not objective evidence of sustainable region economic growth, but only the subjective opinions of the stakeholders. However, Jung acknowledged the limitations of his evaluation, and called for further research in the connection between STEM education and regional economic growth. This is a valid point and a call to action.

As demonstrated, constructivist evaluations use qualitative methods to promote the shared values of the evaluators and stakeholders, even if the stakeholders need to be influenced to adopt the values. This spectrum of evaluations, beginning with impartial observers and quantitative methods and transitioning through pragmatic and constructivist evaluations, ends with transformative evaluations. Transformative evaluations promote social justice and change through qualitative or mixed methods. Rather than impartial observer or program participant, the evaluator in transformative evaluations is an agent of change for social platforms. In STEM professions, social justice will occur with the equitable treatment of underrepresented populations, such as female, minority, and the economically disadvantaged individuals.

Transformative Evaluations (qualitative or mixed methods, social justice)

In 2004, the NSF amended its charter to supervise government programs that serve as proponents for STEM education, by stating the NSF needed to ensure the

increase of females, underrepresented minorities, and people with disabilities in STEM fields (Mertens & Hopson, 2006). In the spirit of this mandate, Mertens and Hopson examined the types of program evaluation that would best serve to increase the participation of these groups in STEM fields. In a qualitative analysis of literature, they examined "responsive, constructivist, and deliberative-democratic evaluations (DDE)" (p. 40).

In terms of the paradigms of program evaluation, a responsive evaluation is a form of pragmatic evaluation. Pragmatic evaluations are mixed method evaluations that focus on the utility of a program, establishing its worth. Evaluators partner with the stakeholders to build the parameters of the evaluation, and consequently to determine whether the program is successful based on the established parameters. In contrast, constructivist evaluations are primarily qualitative, and focus on establishing the values within the program. Finally, the DDE is a form of transformative evaluation in which the evaluator serves as a change agent for social justice.

After consideration of these three paradigms of evaluation, Mertens and Hopson concluded that the transformative evaluation, DDE, is best suited for a situation that requires increased participation of females, underrepresented minorities, and the disabled in STEM fields. This is significant because in the past the NSF has indicated that a quantitative methods evaluation is the "gold standard" for program evaluation. Yet Mertens and Wilson (2012), prominent scholars in the field, argued for a social justice intervention to ensure the NSF mandate is accomplished. This flexibility in program selection is in harmony with the "methodological pluralism" proposed by Lawrenz and

Huffman (2006). It makes sense to match the evaluation type with the evaluation purpose and context of the situation.

Comparison of Program Evaluation Methodologies

As of 2004, the Department of Education advocated a true experimental design, with a randomized sample, treatment, and control, as the priority for program evaluations sponsored by the National Science Foundation (Lawrenz & Huffman, 2006). This design was followed by quasi-experimental designs and correlational approaches to longitudinal studies. Qualitative approaches to program evaluation were not listed among the priority approaches to program evaluation. In an assessment of program evaluation methodologies, Lawrenz and Huffman argued that qualitative methods of program evaluation meet the "methodological rigor" (p. 20) found in quantitative methodologies. In fact, they noted that several well-known proponents of quantitative methods have made convincing arguments for both a qualitative and mixed methods approach.

Having examined the quantitative and qualitative branches of program evaluation, Lawrenz and Huffman (2006) proposed a situational web-like framework for designing an evaluation (Figure 2.2). Among the quantitative strands of the web were randomized experimental, quasi-experimental, and correlational evaluation models. On the qualitative side of the web, the strands were case study, status and survey design, and interpretative design evaluation models. Considering these two approaches, they concluded that the most appropriate approach to selecting an appropriate STEM program evaluation methodology is what they termed "methodological pluralism" (Lawrenz & Huffman, p. 30). Essentially, it is a situational approach, in which the context of the

84

program (its components, its purposes, and its setting) drives the purpose, the philosophical approach, and the means of the program's evaluation. The significance of this research is two experienced practitioners of program evaluation making a convincing argument that the best program evaluation method is not any specific evaluation method at all. Within the context of the evaluation, the most appropriate evaluation method is the one that provides a clear and accurate portrayal of the program and accomplishes the purpose of the evaluation as specified by the evaluator and the customers.
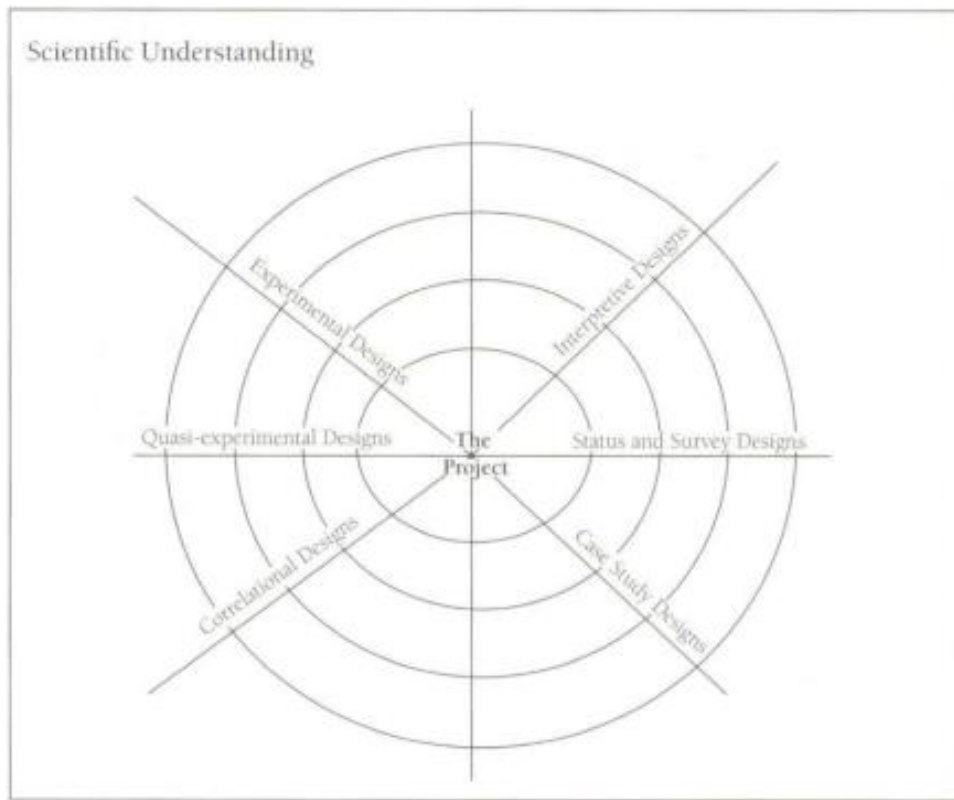
Figure 2.2. Strands of a STEM Educational Evaluation (Lawrenz & Huffman, 2006, p. 23)

A diverse group of educational researchers from Portland formed a working group to study the state of STEM education in the United States (Saxton et al., 2014). In their study of the literature on STEM education, they came to three conclusions. First, based on performance in science and math on the National Assessment of Educational Progress

www.manaraa.com

(NAEP) and the Trends in International Math and Science Studies (TIMSS), students in the United States are underperforming in science and math studies. Second, there are documented shortfalls in teacher practices in science and math instruction, including the tendency to teach these subjects in isolation and an emphasis on recall of knowledge rather than the application of higher order thinking skills. And third, there are limitations in current assessment practices.

According to Saxton et al. (2014), many science and math teachers focus on assessing retention of knowledge rather than the application of knowledge and skills. Additionally, current assessment practices focus on recall of knowledge rather than application and synthesis of knowledge and skills. There should be a balance of carefully selected multiple choice and constructed response items assessing higher order thinking skills. These higher order skills include problem solving, developing an argument based on evidence, communicating solutions orally and in writing, and using metacognitive skills.

In response to this dilemma, the Portland group (Saxton et al., 2014) designed what they have coined the STEM Common Measurement System, which is shown in Figure 2.3. This system of measurement interlaces four dimensions: schoolwide supports, professional development, teacher practices, and student learning characteristics. Currently, the measurement system consists of nine constructs for the four dimensions listed, and contains eight measurement instruments, including the UTEACH observation tool from the University of Texas at Austin's STEM teacher preparation tool. The group plans to add five more measurement instruments as they take

their system from its current theoretical state to an operational vehicle for STEM program evaluation.
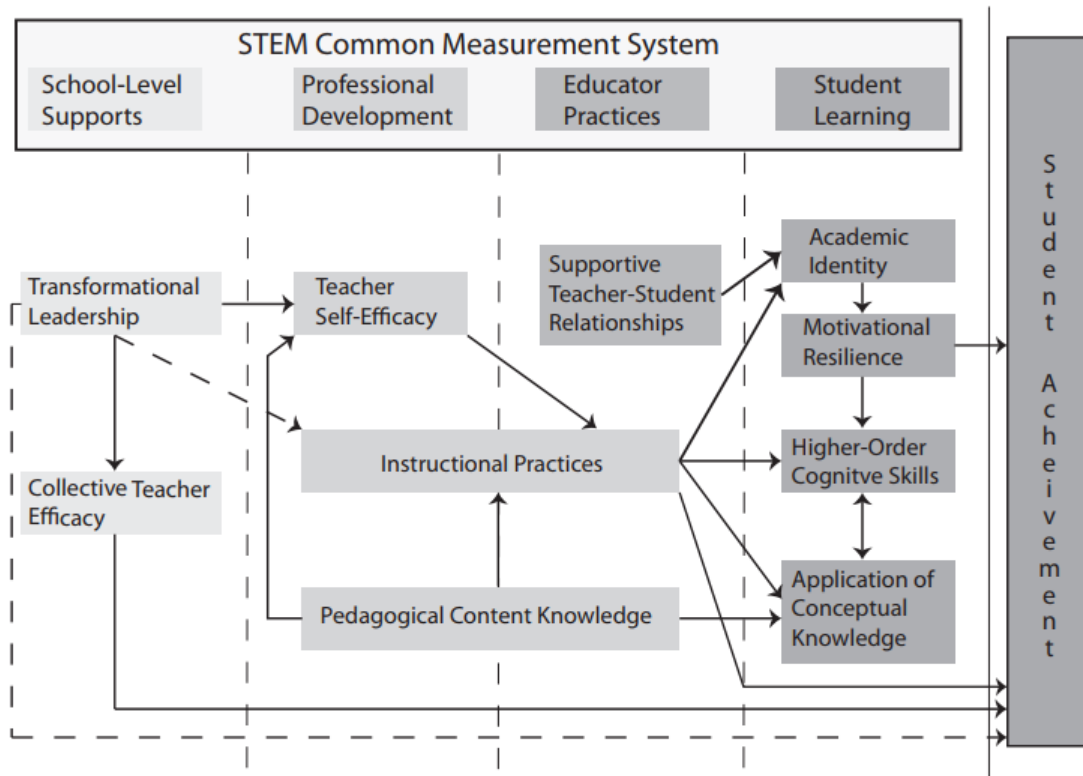
Figure 2.3. The dimensions of the STEM common measurement system (Saxton et al, 2014, p. 30)

This common measurement system is significant because it establishes a framework for conducting a STEM program evaluation, without advocating an approach to the evaluation. It is neither quantitative nor qualitative but allows elements of both and supports the situationally dependent "methodological pluralism" of Lawrenz and Huffman (2006). The dimensions, constructs, and measurement instruments enable the evaluator to develop and conduct the most appropriate and comprehensive evaluation for the program involved.

This literature review is a critical examination of the background of integrated science, technology, engineering, and mathematics (STEM) education, and the importance of STEM education in building a STEM-trained workforce. As outlined by the Obama administration in its "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009), there is a defined need for STEM-focused schools, STEM teachers, and STEM-trained students in our workforce. These STEM-trained graduates will have the critical thinking, collaborative, technical, and communication skills necessary to grow the economy in a world in which the United States is losing its economic dominance.

Having established the importance of STEM education, the literature review addressed the recruitment of students into STEM education pathways at high school, college, and beyond. If the end state of STEM training is the graduation of a student into a STEM profession, then the starting point is developing student interest in STEM fields as early as possible (Dutta-Moscato et al., 2014; McNally, 2012; Reiss & Mujtaba, 2017). This portion of the literature review enumerated the numerous practices that have proven to attract students into the K-12 STEM education "pipeline."

Successful STEM/STEAM program implementation follows successful recruitment efforts. This section outlined the components of successful STEM/STEAM education programs. Structurally, STEM programs require a sound definition of STEM education, enough funding, and a comprehensive curriculum that successfully integrates technology (Bybee, 2010). Pedagogically, these programs provide students challenging, relevant, technology-driven educational experiences using a student-centered, problem-

based learning model (Wells, 2016; Ferrara-Genao, 2015; McDonald, 2016). This pedagogical model builds student self-efficacy, defined as the confidence in one's ability to solve complex problems with no easily discernible solution. The program also includes plentiful opportunities to research and learn about STEM careers, and student supports in the form of tutoring, mentoring, and social interaction (Sithole, 2017).

The section on program implementation concluded with a discussion of STEAM education, which includes art, and liberal arts, as an integrated part of the STEM program of education. In STEAM education, there are two viewpoints. The first considers art, and liberal arts, as an integrated, equal partner in the curriculum (English, 2017; Herro & Quigley, 2016). The second considers art, and liberal arts, as a contributing addition to the STEM curriculum (Jolly, 2017).

Confident and capable teachers are key to the successful implementation of a STEM/STEAM curriculum. To provide inquiry-based, cross-curricular, relevant, and engaging learning experiences teachers require training and a change in thinking from a traditional, teacher-centered paradigm. In the STEM/STEAM education model, the students are the center of the learning, and the teacher becomes the facilitator. Consequently, the teacher preparation section of the literature examined professional development programs for pre-service teachers and those for in-service teachers who find themselves in a STEM/STEAM program. An interesting aspect of all professional development programs is the consistent emphasis on relevant, hands-on learning experiences. For in-service teachers, this hands-on aspect occurred in workshops dedicated to teaching the engineering design process (Page et al., 2013; Avery & Reed, 2013).

89

For pre-service teachers, in programs such as the Woodrow Wilson Fellowship Program (King et al., 2013; Schuster et al., 2012) and the UTeach program at the University of Texas Austin (Perez & Romero, 2014), this emphasis on hands-on training occurred in rotations through classrooms as an acting STEM/STEAM teacher. In both in-service and pre-service teacher education programs, this emphasis on hands-on, relevant, engaging educational experiences corresponds to the project-based, student-centered learning experiences the teachers will guide their students through. The goal of these professional development programs is the self-efficacy of the teachers who implement STEM/STEAM education programs, just as these teachers will promote the self-efficacy of their students.

One of the goals of the Obama administration's "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009) was the inclusion of female and minority students in the STEM workforce. Although female and minority students have achieved parity in some technical fields, such as biology, chemistry, and mathematics, they remain significantly underrepresented in the fields of physics, computer science and engineering (Cheryan et al., 2017). Therefore, the inclusion of females and minorities should be a component of any STEM/STEAM education program. This section of the review examined what these educational programs, at all levels, are doing to build interest, efficacy, and resilience of women (Blackburn, 2017; Tsui, 2009; Toglia, 2013) and minorities (Museus & Liverman, 2010; Museus et al., 2011; Griffin et al., 2010).

There are several themes repeated throughout the literature review. Student interest in STEM/STEAM (Ferrara-Genao, 2015) and self-efficacy (Sithole, 2017) are goals of all STEM/STEAM programs. This revelation led to the formulation of the first

90

and second research questions. Similarly, capable teachers who can subordinate themselves to student learning, rather than being the focal point for the classroom, was another common theme. Teacher self-efficacy, forged in hands-on learning experiences in workshops and professional development sessions (Avery & Reeve, 2013; Page et al., 2013), and in classroom rotations (King et al., 2013; Schuster et al., 2012; Perez & Romero, 2014), led to the creation of the third research question. Additionally, the inclusion of female and minority students resonated throughout the literature. It is explicitly stated in the campaign goals of the presidential "Educate to Innovate" program (2009). Therefore, exploring this facet of STEM programs influenced the focus on underrepresented populations in the second research question. Finally, a potential attraction of STEM/STEAM programs is the influence of these programs on improving student achievement, particularly in science and math. The literature is not united for STEM/STEAM influence on student achievement. This ambiguity in the research led to the question of program influence on academic achievement. The four research questions that guided this study are repeated below:

1. What is the STEAM program's impact on student interest in STEM/STEAM professions?

2. How has participation in the STEAM program influenced the self-efficacy of students in STEAM knowledge and skills, with a focus on females and minorities involved in the program?

3. How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students?

4. What is the STEAM program's influence on student achievement?

Conclusion

A program evaluation is the most appropriate method to investigate and answer the stated research questions. According to the Joint Committee, an evaluation is "the systematic investigation of the worth or merit of an object" (1994, p. 3). In this case, the object of the evaluation is a middle school STEAM program. The primary purpose of the evaluation is to provide the middle school conducting the STEAM program with specific, useful feedback concerning their program implementation, and educationally sound recommendations for improving program implementation. A secondary purpose is to contribute to the professional literature on middle school, STEM/STEAM program evaluation. In their chronology of education evaluation with the National Science Foundation, Katzenmeyer and Lawrenz (2006) noted a shortage of trained STEM evaluators, and "a serious lack of instruments of determined validity and reliability to measure important outcomes of STEM education and interventions" (p. 7). They wrote their article 11 years ago, but there remains a shortage of evaluators and a lack of evaluation instruments. This program evaluation of a middle school STEAM program may contribute to the methodology of STEAM evaluation.

A phrase that resonates in the research on program evaluations is "methodological pluralism" (Lawrenz & Huffman, 2006, p. 30). Essentially, this phrase means to let the specifics of each program guide the selection of the program evaluation paradigm. Prior to 2004, the National Science Foundation mandated the use of quantitative methods, experimental design for program evaluations (Lawrenz & Huffman, 2006). However, since then, evaluators have conducted program evaluations of STEM/STEAM programs using each of the evaluation paradigms (Mertens & Wilson, 2012): post-positivist

92

(quantitative methods), pragmatic (utility-based, mixed methods), constructivist (values-oriented, qualitative), and transformative (social justice-focused).

Consequently, the researcher chose to conduct a pragmatic, mixed-methods, case study of a middle school STEAM program. This approach provides a useful evaluation and necessitates working *with* the stakeholders to examine their program, which fits the purpose of the evaluation. During the exploration of the perceptions of interest and self-efficacy with the program's stakeholders, it makes sense to record their thoughts. This argues for qualitative methods, such as interviews and focus groups. In contrast, to compare the differences of the subgroups (male versus female, majority versus minority), quantitative methods are the best way to collect and analyze objective data. Chapter 3 will fully explore the evolution of this methodology.

CHAPTER 3

METHODOLOGY

Introduction

The literature review established the legitimacy of STEM and STEAM programs in education, and the various elements that contribute to program success. In addition, the literature review provided an in-depth examination of the various program evaluation designs of a middle school STEAM program and explored the various paradigms for program evaluation. Comparing the various paradigms using the concept of "methodological pluralism" (Lawrenz & Huffman, 2006, p. 30), the most suitable method to conduct a beneficial evaluation of a middle school STEAM program is a pragmatic, mixed-methods case study. The methodology proposes the research design, the stakeholders, and the data collection and analysis plan. These elements are subject to the ethical requirements of program evaluation (Joint Committee, 1994) and the necessity for valid collection instruments that produce reliable data (Huck, 2012).

Given unlimited time and resources, a longitudinal study might be the desirable design in order to track students through high school, college, and beyond. A longitudinal design would produce a measure of the influence of the STEAM program on student topics of study and choice of career. However, the trade-off is that a longitudinal study is not sensitive to the immediate needs of the administration and faculty of the school for constructive feedback on the state of their program. Mertens and Wilson discussed establishing the worth of a program evaluation by situating it "in a particular

94

context" (2012, p. 6). In this case, the context is a STEAM program in a middle school during a school year. Recommendations for capturing data on student course selection, field of study, and eventual career may emerge from the discussion of the program's next steps. Nevertheless, the evaluation itself will capture the state of the program in a specific window of time, and its data and conclusions are time sensitive.

Methodological Design

When designing a program evaluation, there are four assumptions that the evaluator makes prior to settling on an evaluation methodology (Mertens & Wilson, 2012). The first assumption is axiological, concerning the nature of ethics. In the program evaluation of a STEAM program in a middle school, the data collected is practical, informing the school and its district of the state of the program. The evaluation is not an assessment of values and moral standards, but a practical measure of the utility of an existing program. This evaluation will inform the school and district leadership whether to retain the program, modify it to improve its effectiveness, or dismantle the program.

The second assumption is ontological, concerning the nature of reality (Mertens & Wilson, 2012). For the purposes of the evaluation, the assumption is one reality, although all the stakeholders will have differing views of that reality. The third assumption is epistemological, concerning the nature of knowledge. In practical terms, this assumption concerns the nature of the relationship between the evaluator and the stakeholders. In a pragmatic evaluation, the evaluator and stakeholders (faculty and staff) form a partnership, working to gather data that will inform decisions on the future direction of the program. That will be the case with this evaluation.

95

The final assumption is methodological, concerning the systematic approaches to gathering data. Stemming from the mandate to increase the numbers of scientists, mathematicians, and engineers in the United States, the "Educate to Innovate" campaign of STEM and STEAM education works to increase STEM literacy, increase opportunities, particularly for female and minority students, and improve STEM education (Office of the Press Secretary, The White House, 2009). While some of this can be measured with test scores and other measures of student performance, much of the information concerns the perceptions of the stakeholders. Therefore, to capture the raw data and the perceptions of the stakeholders, the instruments for this evaluation are both quantitative and qualitative.

Based on these four assumptions, the program evaluation of a middle school STEAM program is best served by a pragmatic, mixed methods case study. The purpose of the evaluation is to provide meaningful feedback to the stakeholders to assess and potentially improve its processes. This is the essence of a pragmatic evaluation (Mertens & Wilson, 2012, p. 90). The reality of a middle school STEAM program is common to all the stakeholders (faculty and students), although the stakeholders will have differing perceptions of that reality.

As a fellow educator, the researcher's role will be as a partner working to improve the program with faculty and administration. Before administering the surveys and focus group, the researcher will meet with the faculty to explain the evaluation process and share the data collection instruments. The feedback from the faculty will inform and potentially alter the data collection instruments. The intent is to provide the teachers and administration with a clear snapshot of their program that they understand and are

96

invested in. Finally, since the concepts of interest in STEM/STEAM and self-efficacy are personal perceptions of the stakeholders, the data collection instruments will be quantitative (Likert scale) to assess the extent of individual feelings, and qualitative (open-ended questions) to explore the variable nature of these constructs.

Research Questions

As explained previously, the following four questions guided the focus of this program evaluation.

1. What is the STEAM program's impact on student interest in STEM/STEAM professions?

2. How has participation in the STEAM program influenced the self-efficacy of students in STEAM knowledge and skills, with a focus on females and minorities involved in the program?

3. How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students?

4. What is the STEAM program's influence on student achievement?

In the research on STEM and STEAM programs, three themes emerged. One purpose of STEM/STEAM programs is to promote student awareness and interest in STEM/STEAM professions. The second purpose is to foster students' confidence in their ability to think critically, work collaboratively, and communicate verbally and in writing. These themes reflect the intent of the first two research questions. The third theme that emerged was the skill set required for teachers to facilitate learning in STEM/STEAM programs, and the professional development required to foster that skill set. This is the focus of the third research question. A fourth theme in the research is the potential for these programs

97

to positively influence student achievement. There are mixed results in the research on this topic. The fourth research question examines achievement data from the school to determine whether the implementation of a STEM/STEAM program has positively impacted student achievement.

Research Design

The four required attributes of a program evaluation are utility, feasibility, propriety, and accuracy (Joint Committee, 1994). Utility standards meet the needs of the evaluation audience by being "informative, timely and influential" (Joint Committee, p. 5). Feasibility standards ensure the evaluation is realistic, and within resource limitations. Proprietary standards "promote sensitivity" (Joint Committee, p. 6) and are ethical and legal. Finally, accuracy standards measure whether the evaluation has produced comprehensive and correct information.

To ensure the "integrity and credibility of evaluations," (Stufflebeam, 2001, p. 205), program evaluators conduct meta-evaluations of the evaluation utility, feasibility, propriety, and accuracy. In large-scale evaluations, independent auditors will be engaged to conduct the meta-evaluation. However, for "small-scale, locally focused, and improvement-oriented evaluations," (Stufflebeam, 2001, p. 205) an informal, formative meta-evaluation may suffice. In this case, Stufflebeam's eight-page, abbreviated checklist (1999) is appropriate to informally assess the utility, feasibility, propriety, and accuracy of the evaluation.

Utility and feasibility. To produce useful feedback and recommendations for a middle school STEAM program in a program evaluation, a mixed-methods, pragmatic program evaluation is appropriate and feasible. The data collection and analysis occurred

predominantly during the fall semester of the school year. The school will receive the results and recommendations following the completion of this program evaluation. This meets the utility standard (Joint Committee, 1994), being timely, informative, and useful. The collection of data occurred over several days using data instruments that were specifically designed for this program evaluation. The researcher taped and transcribed the administrator interview and teacher focus groups. The vehicle for both surveys was a Microsoft Office 365 form, anonymously administered to participants. These conditions meet the requirement for feasibility (Joint Committee, 1994).

Propriety. In the data collection, the surveys were anonymous and encompassed the entire student body, so the students retained their privacy despite providing demographic data (sex, race, and grade). In the focus group transcript, the redaction of teacher names and job titles preserved confidentiality. Identifying a teacher by subject and grade will spotlight the teacher and may inhibit responses if confidentiality is not guaranteed. These conditions establish the sensitivity of the instruments and the necessity for maintaining client confidentiality, thus meeting the requirement for propriety (Joint Committee, 1994).

Accuracy. Finally, to establish the condition of accuracy, the Likert responses have only four options. The respondents will either agree or disagree with a statement. There is no fence sitting. In the transcripts of the focus groups and interviews, the same or similar language should emerge to describe perceptions of the program. If in doubt about the meaning of a phrase, the researcher can follow up with an individual, or omit the phrase from the analysis. The results of the surveys and focus groups will provide a clear snapshot of the student interest, student self-efficacy, and teacher self-efficacy of

99

the school at the time of the investigation. Likewise, the evaluation itself will have a

shelf-life, most likely for the remainder of the school year. If the school uses the survey

instruments (or a version of them) consistently over the three years of each grades'

enrollment at the middle school, the instruments can provide a longitudinal study of

student and teacher perceptions as the program ages. These conditions promote accuracy

of the data collection (Joint Committee, 1994).

Research Site/Data Source

The research site for the program evaluation is a middle school within South

Carolina.   The school implements an activities-based program of STEAM study. This

differs from models which offer a STEM/STEAM curriculum or models which insert

STEM/STEAM lessons into traditional classroom instruction (Herro & Quigley, 2016).

However, it is a valid approach to STEM/STEAM implementation recognized by

accrediting institutions (SREB, 2017). The data collection instruments include an

administrator interview, teacher focus groups, surveys of teacher and students, and

classroom observations using the instruments described later in this chapter. The

interview, focus group, survey, and observation data will come directly from the students,

faculty, and administrators of the school. The administration of the evaluation

instruments will occur during school hours. Additional data will be collected through

document analysis of artifacts and school assessment documents (report card), which are

publicly available for examination on the Internet. Further documents and analysis may

emerge during the interviews, such as program manuals or documents unique to the

STEM program and school operations.

100

Participants

        The stakeholders in the program evaluation were the faculty and students in the STEAM program at the middle school. The term "stakeholders" refers to the "individuals or groups that may be involved or affected by a program evaluation" (Joint Committee, 1994, p. 3). The faculty within the school previewed the instruments in the program evaluation and contributed to modification of the content or composition of the instruments. The students took the student survey. As the focus of the entire evaluation, the students were the major stakeholders. Parents can play a significant role in student's decision to pursue STEM fields (Sjaastad, 2012), but have little influence in the implementation of a school-wide program.

Data Collection

        One framework to organize the data collection for the evaluation is the four-faceted framework found in the STEM Common Measurement System proposed by Saxton et al. (2014, p. 30). In this measurement system, the four lenses in which the evaluator collects, and analyses data include school supports or resources, professional development, teacher practices, and measures of student learning. This STEM Common Measurement System model starts with the large-scale view of the STEM program and eventually narrows down to the individual students participating within the program. It organizes the data collection into the four distinct compartments for data collection and enables the evaluator to ensure that the data collection instruments encompass all aspects of the program. Figure 2.3, found on page 80 of this thesis, depicts the dimensions of the STEM Common Measurement System (Saxton et al., 2014, p. 30).

School supports. In her examination of middle school principals leading STEM programs, Ferrara-Genao (2015) discussed business partners, district support, and funding as essential to support the STEM program. The principals she interviewed indicated that the search for funding is never ending. When a school receives a grant or donation to fund their program, they should already be working on the next source of funding. Federal grants end or they diminish in funding from year to year, so schools need to be creative in locating and obtaining funds. Foundations and local industry may serve as partners and funding sources.

The campaign to introduce the Common Core State Standards (CCSS) relied on funding from the Gates Foundation, the General Electric Foundation, and the William and Flora Hewlett Foundation (McDonnell & Weatherford, 2013). While the CCSS campaign eventually foundered, it was not because of inadequate funding. Similarly, to fund STEM programs, schools and school districts can form partnerships with local industries and foundations, which may double as sources of programmatic funding. There may be conditions, but if these conditions involve employment for our young scientists, engineers, and mathematicians, then they are worth considering.

Other school supports include district and school direction, funding, and assistance. This may involve providing enough professional development, structuring a school day schedule that facilitates work on projects, or simply leader involvement in the planning and implementation of the STEM/STEAM program itself. One construct that Ferrara-Genao (2015) identified and focused on in her work was the leadership of the building level administrators. Her research indicated that successful STEM/STEAM programs need supportive staff led by leaders who are knowledgeable and "passionate"

102

about developing a STEM/STEAM program that "meets the needs of all students" (Ferrara-Genao, 2015, p. 112). School and district leaders will be able to explain whether school supports are in place; however, the teachers will be the litmus for this construct. If teachers perceive they are supported by the school and district leadership, then school supports are enough. This perception may require the mythopoesis (Merriam-Webster online dictionary, n.d.) ability of the administrator; specifically, can the building level leader, the STEM/STEAM program's number one cheerleader, convince the teachers in the building of the worth of the program and the external support available?

Professional development. In their report, Nakamoto and Bojorquez (2017) used professional development and ongoing support of teachers in STEM as two of the criteria for their evaluation of the STEM program in Clark County schools. The emphasis on professional development is prevalent throughout the literature on teacher preparation for STEM instruction (Nakamoto & Bojorquez, 2017; Lesseig, Slavit, Nelson, & Seidel, 2016). Professional development for teachers who are responsible for STEM instruction has two levels; it begins during pre-service preparation and continues at the school level during the implementation of the STEM/STEAM program.

The first level of professional development begins with undergraduate and graduate teacher preparation programs focused on recruiting and training STEM teachers. There are currently numerous college programs that have taken to heart President Obama's challenge to recruit and train 100,000 STEM teachers by 2021 (Executive Office of the President: PCAST, 2010). The UTeach program at the University of Texas Austin is a highly regarded program, replicated at 44 universities in 21 states, that has demonstrated success in training teachers in science, technology, engineering, and math

instruction (Backes, Goldhaber, Cade, Sullivan, and Dodson, 2016). Another multi-school initiative in STEM teacher education is the Woodrow Wilson Fellowship program at six universities in Michigan (King, Lancaster, Defrance, Melin, & Cleveland, 2013). Some of these programs train the teachers to be integrated STEM teachers, while others emphasize becoming a science or math teacher.

The second level of professional development occurs at the schools that implement STEM curriculum. Generally, teachers receive some form of initial instruction in the implementation of STEM curriculum, instruction, and assessment, focused on the engineering design model. This may occur at a workshop of some kind, such as the Enrichment Experiences in Engineering (E3) program at Texas A&M, a four-week summer enrichment program that engages high school STEM teachers in engineering practices and instruction (Page, Lewis, Autenrieth, & Butler-Purry, 2013). The purpose of the E3 program is to prepare these teachers to return to their schools and integrate engineering practices into their core instruction. The proposed outcomes of the program are an increase in the professional knowledge of the teachers in the program, and increased exposure of the students to the engineering profession.

Following the initial training in STEM curriculum, instruction, and assessment, schools continue to train their teachers throughout the life of STEM education in the school. This may occur through an association with STEM instructors at a university, through offsite participation in conferences and training, or through in-house professional development and reflection. All these elements of professional development build teacher self-efficacy.

104

Teacher practices. Similarly, using best pedagogical practices appears frequently in the literature for STEM implementation. These practices include inquiry-based learning, effective use of instructional technology, emphasis on critical reasoning and debate, and computer simulations and robotics (Parker, Stylinski, Bonney, Schillaci, & McAuliffe, 2015; McDonald, 2016). Other teacher practices which emerge include relevant, hands-on experiences, a rigorous and challenging curriculum, and student-centered instruction. Many programs emphasize the universal design for learning (UDL), an instructional model used by special educators that emphasizes using multiple means of presentation, multiple types of activities and engagement, and multiple strategies of instruction (Burgstahler, 2012).

In their program evaluation of the middle schools in Clark County, Nevada, Nakamoto and Bojorquez (2017) collected empirical data on the availability and attendance of tutoring for students struggling with the subject material. In the Bridging the Valley program among four universities in the Shenandoah Valley, Kolvoord et al. (2016) documented the implementation and influence of collaborative learning communities in developing student resilience and persistence in completing the technical programs. In research on the retention of minorities in undergraduate engineering programs, Museus et al. (2011) found the programs with support groups, mentoring, and academic assistance were more successful than their counterpart programs that lacked student services. To assess whether our students are developing "grit," (Duckworth, 2016), it will be worthwhile to learn whether the students perceive there is help available from teachers, in the form of tutoring, encouragement, and advice.

Measures of student learning. The importance of relevant, hands-on experiences, a rigorous curriculum, and student supports cannot be over-emphasized. Relevant experiences provide the "hook" that attracts the students to the STEM fields, fields often thought too difficult or too boring to consider. Student supports consist of extra help in the academic challenges of the program (tutoring), the mentoring and positive role models provided by parents and teachers, and social activities involving STEM activities, such as the math team, the robotics club, or the debate team. Properly integrated, inquiry-based, student-centered learning, relevant, hands-on experiences, a rigorous and challenging curriculum, and student supports (academic, emotional, and social) contribute to student persistence and self-efficacy in STEM, and continued interest in the STEM fields (Museus, Palmer, Davis, & Maramba, 2011).

An intended side-effect of student self-efficacy is the recruitment of students into STEM education and professions, with a special emphasis on the recruitment of female and minority students. In fact, the official press release for President Obama's "Educate to Innovate" campaign for STEM included in its three overarching priorities the expansion of "STEM education and career opportunities for underrepresented groups, including female and minority students" (Office of the Press Secretary, The White House, 2009, para. 6). The focus of data collection for student interest will be to determine whether the STEAM program at the middle school contributes to student participation in further STEM education and eventually a STEM profession.

One component of the STEM program not specifically delineated in the STEM Common Measurement System is self-assessment and reflection. Most of the STEM education programs in the research have had some process for self-assessment of

106

program effectiveness, and a provision for modifying the program to meet student needs.

Table 3.1 contains the data collection instruments. It is a work-in-progress and will continue to evolve as the evaluation proceeds. In accordance with the STEM Common Measurement System framework, we will classify the data sources as school supports (SPT), professional development (PD), teacher practices (TP), or student learning (SL). Some data sources will provide information for multiple categories of the program.

Table 3.1. *Components of the Evaluation*

Data Sources	Number	Data Description	Data Collection Methods	Research Questions
School Profile (TP, SL)		Demographics of student and teacher population	Report Cards	RQ4
Students (SL)	255	Academic achievement	Standardized Test Scores	RQ4
Artifact Analysis (SL, SPT)		STEM program characteristics Evidence of student learning	Brochure Student projects School website Event agendas	RQ1, RQ4
Admin (SPT, PD, TP, SL)	1-2	Goals of program Program support Student interest Student efficacy Teacher efficacy Academic achievement Assessment/ reflection	Interview(s)	RQ1, RQ2, RQ3, RQ4

(continued)

107

Data Sources	Number	Data Description	Data Collection Methods	Research Questions
Teachers (SPT, PD, TP, SL)	14	Commitment to program Interest in STEM Professional development Student supports Assessment and reflection	Survey	RQ2, RQ3
Teachers (SPT, PD, TP, SL)	14	Student interest Student efficacy Student supports Prof. development Teacher interest and efficacy External supports Assessment and reflection	Focus Group(s)	RQ1, RQ2, RQ3
Students (TP, SL)	255	Student interest Student efficacy Student supports Likeliness to pursue STEM (studies, activities, career)	Survey	RQ1, RQ2
Students, Teachers (TP, SL)	2-3	Student interest Student efficacy Teacher efficacy Student supports	Classroom Observations	RQ1, RQ2, RQ3

Instruments

The specific instruments for the program evaluation are the student and faculty

surveys, focus group document, administrator interview, and classroom observations.

These instruments are included in this document as Appendices C through G. The

constructs for assessment with these instruments relate directly to the research questions. The constructs are *student interest* in STEAM, *student self-efficacy* developed during their participation in the STEAM program, and *teacher self-efficacy* in providing competent instruction in the STEAM program. Teacher self-efficacy arises from teacher confidence developed during professional development, planning for STEAM activities, and instruction using the principles of the Universal Design for Learning (Burgstahler, 2012) and the engineering design process.

Reliability and Validity

Reliability

According to Huck (2012), reliability refers to the consistency of the results for a variable within an assessment or other form of research instrument. In this program evaluation, we will gather the data from the surveys, focus groups, interviews, and observations within a relatively brief timeframe, perhaps several weeks. This circumstance rules out reliability based on multiple administrations of an instrument, or multiple raters of an instrument. However, the same constructs will occur in the different instruments, so there will be some comparison of measures for the constructs, referred to as alternate forms reliability. However, because it will be different to compare constructs measured in the Likert scale of surveys with the less precise comments of teachers in a focus group, or administrators in an interview, alternate forms reliability will be intuitive.

The most appropriate form of reliability with the Likert-scale instruments in the evaluation will be measures of internal consistency (Huck, 2012). There are two options for measuring internal consistency. In one, the researcher combines item means that are tied to a specific construct (student interest, student self-efficacy, or teacher self-efficacy)

109

to determine if there is consistency across items under a single construct. In the other option, the researcher measures each item in the surveys separately, but administers the surveys twice, with a month break in administration, to a control group of students, to see if their responses remain consistent. This is a form of test-retest reliability, that would break with the initial plan to administer the data collection instruments within a several-week span. This will depend on stakeholder cooperation and externally imposed time constraints.

Validity

Validity refers to the accuracy of the results (Huck, 2012). Specifically, does the instrument measure what it is supposed to measure? In an experiment, validity (accuracy of results) requires that the results are reliable (consistent), but reliability does not guarantee validity. To meet the epistemological requirements of a pragmatic evaluation, the evaluator shares knowledge with the participants. In this case, the faculty will preview the instruments of the evaluation prior to implementation and have an opportunity to recommend changes. This sharing of the evaluation instruments will ensure their content validity, or sense that the instruments measure the characteristics they are supposed to measure. This "face" validity is not a statistic in the truest sense, but rather the perception of the stakeholders that the constructs they perceive the instruments measure are indeed the constructs the instruments are designed to measure.

<div align="center">

Data Analysis

</div>

The data for the program evaluation included student and teacher responses from the surveys, the transcripts from the teacher focus group(s), classroom observation

records, the transcripts from the interviews of school administrators, school demographics, standardized test scores, and artifacts.

Surveys

The surveys contain statements with Likert scale responses (four) from "Strongly Disagree" to "Strongly Agree." The responses have increasing numeric values for each response, with "Strongly Disagree" assigned a score of one (1) to "Strongly Agree" assigned a four (4). The statements for the teacher survey (Appendix E) assess the constructs of teacher self-efficacy (Items 3 – 7), and student self-efficacy (Items 12 – 14). They also assess student supports, program supports, and data collection and analysis. For each of these constructs, the researcher compiled descriptive statistics (mean and standard deviation) and produced a graphical portrayal (bar graph).

The statements for the student survey (Appendix D) emphasize two constructs: student interest (Items 7, 8 and 12) and student self-efficacy (Items 2 – 5, 10, 13 and 14). The student survey also contains statements on student supports (tutoring, mentoring, and social activities). In their program evaluation of middle school STEM programs in Nevada, Nakamoto and Bojorquez (2017) cited research that emphasized the importance of student supports in establishing the conditions for program success. Student supports also factor in student resilience and persistence in completing undergraduate programs (Museus & Liverman, 2010; Museus et al., 2011; Kolvoord et al., 2016).

In the student survey, the students stated their demographic data (sex, race, and grade) before answering the survey questions. This facilitated the comparison of different sub-groups within the student population. All students enrolled in the

111

STEM/STEAM program took the survey, unless they returned the opt-out form signed by their parents and supplied to them before the survey administration. The students completed the online survey and all names were removed in the electronic system.

This allowed comparison of the mean and standard deviation of the different groups. Given the type of data collected, a nonparametric t-test was used to discern whether there are any statistically significant differences in student interest and self-efficacy between students based on sex and race. This is directly related to the second research question.

Focus Groups and Interview

For the focus group (Appendix C) and interview (Appendix F), the researcher transcribed the questions into a text document. Coded consistently, patterns in the teachers' responses emerged from the transcript of the focus group and interview. Coding analysis (Mertens & Wilson, 2012) enables the researcher to find phrases that consistently emerge across the data and categorize the data into segments of similarly phrased language from the different participants. Performing this coding and analysis facilitates the determination of any biases within the faculty, their commitment to the program, and their sense whether the program is accomplishing its goals. In the focus group, the researcher coded by counting the number of responses, assessing whether the teachers answered the question, and documenting responses using the same, or similar, words and phrases. Likewise, in the interview with the administrator, the researcher coded by assessing whether the administrator answered the question and then searching for language that supported a focus on student interest, student efficacy, and teacher efficacy.

Observations

During the instructional periods set aside for the students to work on their annual STEAM project, the researcher conducted 2-3 classroom observations. These observations were holistic snapshots of the school's STEAM program in action recorded on an observation instrument (Appendix G). The purpose of the observations was to gauge the validity of the data collected from the surveys, focus groups, and administrator interview(s). There may be a tendency for the students, teachers, and administrator to inflate their perception of student interest, student efficacy, and teacher efficacy on the data collection instruments. The observations will verify, or temper, these perceptions. The focus of the observations was on student interest in the STEAM project, their confidence in their implementation of the engineering design process and use of technology, and teacher behaviors. Teacher behaviors in a STEM/STEAM classroom include facilitation of the learning process, encouragement, and assistance of the students.

Table 3.2 contains a mapping of the data collection instruments and the four STEM dimensions from the STEM Common Measurement System (Figure 2.3). The constructs student interest and student self-efficacy are the two components of Student Learning. The construct of teacher self-efficacy corresponds to the Professional Development dimension.

Table 3.2. *Data Collection Instruments Mapped to STEM Dimensions*

Documents	Stem Dimensions				
	School Supports	Pro. Dev. Teacher Efficacy	Educator Practices	Student Learning	
				Interest	Efficacy
Appendix C Focus Group	7	4, 5	6, 8	1	2, 3
Appendix D Student Survey			9, 11	6, 7, 8, 12, 15	2, 3, 4, 5, 10, 13, 14
Appendix E Teacher Survey	11, 12, 16	3, 4, 5, 6, 7, 8	9, 10, 17		13, 14, 15
Appendix F Admin Interview	8	6, 7	5, 10	1, 3	2, 4, 9
Appendix G Observation		Instruction Facilitate	Encourage Assist	Interest	Confidence

The student standardized test scores and school demographics will provide
descriptive statistics for the school performance and school profile. The artifacts from
the school and students (STEAM brochure, projects, website, event agendas) will provide
evidence of student learning and school commitment to the STEAM program.

Research Ethics

The program evaluation in this study occurred within a public middle school in
South Carolina or Georgia, selected based on accessibility and convenience. To conduct
research within a public-school district requires a research proposal accepted by the
school district that establishes guidelines for the conduct of the research. These

114

guidelines establish parameters for access to the students and teachers, and discretionary requirements on the use of data collected during research. Consistent with these guidelines, the analysis withholds stakeholder names or other identifying characteristics when citing examples to support, or discredit, a hypothesis. Ultimately, the purpose of the program evaluation of a STEAM program at a middle school is to characterize the nature of the program and recommend strategies the stakeholders can use to improve the program. Using the data or observations gathered during the conduct of the evaluation in any manner that harms the program or betrays the trust of the stakeholders is repugnant and counterproductive.

Summary

The methodology explained the research design for a pragmatic, mixed method case study approach to conducting a program evaluation of a STEAM program in a middle school. As described, the design meets the Joint Committee's requirements for utility, feasibility, propriety, and accuracy (1994). The data collection plan encompasses the four dimensions of the STEM Common Measurement System (Saxton et al., 2014) and directly corresponds to each of the four research questions. The mapping in Table 3.2 illustrates this correspondence between the data collection items, the STEM dimensions, and the constructs of student interest, student self-efficacy, and teacher self-efficacy. The items in the collection instruments have face validity (Huck, 2012), and the use of quantitative measures with the Likert scale should allow for the computation of reliability. The next chapter will begin with a discussion of the research site, its appropriateness as a site for an evaluation of its STEAM program and conclude with the analysis of the results of the data collection. The product of this analysis is a snapshot of

115

the school's implementation of STEAM and research-based recommendations for

potential improvements to the program. Also, this evaluation may serve as starting point

for future program evaluations of middle school STEM and STEAM programs.

CHAPTER 4

FINDINGS

Introduction

The previous chapter concluded with the establishment of the program evaluation methodology and its connection with the literature on STEM/STEAM education and program evaluation. This chapter begins with a discussion of the research site and its suitability as a site for an evaluation of its STEAM program. It concludes with the presentation of the data from the five data collection instruments and the analysis of the data. As this is a mixed method evaluation, with both qualitative and quantitative data instruments, the analysis contains both narrative and statistical elements. The product of this analysis is an assessment of the school's STEAM program and research-based recommendations for improvement of the program. It may also contribute to the literature for STEM and STEAM programs, serving as a starting point for future program evaluations of middle school STEM and STEAM programs.

Description of Participants

Administrator

The school principal is serving her seventh year as the principal of the middle school (Novit, 2013) and her twelfth in education. An African American female, she began her career in education as the school counselor at this middle school. She subsequently spent several years as an assistant principal at another middle school in the district prior to returning to this middle school as its principal. With the STEAM

117

program since its inception at the middle school, the principal and a few of the teachers within the school serve as the institutional memory and guiding force for the STEAM program.

Teachers

Beginning in the 2018-2019 school year, the school district's board of education rezoned several areas in the school district (Wood, 2018), including the area in which the target school resides. Because of this rezoning, in the 2019-2020 school year the school grew by 70-80 students and added three new full-time teachers (New Ellen STEAM Magnet Middle School (NEMS) website, 2019).

There are 17 full-time teachers and two part-time teachers in the school, with a variety of expertise and professional education (NEMS website, 2019). The yearly turnover of faculty has been approximately two teachers per year in the last five years, often due to retirement. This turnover has injected new blood into the faculty, while a small group of teachers has remained, becoming the leadership for the STEAM program. Between the 2018-19 and 2019-20 school years, no teachers departed the school.

Students

According to the state report cards for the years between 2015 and 2019 (SCDE website, 2019), the student population fluctuated between 160 to 200 students. In the 2019-20 school year, the school grew 70-80 students to a population of approximately 270 students (NEMS website, 2019). The racial mix is equally distributed between the African American and white students, with a handful of Hispanic students. The school is a Title I school, with half to three quarters of the students eligible for free or reduced lunch. The tables below contain data on student achievement from statewide,

118

standardized assessments students have taken each spring for the past four years. This

data supports the discussion of the STEAM program's influence on student achievement

posed in Research Question 4.

Math achievement. The state's current measures of mathematics and English

language arts achievement for middle schools are the South Carolina College and Career

Ready assessments, referred to as the SC READY. For the period 2016-2019, the

school's math scores on the SC READY are included in Table 4.1 (SCDE website,

2019).

Table 4.1. *Math Scores for Targeted Middle School*

	2016 Exceeds or Meets Expectations (n = 185)	2017 Exceeds or Meets Expectations (n = 166)	2018 Exceeds or Meets Expectations (n = 174)	2019 Exceeds or Meets Expectations (n = 195)
School	24.9%	33.1%	35.1%	34.4%
District	26.0%	28.6%	29.9%	31.8%
State	35.5%	36.5%	38.1%	38.7%

In the math scores, school-wide math performance on the SC READY increased

between 2016 and 2019. In the 2016-2017 and 2017-18 school years, the school closed

an achievement gap with its district and the state. In testing populations of 160 to 200

students, the school's yearly increases in math achievement may be due to year to year

fluctuation. However, the growth from 2016 to 2019 is 9.5%. For the 2019 testing

population of 195 students, an increase of 9.5% translates to an improvement of math

scores for 19 students.

Science achievement. The school's measure of scientific achievement is the South Carolina Palmetto Assessment of State Standards, commonly referred to as the SC PASS. The school's SC PASS scores for the period 2015 to 2019 are in Table 4.2 (SCDE website, 2019).

Table 4.2. *Science Scores for Targeted Middle School*

	2015 Met or Exemplary (n = 183)	2016 Met or Exemplary (n = 189)	2017 Met or Exemplary (n = 166)	2018 Met or Exemplary (n = 118)	2019 Met or Exemplary (n = 121)
School	51.4%	48.1%	55.4%	63.6%	59.5%
District	56.6%	58.6%	43.1%	47.3%	53.0%
State	65.7%	66.3%	48.0%	49.4%	49.1%

In the 2017-2018 school year, the cohort of students who take the PASS changed, removing the seventh grade from the science testing cohort. This explains the drop in testing population midway through this set of data. Instead, the seventh grade took the social studies PASS while sixth and eighth grades took the science assessment. In science scores, school-wide performance on the SC PASS did not increase every year between 2015 and 2019. However, school performance increased 8.1% during this period. For the 2019 testing population of 121 students, an increase of 8.1% translates to 10 students. Of note, during this same span, district scores declined 3.6% and state scores dropped 16.6%.

English language arts achievement. During the period 2014-19, the middle school English language arts (ELA) tests have changed several times (SCDE, 2019), like the middle school math test. However, in the last four years, the test for ELA has

120

remained the SC READY. These four years represent a consistent measure of the

literacy of the students (SCDE, 2019).

Table 4.3. *English Scores (SC READY) for Targeted Middle School*

	2016 Exceeds or Meets Expectations (n = 185)	2017 Exceeds or Meets Expectations (n = 164)	2018 Exceeds or Meets Expectations (n = 175)	2019 Exceeds or Meets Expectations (n = 195)
School	34.6%	39.6%	46.3%	42.1%
District	37.8%	31.7%	34.9%	38.2%
State	42.1%	38.7%	39.7%	43.2%

Between 2016 and 2019, school performance on the ELA SC READY increased

7.5%. In a testing population of 195 students this corresponds to an improvement by 15

students on the ELA assessment. District and state scores also improved over this period,

but only by .4% and 1.1%, respectively.

During the past four years, the middle school has improved its achievement in

mathematics, science, and English language arts on the statewide tests. The 2018-19

school year corresponded to the school's fifth conducting the STEAM program and the

principal's sixth as the school's leader. After five years under the leadership of a single

principal and a stable faculty, the emphasis on critical thinking, collaboration, and

communication which are the hallmarks of STEAM education have become embedded in

the school's culture. In her dissertation on middle school STEM programs, Ferrara-

Genao (2015) remarked on the coincidence of inspired building leadership, dedicated

faculty, faithful conduct of the STEM program, and successful schools. The scope of this

121

dissertation does not predict school academic success based on rigorous implementation of the school STEAM program; however, if school achievement continues in step with the maturity of the STEAM program, and under the supervision of an inspired building principal working with a dedicated faculty, there may be a case for attempting to establish an association.

Description of the Study Site

The middle school for this study is a small, rural middle school in the western side of South Carolina. It is approximately 20 miles East of Augusta, Georgia and positioned on one of the northern entrances to the Savannah River Site (SRS), a federal nuclear facility. Built in 1996, this school and its sister middle school originally relied on SRS as the area's major employer. This has changed in the last decade, as the site has faced budgetary cuts and threat of elimination. The school is a community school, taking its name from the local town and competing with SRS as a major employer in the area. Most of the parents, and many of the grandparents, attended the school, and several teachers live in the community. Communication between the school and the families is frequent and cordial. In fact, during the 2017-18 STEAM project, in which the students attempted to discover "patient zero" for a mysterious disease afflicting the school, parents in the car line and at after school events queried teachers and administrators to discover the identity of "patient zero" (NEMS website, 2019).

The school's mission statement identifies their reason for implementing a STEAM program. Specifically, the mission statement indicates the school will be "a school of academic excellence that fosters academic achievement through innovative teaching practices, which will include the infusion of Science, Technology, Engineering,

122

Arts, and Math" (NEMS website, 2019). The specific goals for STEAM program implementation are grade level technology guarantees, based on the International Society for Technology Education (ISTE, 2018) standards for students. Sixth graders work on the ISTE goals for becoming an empowered learner and digital citizen. The seventh grade works on the standards for becoming knowledge constructors and computational thinkers. In the eighth grade, students work towards becoming innovative designers, creative communicators, and global collaborators. As the capstone for their work with STEAM, eighth grade students conduct an exit conference with a panel of stakeholders, including an administrator, teachers, parents, and local partners. In this conference, the students use evidence from their STEAM experiences to present a portfolio of their work that demonstrates achievement of the technology guarantees.

Description of STEAM Program

The middle school is in its sixth year of STEAM implementation. During the 2018-19 school year, the school graduated its third set of eighth grade students who had completed three years in the program. According to the technology guarantees (NEMS website, 2019), these students should be competent in the seven ISTE standards for students (2018). This is an ideal time to begin tracking graduates after graduating the school to determine whether participation in the STEAM program is influencing their subsequent education and career choices.

The school received STEM certification through the Southern Region Education Board in the fall of the 2017-2018 school year. Additionally, in the 2016-17 school year, the graduating eighth-grade class became the first group to complete the STEAM program. According to the school's technology guarantees, these students graduated the

123

middle school with competence in the seven ISTE standards for students (ISTE, 2018). This is a critical point in the school's STEAM program. The administrators and faculty have an opportunity to revamp and recycle projects, applying lessons learned, with the knowledge that the students participating in the projects will not have seen them before. Also, they may want to begin to track the graduating eighth-grade classes, through high school, college, and into the work force. The purpose of tracking graduates would be to gauge the impact of the STEAM program on student education and career choices.

The school uses a school-wide, project-based model. Rather than have a dedicated STEAM course, the entire school completes a project together at some point in the school year. This is a side effect of the small school size, the limited number of teachers (n = 17), and the lack of a STEAM budget. Consequently, the teachers develop, implement, and grade the projects in-house. The teams with the highest scores, according to the grading rubric, present their projects to a panel of judges, consisting of teachers, parents, and STEAM partners. Recent projects include The Great Escape (Wood, 2016), in which the student teams designed a vehicle to escape a dying planet. The project during the 2017-18 school year was identifying patient zero (Wood, 2017), in which the student teams worked together to address a mysterious illness in the school and attempt to identify the student or faculty member who brought the illness into the school.

In the 2018-19 school year, the school did not complete a school-wide project. However, in November 2019 the students and faculty worked through Project IMPACT, in which the students chose from a variety of global dilemmas, such as homelessness or animal cruelty. Within their groups, teams of students used the Engineering Design Process to research and propose solutions to these issues.

124

While these projects are the capstone of the school STEAM program, they are not the only evidence of STEAM implementation within the school. During the fall, sixth grade students attend a STEAM boot camp for several weeks, in which they learn the engineering design model and participate in several STEAM mini courses. These mini courses include the construction of toothpick sculptures, project runway, a cardboard tube marble race, the crash test into STEAM, and a wicked fast water slide (NEMS website, 2019). During the school year, the students also sign up for exploratory courses, which often support the school's STEAM orientation. Several of the courses listed on the school's STEAM brochure (2016) include Girls in Engineering, Intro to Coding, Multimedia Design, and STEM 101. Other activities that support the school's STEAM focus include STEAM open house events, field trips, speakers, and a mentorship program in which STEAM partners work with individual students.

Data Collection and Analysis

The data collection at the middle school occurred in two phases. During the 2018-19 school year, the school-wide STEAM project was to occur in October and November 2018. In preparation for this event, the researcher conducted the first three data collection instruments documented in Chapter Three: the interview with the principal, focus groups with teachers, and an online survey of all teachers. The observations of the STEAM project implementation in the classroom and the student survey were to occur during the school-wide project and after project completion, respectively. Unfortunately, the faculty was unable to complete preparation for the project during the 2018-19 school year. The actual implementation of the project occurred in November 2019, during the 2019-20 school year. Consequently, the

125

researcher completed data collection using the final two instruments, a student survey and classroom observations, during November 2019.

With participant permission, the researcher recorded the interview and focus group sessions. The survey delivery occurred using email and Microsoft Office 365, and all responses from teachers and students are anonymous. The classroom observations were of classes in the school participating in the school-wide STEAM project. Listed below are the summaries and statistical analysis of the data collection instruments as they occurred. The actual survey instruments, interview and focus group questions, and transcripts of conversations are included as appendices.

Administrator Interview

The interview with the principal occurred on October 19, 2018, in the principal's office. During the interview, the principal responded to the 10 questions in Appendix F. The transcript of her responses is in Appendix I. Each question corresponded to the STEM dimensions in the STEM Common Measurement System (Saxton et al., 2014) and aligned with the research questions for this evaluation. Rather than list the questions and principal's responses in order, they are listed in order of their alignment with the STEM dimensions and research questions.

Student learning. The STEM dimension of student learning naturally splits into two facets that address the first two research questions: student interest (Research Question 1) in STEAM education and professions, and student self-efficacy (Research Question 2) in STEAM knowledge and skills. This second question is focused on female and minority students, two populations traditionally underrepresented in STEAM fields.

126

Beginning with student interest, principal responses to Questions 1 and 3 are presented below.

Question 1: What are the goals of the STEAM program and why has the school become a STEAM school?

In her response to Question 1 on the goals of the STEAM program and the reason the school has accepted the STEAM mission, the principal explained the initial goal of the program was "to increase our enrollment." She elaborated that since becoming a STEAM school, the program has grown roots," becoming a "fundamental part" of the school culture. The reason for the continued evolution of the STEAM philosophy in the school has become a quest to become "a school without walls." In this open environment focused on inquiry-based learning and a deep understanding of technology, students develop twenty first century skills and prepare themselves to enter the work force of the future. This rationale is in synch with the mandate of the Obama administration's "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009). What began as an effort to recruit students to the school, has grown into a mission to "broaden the horizon of our students," "deepen their knowledge," and become the mathematicians, scientists, artists, engineers, and computer experts of the twenty first century.

Question 3: From your perspective, have students who have participated in the STEAM program become more interested in the STEAM professions?

The principal responded affirmatively to this question, adding that the school is a STEM- accredited school which has adopted the fundamental focus of AdvancEd. She further explained that this means the school is "supposed to do outreach for those

demographics that are underserved in the STEAM professions. Those are minorities, people with disabilities, and women, or girls."

In addition, the principal explained the important role of a career counselor who facilitates students' development through activities such as field trips, speakers, and career days. Yet, she also shared the difficulty of finding diverse female engineers. She identified several strategies used to achieve this goal, such as reaching out to the Women in Engineering Association. She bluntly explained the school focus on increasing participation by females in STEAM, "I need some African-American, women engineers. Most importantly, I have an increasing population of female, Hispanic girls, and I want them to see somebody that looks like them. That's so powerful."

One of the factors Reiss and Mujtaba (2017) emphasized in their research was that students understand that STEM and STEAM careers are beneficial and viable. The principal highlighted this when she described the goal of the STEAM program as "broadening the horizon of our students," allowing them to "make references" and "deepen their knowledge" of the content in their classes by the adoption of the engineering design process. Her reference to a "school without walls" is particularly powerful when it becomes clear that the "walls" she is referring to are the "walls" erected by student misperception and lack of knowledge of the STEAM fields in the greater world surrounding the school.

The principal illustrated the school's efforts to build interest in the STEAM professions by listing the numerous venues the school pursues. These efforts include short-term endeavors, such as speakers and field trips, and long-term efforts, in which the students work closely with a teacher or STEAM professional for an extended period.

128

These long-term efforts include clubs, such as Cyber Patriots, and classes, such as the

Girls in Engineering. These long-term efforts are particularly effective, when the

students get the opportunity to work with positive role models, or "definers" (Sjaastad,

2012), for an extended period. While the research downplays the value of short-term

efforts to expose students to STEAM fields (Banerjee, 2017), bringing in a Hispanic or

African American, female engineer to a school with a large population of female minority

students could be a powerful experience. This would be particularly powerful if the

school is able to partner with the female, minority STEAM professionals in the

community for an extended period.

Student self-efficacy refers to a student's perceived knowledge and skills.

Questions 2, 4, and 9 refer to student self-efficacy, the focus of the second research

question.

Question 2: How do you make sure the students know what STEAM is and the reasons
they are in a STEAM program?

The principal's response to Question 2 reaffirmed school-wide commitment to the

STEAM program. For example, the principal explained

Our students, when they walk in, they're STEAM students, all of them.

How we make that students know what STEAM is, is that every year we

have a boot camp. We start with a boot camp. It starts in September and

it talks about what STEAM is, STEAM looks like, the principles of

STEAM. We talk about the metacognition piece, reflecting, thinking

about your own thinking, growing them personally as students, helping

students take ownership in their learning. Growing in that aspect.

129

As the principal explained, the faculty and administration immerse the students in the STEAM program, beginning with the boot camp, continuing with course work and extracurricular activities, and culminating in a school-wide project.

The principal also explained how vital technology was to the STEAM focus of the school. She stated that technology is "the driving force of our school. We have certain principles, when you're a student as a sixth grader, when they leave sixth grade, they have this skill set, the technology guarantees." Reflection and student ownership of learning are also emphasized as key components of the STEAM program. The school is guided by the ISTE technology standards and adheres to an overall technology guarantee and focus on instruction and student learning. Specifically, the principal explained,

> This year what we did, we felt that seventh and eighth grade were seeing
>
> the same thing over and over and were ready for a step up. Sixth grade
>
> had the generic – this is what you do. The seventh and eighth grade we
>
> focused more on the aspect of the technology guarantees. We also talked
>
> about the fundamentals of STEAM and what that is because we recognize
>
> that we also have new students that enter in. Everybody does boot camp.
>
> We all move together as a school.

Question 4: How has student perception of their self-efficacy in STEAM knowledge and skills changed since their involvement in the STEAM program? Has there been a change in the perceived self-efficacy of females and minorities involved in the program?

In her response to Question 4, the principal provided her impression that student self-efficacy grows during the students' three years within the STEAM program. This is based on her observations of the three different classes performing the STEAM projects. She noted that she sees "the STEAM skills, that skill set … confidence and self-efficacy,

130

especially in our eighth-grade students." Although she did not discuss differences between the races, she gave an anecdote from the last school year in which sixth grade Girls in Engineering class formed the school's Cyber Patriots club, winning awards in their first competition. This is evidence of a deliberate effort to level the playing field for females and minorities.

Question 9: Has the implementation of the STEAM program improved student achievement in science and math? Does the data support this?

In responding to Question 9, the principal asserted that the data supports an association between student participation in a STEM or STEAM program, and student achievement (Research Question 4). In this case, student performance in statewide standardized tests of math, ELA, and science had improved for three years running (SCDE, 2018) and the principal acknowledged this. However, she did not attempt to infer a causal relation between participation in STEAM and student achievement. Her response focused on building student "stamina and grit," mastering the concepts, and explaining to students the reasoning behind the instruction. One of the concepts she emphasized was allowing the students "struggle time." Her explanation is clear and illuminating.

Sometimes struggling to figure it out, thinking about putting those

connections together, asking your neighbor, seeing what they're doing,

and pulling it together. That's more than a teacher would ever tell you.

You would get more out of that than that teacher just giving you the

answer.

Duckworth's (2016) research on grit emphasized the importance of developing student perseverance, or grit, as an attribute necessary for prolonged success. Cheryan,

Ziegler, Montoya, and Jiang (2017) also emphasized developing persistence, or grit, as a necessary ingredient for students, particularly underrepresented populations, to develop the self-efficacy they will need to succeed in STEAM studies and STEAM professions. Perseverance, or grit, is one of the defining characteristics in student self-efficacy. The principal clearly understands her student population and is working with her teachers to establish the conditions in which grit will blossom, and student achievement will follow.

Professional development/teacher efficacy. The third research question explores the relationship between teacher participation in professional development on STEM/STEAM and their confidence in their own efficacy at teaching the STEAM curriculum. Questions 6 and 7 address the professional development of teachers and their teaching efficacy.

Question 6: How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students? What are your current and future needs for professional development?

In her response to Question 6, the principal described teacher confidence as "through the roof." Specifically, teachers are using technology not as a "dictionary," but rather as a "tool to extend knowledge, deepen knowledge." They are referencing the ISTE technology guarantees in their instruction, discussing meta-cognition, and referencing different disciplines to "deepen student learning." The primary driver for this evolution has been the initial professional development the school undertook prior to embarking as a STEAM school, and the ongoing discussion between teachers in their professional learning communities. The initial professional development took the form of book study and STEM/STEAM school visits. It is evolving as the school's program evolves. This particular response begins to address the third research question, whether

professional development has influenced teacher confidence in providing STEAM instruction. Teacher responses in the focus groups and the STEAM survey, and teacher instruction during classroom observations will provide a more comprehensive indicator of the influence of professional development on teacher efficacy.

Question 7: Has participation in the professional development, and in implementing the STEAM curriculum, influenced your teachers to adjust their instructional practices? If so, in what manner and in what circumstances have they adjusted their instruction?

In her response to Question 7, the principal noted the professional development and ongoing professional learning communities have influenced a change in the language of instruction. The teachers make STEAM connections in each lesson and explain "how what you do in one class is relevant in another." Every lesson begins with an activator that makes a real-world, STEAM connection with the day's learning objective. Specifically, "with my demographics, my kids need to see the why in it." Additionally, the teachers have trained to provide the school's ISTE-based technology guarantees the students master by the end of each grade. In the principal's perception, this specific emphasis on technology, STEAM connections, metacognition, and precise STEAM language has moved the school toward becoming a "school without walls."

Educator practices. Questions 5 and 10 explore teacher practices that promote the STEAM instructional program. Although these questions are not specifically related to the research questions, they examine teacher behaviors that contribute to school climate, and are a legitimate dimension in the STEM Common Measurement System (Saxton et al., 2014). Additionally, school interventions (Question 5) assist students in growing their self-efficacy, stamina, and persistence. Question 10 seeks to determine

whether the school has attempted to determine student long-term success in STEM/STEAM.

Question 5: What interventions does the school employ to increase student knowledge, ability, and persistence (self-efficacy)?

In their article on recruiting students to the undergraduate engineering programs of four universities in Virginia's Shenandoah Valley, Kolvoord et al. (2016) discussed the academic supports necessary to enable prospective engineers to survive the rigorous engineering programs of the schools. These supports include tutoring, establishing collaborative learning communities, faculty mentoring, and encouragement. These themes resonate in the literature on building student persistence in rigorous programs of study in STEAM fields (Museus and Liverman, 2010; Museus et al., 2011; Griffin et al., 2010).

In her response to Question 5, the principal discussed the supports the school provides the students, which include tutoring, time to catch up on missing work in the "Catch Up Café," and her personal mentoring of students. In these mentoring sessions, the principal meets with students from each grade level to inform her of "stumbling blocks are in their way." This allows the principal to develop "powerful" relationships with her students and build trust. In a small, rural middle school, the relationships between the adults and the students have a positive influence on student success. Additionally, these relationships contribute indirectly to the success of student interest, student efficacy, and teacher efficacy referred to in the first three research questions.

The principal also discussed the school response to student success and student effort on their tests of academic achievement, such as quarterly benchmarks in academic subjects. The principal, faculty and students set goals for achievement, and celebrate the

accomplishment of those goals. The principal had this to say about goal setting and achievement. "I think it is important for us to bring that full circle. You set your expectations. You monitor them. You do all these things, but at the end of the day you … celebrate."

Question 10: What is your plan for collecting and analyzing student data? Do you plan to track students through high school and beyond? How will you use the data you collect?

In her response to Question 10 on tracking student data through and beyond the students' three years in the school, the principal discussed her use of student performance data while students are at the school. She and her faculty monitor student achievement on local assessments, such as the reading inventory and math inventory, and statewide assessments, such as the SC Ready and SC PASS tests. They use this information to adjust instruction and group students. She acknowledged that she has not collected data on her students following the program. In her words, "It's difficult when you don't have control. When you're leaning on someone else to give you that information."

In his "Educate to Innovate" campaign, President Obama specifically emphasized growing the engineer work force and the engineer training programs in the country (Office of the Press Secretary, The White House, 2009). The long-term goal is to keep the engineering and technology work force viable and relevant, sustaining the country's competitive edge in technology. To accomplish this requires graduating engineers, mathematicians, and scientists. In this instance, the journey begins in a middle school in rural South Carolina. The first step is to track the students through the middle school. The principal discussed having the students take a "career assessment at the beginning of the school year and then after we employ all of our curriculum and things of that nature."

The next step is tracking the students beyond the middle school. This would provide the principal and her teachers with an indication whether the STEAM program is having a lasting impact on student interest and efficacy. It would also assist the school in adapting the program throughout its life cycle..

School supports. Question 8 examines whether the school perceives that it has external support from the school district, state, and partners. Again, while school supports represent a dimension in the measurement system, this question is not specifically related to one of the research questions. However, external support is essential for a STEM/STEAM program to exist and prosper.

Question 8: What are the challenges in implementing an effective STEAM program? Is district and state support available and adequate?

In her response to Question 8, the principal identified the challenges to running a fully comprehensive STEAM program.

It's not just a moment in time. It's something that you have to work on

constantly and you have to stay ahead of it. And it's fully involved. You

have a program that's comprehensive and fully involved, and you have

district initiatives that you have to work out at the same time.

This response is indicative of the dual requirements of STEAM education and academic achievement the school faces.

In her study of three middle school STEM programs and their leaders, Ferrara-Genao (2015) noted that running STEM programs is resource-intensive. One of the principals she interviewed remarked that when you have secured a funding source, it's time to begin looking for the next fund source. In her response to the resource component of Question 8, the principal noted that the district supports the program, but

not the state. The school is reliant on Title I funding and whatever discretionary monies the school receives from the school district. The principal did identify an "ADC grant" that the school's art teacher has procured for the arts aspect of the STEAM program. At some point, the school may want to research and acquire grant money to source more technologically sophisticated projects for the school and establish a baseline of technology and equipment to use in its STEAM program.

Teacher Focus Groups

Following the principal interview, the researcher met with teacher focus groups. The data collection for the teacher focus groups occurred on October 30, 2018. After coordinating with the principal, the researcher met with the grade level professional learning communities, limiting the group time to 30 minutes. The sessions occurred during teacher common planning periods and the principal wanted to ensure the teachers had some time to collaborate after the focus group. The focus groups met in teacher classrooms and the researcher asked the focus group questions in Appendix C. The transcript of the student focus groups is in Appendix J. The data from these sessions informed the discussion on Research Question 1 (student interest), Research Question 2 (student efficacy), and Research Question 3 (teacher efficacy).

During the focus groups, the researcher took notes and recorded the sessions. Following the groups, the researcher transcribed the questions into a text document. After the focus groups concluded, the researcher coded the transcripts, searching for patterns in the teachers' responses that emerged during the discussion. During this coding analysis (Mertens & Wilson, 2012) consistent phrases emerged across the data that enabled the researcher to categorize the data into segments of similarly phrased

137

language from the different participants. Performing this coding and analysis uncovered biases within the faculty, their commitment to the program, and their sense whether the program is accomplishing its goals.

The teacher responses occurred in three focus groups of four teachers each. In order to protect the confidentiality of the participants, the researcher assigned the responses for each respondent a random alpha-numeric identifier. The groups met in order of grade – sixth, seventh, then eighth grade. In the transcript, the grade order is random in each section; however, the responses for each grade remain together. This is because in several instances, the teachers in a group responded to each other, or elaborated the response of the previous respondent. These exchanges would be lost if the teacher responses were randomized.

Student learning. Like the principal interview, the questions on student learning naturally split into the topics of student interest in STEM/STEAM (Research Question 1) and student confidence in their academic ability (Research Question 2). Question 1 addresses student interest, Questions 2 addresses student efficacy, and Question 3 addresses the interest and self-efficacy of females and minorities. President Obama's administration specifically targeted females and minorities in its "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009), and they represent a significant proportion of the student population of the middle school.

Question 1: From your observations, have students who have participated in the STEAM program become more interested in the STEAM professions?

The teacher responses to Question 1 on student interest in STEM/STEAM (Research Question 1) were consistent across the three focus groups. Nine of 12 teachers responded to the prompt, all but one of them citing the exposure to science and

engineering the program is providing to the students. The teachers used some form of the term "exposure" four times, but also mentioned the "door" to the outside world provided by STEAM instruction, opening student eyes to STEAM opportunities, and making them aware of potential career opportunities. Three teachers referred to the school's Girls in Engineering class as an agent for exposing female students to engineering and the other STEAM professions. Two of the teachers mentioned students developing an actual interest in STEAM, most confining their comments to the exposure to STEAM professions the program affords the students.

Question 2: How has student perception of their self-efficacy in STEAM knowledge and skills changed since their involvement in the STEAM program?

Five teachers responded to Question 2 on student self-efficacy since involvement in the STEAM program(Research Question 2). Four of the five teachers indicated that participation in the STEAM program has improved student confidence in their abilities. One of the teachers (R36) mentioned that after participating in the program, students "have a different perspective or different ideal" from students not exposed to the STEAM curriculum. Two of the teachers (X58 and Y89) specifically mentioned improved "confidence" in the students after participating in the STEAM program. One teacher (J38) did mention that involvement in the STEAM program may be hindering learning, stating "They're creative but they don't know how to start." Overall, this is not an overwhelming endorsement of the STEAM program's ability to influence student self-confidence, but it may indicate reluctance to make claims that may not be supported by student achievement.

Question 3: How has participation in the STEAM program influenced the interest and self-efficacy of females and minorities involved in the program?

There were seven responses for Question 3, which deals with student interest and efficacy of females and minorities (Research Question 2). Of the seven responses to Question 3, four of teachers addressed student efficacy, or confidence, in their academic abilities. Their comments referred to student confidence, empowerment, and the influence of the STEAM program on the students. Six of the teachers cited the Girls in Engineering classes the school offers and explicitly mentioned the interest and engagement of the school's female population in the STEAM curriculum and activities. This involvement of the females in roles stereotypically assumed to be male professions "boosted their confidence" in their abilities. Only one teacher (R36) mentioned minorities, explaining that she did not hear much about minority interest in STEAM in her classes.

This absence of comments on minority interest in STEAM may indicate a gap in the STEAM program's response to student needs, or it may indicate the absence of the need for an explicit focus on improving minority interest in STEAM. The results of the student survey (Appendix D) will indicate whether there is a gap in interest between the school's racial groups and the need for a corresponding response from the faculty.

Professional development/teacher efficacy. Questions 4 and 5 target teacher professional development and teacher sense of self-confidence in providing the inquiry-based, technology-rich STEAM curriculum they provide in the school (Research Question 3).

Question 4: How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students?

In response to Question 4 on the influence of professional development on teacher confidence in teaching the STEAM curriculum (Research Question 3), there were six responses; however, only two responses indicated that professional development has had a positive impact on teacher instruction. These two responses came from teachers (G99 and X58) who have been with the school since the initial training the school received on STEAM at the beginning of its time as a STEAM school. These two teachers indicated that the professional development helped them in making connections with their subject and explaining the reasoning behind their instruction. Of the other four responses, two of the newer teachers (A57 and B92) indicated an absence of professional development on STEAM instruction, at least during the school year. These responses indicate an opportunity to present professional development to solidify faculty understanding of the inquiry-based, technology-focused instruction required in STEM/STEAM programs. In the words of one of the newer faculty members (B92) regarding professional development on STEM/STEAM instruction, "I could still use some."

Question 5: What are your current and future needs for professional development?

In response to Question 5, which queried the teachers to identify theirs needs for professional development, the teachers indicated there is a "boot camp" before the school year for new teachers. During the boot camp, the new teachers review a book on STEAM and receive instruction on the STEAM process. As they discussed the needs for professional development on STEAM, the teachers digressed into discussions of art integration in the core subjects and the differences between project-based learning and STEAM instruction. One of the teachers (Q10) indicated a need for professional

141

developments to "tie" the different disciplines together. One of the newer teachers (B92) was unaware the school completed a school-wide STEAM project each year, since the school had not initiated the yearly project at the time of the focus group. Another (I91) queried the existence of professional development on STEM/STEAM, "I don't think we've ever really had a professional development, have we?" A peer (L77) who was in the school at the launch of the STEAM program explained the professional development the faculty received at the time. However, this teacher indicated the need to keep professional development a "high focus" in future planning for the STEAM program.

Although there were several lively discussions regarding the implementation and impact of the STEAM curriculum during the responses to Questions 4 and 5, there was little actual discussion overall of the influence of professional development or teachers' needs for professional development. This is a situation the principal and lead teachers may want to consider as they conduct planning for STEAM implementation in the school.

Educator practices. Questions 6 and 8 address teacher practices that enhance the STEAM experience within the school but are not directly linked to one of the research questions. Question 6 inquires whether involvement in the STEAM program has influenced teachers to adjust their instructional practices in general, perhaps becoming more facilitative and comprehensive, adapting the "school without walls" mentality the principal mentioned as a driving characteristic for a STEAM school. Question 8 directly inquires whether the school is collecting data on students after they have graduated the middle school, using it to determine the long-term influence of the school's STEAM program. Specifically, has the school's STEAM program contributed to growing the

STEM/STEAM work force, the driving impetus to President Obama's "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009)**?**

Question 6: Has implementing the inquiry-based, student-centered STEAM curriculum caused you to adjust your instructional practices, during the STEAM projects and in your regular classes? If so, in what manner have you changed your instruction?

Six teachers responded to Question 6, on whether the teachers have changed their instructional practices due to implementation of the STEAM curriculum. This represents half of the teachers in the focus groups. Although not directly related to Research Question 3 on teacher self-efficacy, the implementation of the STEAM curriculum has influenced the teachers to create a more student-centered classroom. Three teachers referenced making the "STEAM connections" the school has adopted in its lesson plans. Three of the teachers referred to implementing "inquiry-driven" learning, with more student interaction and hands-on activities. So, while the responses did not indicate whether teacher confidence has grown, they did indicate that teachers have become more reflective on their instructional practices, focusing on student learning rather than instruction.

Question 8: What is your plan for collecting and analyzing student data, in the short term, and as students exit the program (through high school and beyond)? How will you use the data you collect?

There were five responses to Question 8, which addressed the school's plan for collecting data on the students, in the short-term and in the long-term, after the students have left the school and are progressing through high school, into college and the work force. These responses addressed the collection of short-term data from the students, with the school's technology guarantees, digital portfolios, and exit interviews. When asked about long-term data collection, the teacher responses were tentative. One of the

teachers (I91) simply stated, "I have no idea about high school and how you would get that (data)." These responses regarding long-term data collection mirror the principal's response, although the principal seemed to realize the need to collect longitudinal data from exiting students.

While Question 8 does not relate to any of the research questions, it does address the need for collecting and analyzing data in any school-wide program. The faculty can use this data to adjust or reorient the program as needed. Further, collecting data on the students' long-term education and career choices reflects on the long-term nature of the STEAM campaign. When the Obama administration initiated the "Educate to Innovate" campaign in 2009, the goal was to increase participation in the STEM work force. Correspondingly, the success of the school's STEAM program will rely on the students' long-term educational and work force choices. Collecting data on these choices makes sense.

School supports. Question 7 enquires about the challenges the teacher and school face in implementing the STEAM curriculum. While it doesn't directly concern one of the research questions, the intent of the question is to gather information on school climate and the greater academic environment in which the school operates.

Question 7: What are your challenges in implementing effective STEAM instruction?

The nine teacher responses to Question 7, on the challenges to implementation of the STEAM curriculum, split between logistical considerations and the students' conceptual understanding of the STEAM curriculum. Five of the responses addressed the lack of time, or a variation of time, to effectively implement the STEAM curriculum and the traditional subject areas. In one teacher's words (G99), the primary challenges are

144

"time and money." The other consideration of the teachers was the challenge of providing an environment in which the students develop conceptual understanding on their own. One of the teachers (R36) described this as a struggle for the students to set aside rote memorization in favor of making their own connections regarding the underlying meanings in the material. Another teacher (B92) described this struggle to understand "the why, the significance of what they're trying" to learn. These responses from the teachers indicate a faculty that is diligently trying to implement the STEAM curriculum but has some concerns about conflicts of interest.

Teacher Survey

Following the principal interview and teacher focus groups, the researcher administered the STEAM surveys to the faculty. Thirteen of 14 teachers in the faculty voluntarily completed the anonymous, online survey. The teacher survey (Appendix E) was a 17-item Likert scale survey of the teachers that queried them on teacher perception of their efficacy in STEAM instruction, educator best practices, student efficacy after participation in the STEAM program, and school support of the STEAM program. Items 4 through 15 require the respondents to answer one of four alternatives, from strongly disagree (value = 1) to strongly agree (value = 4). To keep teachers from selecting one answer consistently without thought, two of the questions have a negative bias, requiring the respondent to answer whether they do not agree with a statement. Because the teacher population is small (n = 14), it is implausible to group the teachers by demographic category. There would be too few teachers in each category to meet the requirements for inference. The data from the teachers is consequently descriptive, rather than inferential.

145

While the questions on educator best practices and supports of the STEAM program are informative, they are not directly related to the research questions. Regardless, the principal and faculty of the school will receive information on all the dimensions of the STEM Common Measurement System (Saxton et al., 2014) upon completion of the program evaluation.

The first two items in the survey ask the teachers whether they have participated in STEM or STEAM prior to coming to the school, and whether they have received STEM or STEAM training prior to coming to the school. The intent of these questions is to collect some background information on the teachers. Items 3 and 4 ask about STEM/STEAM training teachers have received since arriving at the school. Although these two items are included in the teacher efficacy dimension in Table 3.2, they are not pure Likert-scale items, including an option that indicates whether they have received initial or ongoing training.

Four items address teacher efficacy in providing STEAM instruction. Item 5 addresses teacher confidence in providing the STEAM curriculum, but is negatively biased, asking teachers whether they do not feel confident. This item should appear different in a side-by-side comparison of the items comprising teacher efficacy. Item 6 enquires about teacher comfort in providing the school's technology guarantees. Item 7 gauges teacher confidence in their ability to adapt instruction and Item 8 inquires whether teaching the STEAM curriculum has inspired interest STEM/STEAM fields of study among teachers. Considered together, these items constitute the teacher efficacy category. The data from these items will support the discussion of the STEAM program's influence on teacher efficacy posed in Research Question 3.

146

Comparing teacher responses for the four items related to teacher efficacy resulted in a Cronbach's Alpha of 0.62, which indicates moderate internal consistency of responses. Figure 4.1 is a set of stacked boxplots with the teacher responses in the teacher efficacy dimension. Note, the item on teacher sense of competence in teaching the STEAM curriculum (item 5) has negative bias and does not have a profile like the other three items.
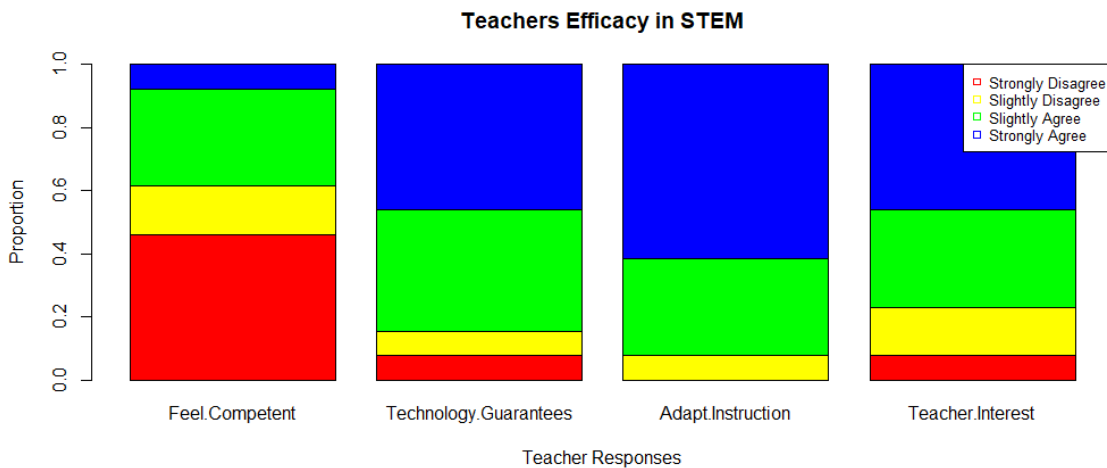

Figure 4.1. Teacher efficacy in STEM/STEAM

Observing teacher responses to the teacher efficacy dimension, it appears that most of the teachers are confident in their ability to teach the cross-curricular, inquiry-based, technology-focused STEAM material. While not overwhelming, the teacher responses indicate a sense of confidence in their ability to provide the STEAM curriculum competently. This sense of cohesion and positive outlook was comparable to the responses of the teachers during the focus groups. Note that the negatively biased item on teacher competence follows this trend, although the teacher responses are not as uniform as the other three items. This may have occurred because of possible confusion engendered because of the negative bias.

Of the thirteen responses, there is one response for each item that indicates strong disagreement. Surprisingly, these strong disagreement responses come from different individuals taking the survey. There is no indication that any one teacher attempted to sabotage the survey administration process.

The next category of survey item concerns teacher sense of student efficacy. Three items ask the teachers about student efficacy after participating in the STEAM program. Specifically, the items concern student improvement in critical thinking skills (item 13), communication skills (item 14), and collaboration skills (item 15). The question on student critical thinking (item 13) has negative bias and will have an inverse profile from the other two items. Figure 4.2 contains the stacked bar plots with teacher responses on student efficacy. Note, the responses to the negatively biased question on student communication are more in synch with the other questions in the dimension. Embedded later in the survey than the question on teacher confidence, the teachers may have been more prepared to work through the reverse logic required to respond appropriately.
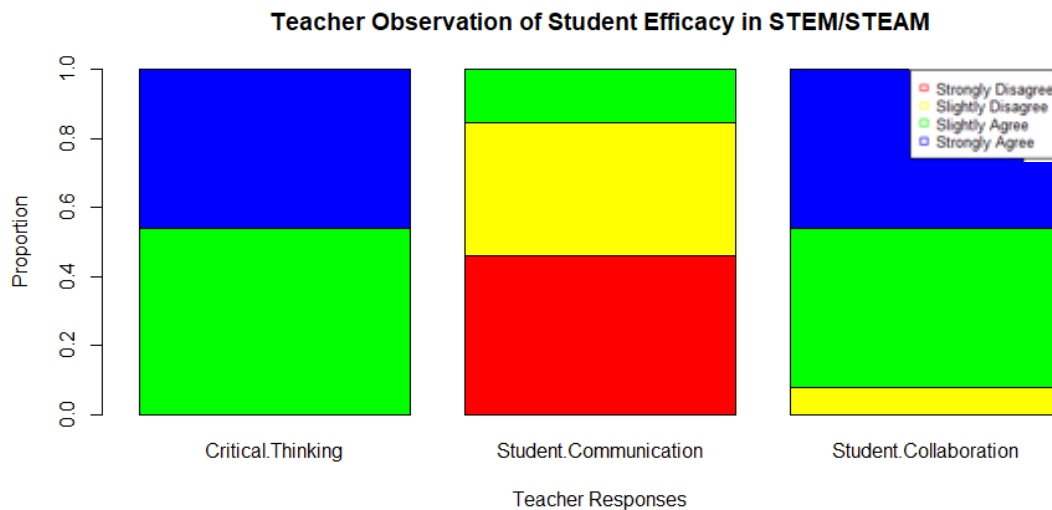
Figure 4.2. Teacher sense of student efficacy in STEM/STEAM

Like their responses on teacher efficacy, the teacher responses regarding student efficacy are positive, but not overwhelming. These responses are also consistent with teacher feedback from the focus groups. The underlying message from the teachers is one of cautious optimism concerning the benefits of the STEAM program.

A dimension that is not present as a research question but is one of the dimensions in the STEM Common Measurement System (Saxton et al., 2014) is support for the school program, monetarily, providing educational or professional expertise, or simply support for the program.

The items in the teacher's survey that correspond to this dimension involve support from the school district (item 11), support from partner enterprises (item 12), and supportive parents (item 16). This lower level of consistency may occur because of teachers who have not interacted with partners or parents confounding the response profile of the dimension. Figure 4.3 is a series of three stacked bar plots representing the three facets of supports for the school STEAM program.
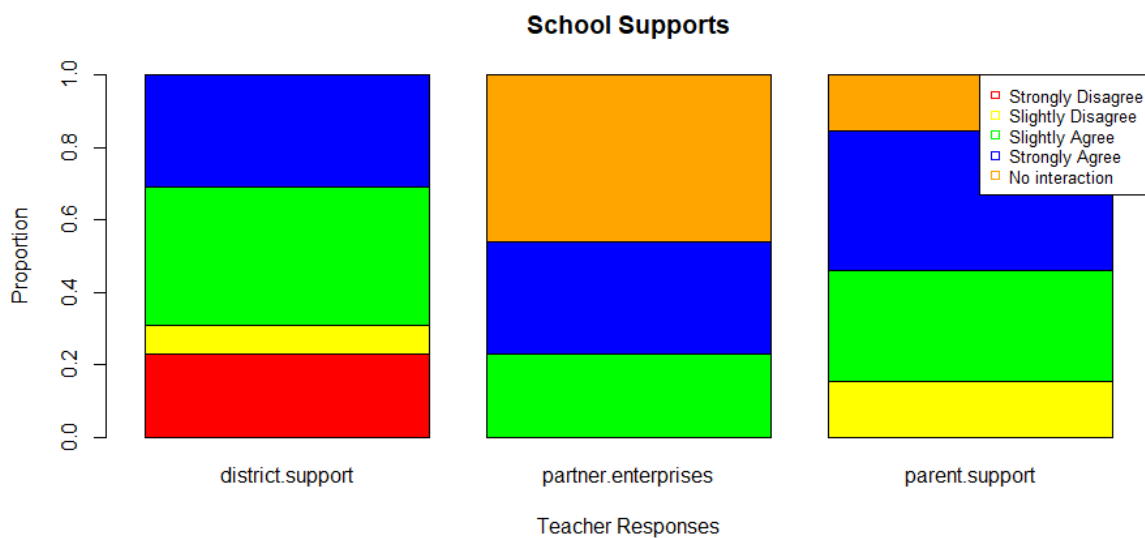
Figure 4.3. School supports for the STEAM Program

The orange section in the partner enterprises represent teachers who have not interacted with the school's partner enterprises (6). Similarly, there are two teachers who have not interacted with parents concerning the school's STEAM program. Despite these responses, the teachers sent a strong endorsement for the importance of interaction with partner enterprises and parental support of the STEAM program. Their endorsement of district support is moderate, at best.

Another dimension that is not considered specifically as a research question but resides as a dimension in the STEM Common Measurement System (Saxton et al., 2014) is educator practices that support student learning. Three items in the survey that demonstrate educator best practices include items that address tutoring (item 9), providing encouragement to students (item 10), and data collection on student interest and efficacy (item 17). The stacked bar plots in Figure 4.4 represent the three educator practices for the school STEAM program.
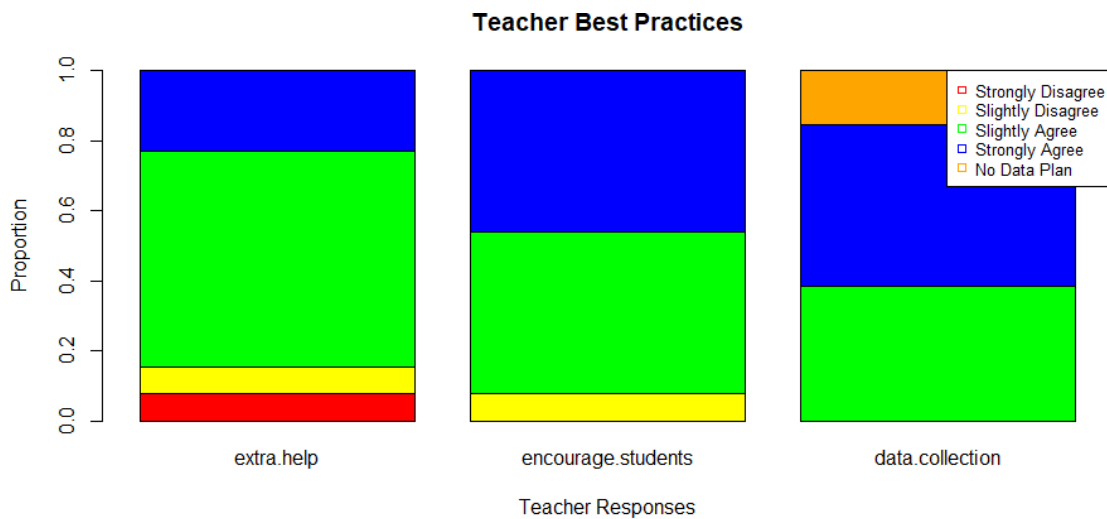
Figure 4.4. Supportive educator practices (teacher survey)

The orange section in data collection represents teachers (2) who were unaware of a plan for collecting data on the STEAM program. Overall, the responses for extra help

150

and student encouragement are positive, indicating that the teachers are willing to assist and provide moral support of their students in excess of their requirement as teachers. This is not surprising, but it endorses teacher willingness to make the STEAM program successful as a means of helping their students. The teacher response to data collection is supportive but may be uninformed. In the focus groups, the teachers indicated some uncertainty of the school's plan for collecting long-term data on their students. There is a solid base of data on students currently enrolled in the school but little information on future student educational and career choices.

Student Survey

In November, 2019, during their school-wide STEAM project, the student body took a 18-item survey that asked them information concerning student interest in STEM/STEAM professions and education (Research Question 1), student efficacy in STEM/STEAM tasks (Research Question 2), and educator best practices. The first question asked the student whether they had participated in a STEAM project in the school and served as a screening question. The researcher removed the data for 15 students who responded negatively. Items 9 and 11 ask students about the availability of academic assistance from their teachers and the encouragement teachers provide their students, both best educator practices. The remainder of the items concern student efficacy derived from participation in the STEAM program and student interest in STEAM education and the STEAM professions. These items on student efficacy and student interest in STEAM are the primary focus of the student survey. To keep the students from selecting one answer consistently, there was some dispersion in the categories of the questions, mixing student efficacy and student interest items. Also, the

151

researcher wrote three of the questions with a negative bias to keep the students from answering consistently positively or negatively without reading the question.

To determine the internal consistency of student answers, the items are grouped based on student efficacy and student interest. The items regarding collaboration, ability to communicate, ability to write, critical reasoning, completion of assignments, responsible technology use, and deeper technology use (items 2, 3, 4, 5, 10, 13, and 14) correspond to student efficacy. Comparing student responses for these items resulted in a Cronbach's Alpha of 0.76, which indicates reasonable consistency among student responses. Similarly, the items regarding students learning about STEAM professions, taking more STEAM classes, and entering STEAM professions (items 6, 7, and 8) correspond to student interest in STEAM. Comparing student response for these three items resulted in a Cronbach's Alpha of 0.41, which indicates weak internal consistency of student answers. It would be interesting to compare student responses to these questions before and after entering the STEAM program.

Student responses for each item range from strongly disagree (value = 1) to strongly agree (value = 4). Rather than selecting a representative sample of students to take the survey, all students present in the school (n = 255) took the survey in a computer lab after receiving instructions from their teachers. Eliminating students who indicated they had not participated in a STEAM project reduced the sample size to 240 students. To ensure independence of student responses, there was no discussion about the survey between students before or after survey administration. Each of the subgroups consists of more than 30 students. The independence of student responses and size of subgroups establish the conditions for inference.

152

Results for all students. Table 4.4 and Figures 4.5, 4.6, and 4.7 show the results of the survey questions for all students (n = 240) based on their Likert-scale responses.

Table 4.4. *Student Survey Results for All Students (n = 240)*

| Survey Item	Strongly Disagree	Slightly Disagree	Slightly Agree	Strongly Agree
2. Collaboration	.02 (5)	.06 (14)	.31 (75)	.61 (146)
3. Communication*	.55 (131)	.25 (60)	.14 (33)	.07 (16)
4. Written language	.06 (15)	.13 (32)	.43 (104)	.37 (89)
5. Solve problems	.04 (10)	.12 (29)	.35 (84)	.49 (117)
6. Learned about STEAM professions	.06 (15)	.15 (37)	.34 (82)	.44 (106)
7. More STEAM classes*	.45 (109)	.28 (66)	.17 (40)	.10 (25)
8. STEAM profession	.24 (57)	.23 (56)	.30 (72)	.23 (55)
9. Help from teachers	.02 (5)	.05 (13)	.15 (37)	.77 (185)
10. Completion of assignments	.04 (10)	.13 (31)	.42 (100)	.41 (99)
11. Encouragement of teachers	.04 (10)	.12 (29)	.35 (84)	.49 (117)
12. STEAM activity participation*	Yes .33 (78)	No .67 (162)		
13. Responsible use of technology	.05 (11)	.05 (13)	.31 (75)	.59 (141)
14. Deeper knowledge of technology	.05 (13)	.09 (21)	.39 (93)	.47 (111)

* Indicates negatively biased questions.

153
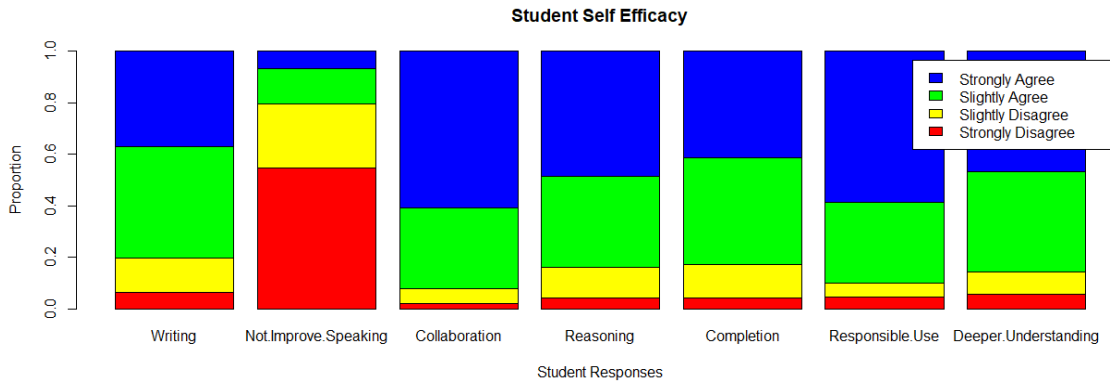
Figure 4.5 Student self-efficacy in STEAM skills

The results for the self-efficacy questions indicate the students have confidence in their abilities to solve problems, communicate verbally and in writing, collaborate, use technology responsibly and have a deeper understanding of technology since participating in the STEAM program. In each of these categories, 80% or more of the students slightly agreed or strongly agreed with the efficacy statement. The exception is Question 3 on speaking, which is negatively biased.

Figure 4.6 shows the student results for the student interest in STEAM.
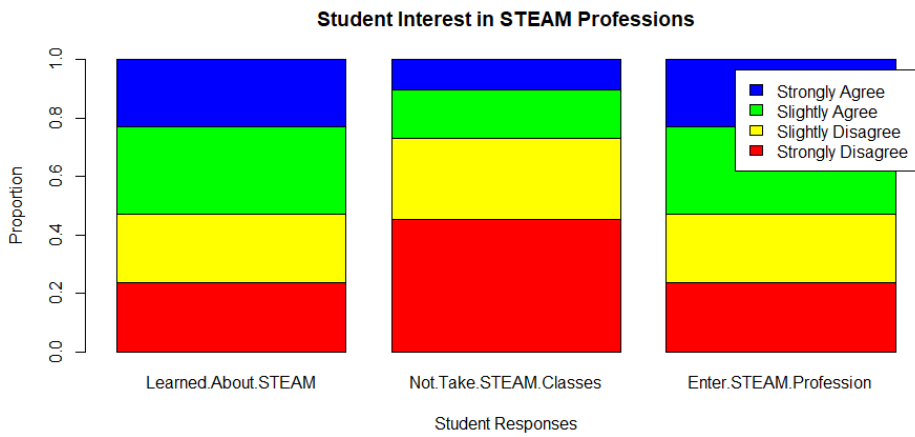
Figure 4.6 Student interest in STEAM learning/professions

The results for the student interest questions are not as strongly positive as the self-efficacy questions. The responses for the questions concerning learning about

154

STEAM professions and taking more STEAM classes indicate confidence levels like the self-efficacy questions. 78% of the students slightly or strongly agreed they have learned about STEAM professions, while 74% slightly or strongly agreed they will take more STEAM classes in the future. However, only 53% of the students indicated an interest, slight or strong, in a STEAM profession. It would be interesting to know what these students would have responded to this prompt on STEAM professions before they entered the STEAM program. If the purpose of the STEAM program is to recruit students to the STEAM professions, a before and after snapshot of student interest would indicate whether the school has accomplished this purpose.

Additionally, 67% of students indicated they have participated in a STEAM-related activity voluntarily in the school. These activities include the Girls in Engineering class, the MATHCOUNTS team, the Cyber Patriot club, and the Arts program. Overall, support for the STEAM program and STEAM learning is strong among the student body. While students may not eventually enter a STEAM-related profession, it is heartening that three quarters of the students will continue to take STEAM classes in the future.

The last table for the responses of the student body is the perception students hold for their teachers who provide the STEAM learning. The questions address getting help from teachers and receiving encouragement from teachers. While these factors do not directly relate to student self-efficacy (Research Question 1) or student interest in STEAM (Research Question 2), they are indicative of good educator practices found in the STEM Common Measurement System (Saxton et al., 2014).
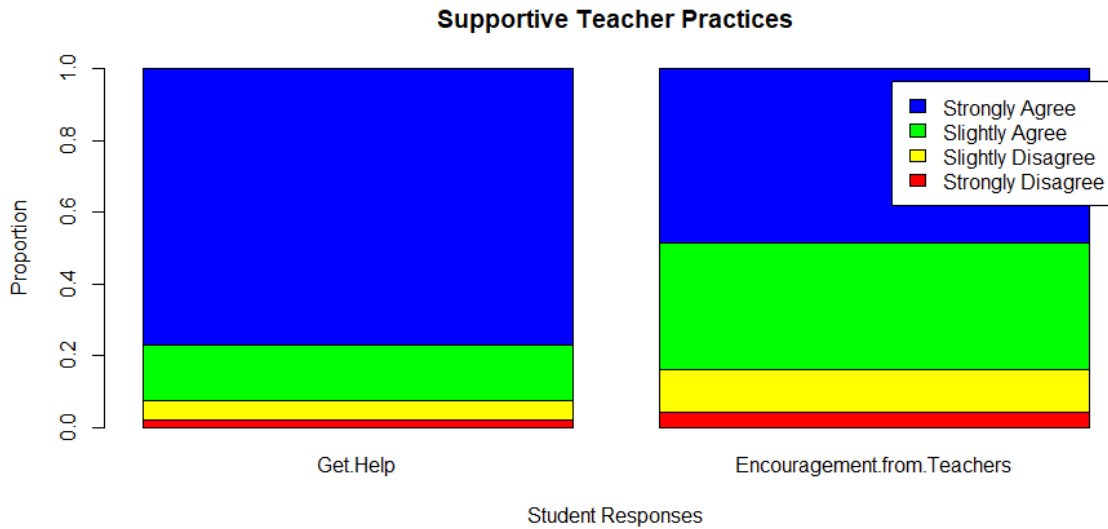
155

Supportive Teacher Practices

Figure 4.7 Supportive educator practices (student survey)

The results to these two questions indicate the students feel very strongly that their teachers are available for help in STEAM learning and encourage them in their learning. 93% of students perceived their teachers were available for help in math and science, either slightly or strongly. Similarly, 84% agreed, either slightly or strongly, that teachers have encouraged them when they struggle in math, science, or STEAM project.

Results grouped by sex and race. In the next three tables, student responses are grouped by sex and race. The means of responses on each item are compared using a t-test. Tables 4.5 through 4.7 are comparisons of the mean responses for different subsets of the student population. Based on the 95% confidence interval of the difference of means and the p-value, it is possible to discern whether there is a statistically significant difference between the mean value of the two groups for comparison. Confidence intervals that are all positive or all negative combined with a p-value of .05 or less indicate there is a statistically significant difference of the mean for the subsets for a survey item. Table 4.5 is a comparison of the mean responses to the females and males

156

in the student population.　　This comparison supports the gender-based distinction in

Research Question 2 and the discussion of student interest in Research Question 1.

Table 4.5. *Student Survey Results for Female vs. Male Students*

Survey Item	Mean Females (n = 134)	Mean Males (n = 106)	Diff. of means 95 percent confidence interval	p-value
2. Collaboration	3.48	3.55	-.25 to .11	.44
3. Communication*	1.72	1.73	-.24 to .24	.98
4. Written language	3.14	3.08	-.16 to .29	.56
5. Solve problems	3.28	3.29	-.23 to .20	.88
6. Learned about STEAM professions	3.25	3.06	-.04 to .42	.11
7. More STEAM classes*	1.91	1.93	-.29 to .24	.86
8. STEAM profession	2.52	2.52	-.28 to .28	.98
9. Help from teachers	3.76	3.57	.01 to .38	.03
10. Completion of assignments	3.18	3.23	-.26 to .16	.66
11. Encouragement of teachers	3.30	3.26	-.18 to .25	.75
12. STEAM Activity Participation*	1.73	1.60	.01 to .25	.04
13. Responsible use of technology	3.49	3.39	-.11 to .31	.35
14. Deeper knowledge of technology	3.36	3.16	-.02 to .41	.08

* Indicates negatively biased questions.

157

The results of the survey indicate little gender bias among the students at the school. However, there are two questions in which it is possible to state with confidence that there is a statistically significant difference between the sexes: Question 9 and Question 12. Question 9 asks whether students perceive they can get help from their teachers in math and science if they need it. In this case, the mean female score is 3.76, the mean male score is 3.57, the difference of means is from .01 to .38, and the p-value is .03. Therefore, it is possible to say with 95% confidence that the female students are more confident in getting help from their teachers than their male counterparts.

Question 12 is a negatively biased question that asks whether students do not participate in a STEAM-related activity. In this case, the mean female score is 1.73, the mean male score is 1.60, the difference of means is from .01 to .25, and the p-value is .04. Since this is a yes or no question, it indicates that more females participate in STEAM-related activities than males.

The lack of a difference between female and male responses to survey questions is heartening. Based on their responses, there is no statistically significant difference between females and males in self-efficacy (Research Question 1) and interest in STEAM studies and STEAM professions (Research Question 2). These results support the recruitment of females into STEAM studies and STEAM professions proposed by the "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009). This female parity is evident in the response to Question 12, about participation in STEAM-related activities. In this school, more females participate in these activities than their male counterparts. The principal noted this in her interview as a focus of the school's STEAM program.

Table 4.6 is a comparison of mean responses for African American students versus the mean responses for white students. The data from this survey support the racially based distinction on student efficacy between different subsets of the student population in Research Question 2 and the influence of the program on student interest in Research Question 1.

Table 4.6. *Student Survey Results for African American vs. White Students*

Survey Item	Mean African American (n = 77)	Mean Whites (n = 110)	Diff. of means 95 percent confidence interval	p-value
2. Collaboration	3.51	3.49	-.20 to .23	.89
3. Communication*	1.75	1.68	-.22 to .36	.63
4. Written language	3.24	3.02	-.03 to .49	.09
5. Solve problems	3.31	3.25	-.20 to .31	.66
6. Learned about STEAM professions	3.08	3.12	-.32 to .24	.78
7. More STEAM classes*	2.01	1.85	-.13 to .47	.27
8. STEAM profession	2.13	2.74	-.93 to -.30	.00
9. Help from teachers	3.71	3.68	-.17 to .23	.75
10. Completion of assignments	3.39	3.10	.05 to .53	.02
12. STEAM activity participation*	1.64	1.73	-.23 to .05	.19
13. Responsible use of technology	3.48	3.51	-.25 to .19	.80

(continued)

Survey Item	Mean African American (n = 77)	Mean Whites (n = 110)	Diff. of means 95 percent confidence interval	p-value
14. Deeper knowledge of technology	3.28	3.28	-.27 to .25	.95

* Indicates negatively biased questions

The results for the comparison of African American and white students indicate no significant statistical difference in responses between the two groups, with two exceptions. On Question 8, white students were more inclined to enter a STEAM profession than African American students. In this question, the mean African American score is 2.13, the mean white score is 2.74, the difference of means is from -.93 to -.30, and the p-value is .00. This student interest question emphasizes one of the most important aspects of the STEAM initiative, the recruitment of minorities and females into STEAM professions. It also indicates the need in middle and high school to continue to recruit minorities for STEAM professions.

In Question 10, African American students indicated more confidence in completing assignments than white students. This efficacy question has a mean African American score of 3.39, a mean white score of 3.10, a difference of means from .05 to .53, and a p-value of .02. The remainder of the interest and efficacy questions have differences in responses between the two groups, but no difference that can be stated with statistical confidence.

Table 4.7 is a racially based comparison of the mean responses for white students versus the mean responses for Hispanic students. It also supports the racial distinction on student efficacy in Research Question 2 and influence of the program on student interest in Question 1.

Table 4.7. *Student Survey Results for Hispanic vs. White Students*

Survey Item	Mean Hispanic (n = 36)	Mean Whites (n = 110)	Diff. of means 95 percent confidence interval	p-value
2. Collaboration	3.61	3.49	-.14 to .38	.36
3. Communication*	1.81	1.68	-.23 to .48	.49
4. Written language	3.17	3.02	-.15 to .44	.32
5. Solve problems	3.33	3.25	-.21 to .37	.59
6. Learned about STEAM professions	3.50	3.12	.06 to .70	.02
7. More STEAM classes*	1.56	1.73	-.36 to .02	.07
8. STEAM profession	2.69	2.74	-.45 to .36	.80
9. Help from teachers	3.58	3.68	-.37 to .18	.48
10. Completion of assignments	3.19	3.10	-.22 to .41	.55
11. Encouragement of teachers	3.14	3.33	-.54 to .16	.28
12. STEAM activity participation*	1.56	1.73	-.36 to .02	.07

(continued)

13. Responsible use of technology	3.31	3.51	-.54 to .13	.24
14. Deeper knowledge of technology	3.19	3.28	-.41 to .23	.58

* Indicates negatively biased questions.

The results for the comparison of Hispanic and white students indicate little significant difference between the responses of students in the two groups. The only question in which there is a statistically significant difference between the two groups is Question 6, which indicates whether students have learned about STEAM professions they were unaware of previously. This interest question has a mean Hispanic score of 3.50, a mean white score of 3.12, the difference of means is from .06 to .70, with a p-value of .02. Overall, the results for both comparisons among racial sub-groups indicate few differences between the responses of the students. The students' perception of the STEAM program, their sense of self-efficacy, interest in STEAM studies and professions, and feelings for their teachers are generally positive and consistently similar. This is a positive endorsement for the school's marketing of STEAM education and STEAM professions, and the professionalism of the faculty.

Classroom Observations

During the annual school-wide STEAM project, the researcher observed two classes on November 12, 2019. The students were conducting their research and developing proposed solutions for global and local problems. The purpose of this observation was to verify that the responses from the other instruments correspond to what is occurring in the school's STEAM classrooms. Specifically, did what was

162

occurring during a school-wide STEAM project match the responses in the principal interview, teacher focus groups, teacher surveys, and student survey? The contents of the observations are in Appendix K.

The learning environment in both classrooms was focused on the STEAM project, but different in the roles of the teachers, both veterans at the school. This difference may be explained by the age of the classes. The first classroom, working on preventing animal cruelty was predominately seventh and eighth graders. They have done STEAM projects for the past two years and proceeded with little teacher impetus. The teacher offered technical assistance to the class but let the students move at their own pace. The second classroom was filled with sixth graders, who chose the topic of homelessness. In the second classroom, the teacher moved between groups frequently and prompted them with questions from the project graphic organizer. When the principal informed the school that the groups will have two more days to finalize their work, this second classroom was visibly relieved.

In both classrooms, the conduct of an actual STEAM project in the school and the content of stakeholder responses on the teacher and student surveys were in harmony. The project was inquiry-based and open-ended. The learning that occurred in the classrooms was student driven. The teacher's role was one of facilitator. The students actively researched the issue and developed their own solution to the global problem. Collaboration within the work groups was evident. Students were required communicate their solution proposals verbally and in writing, in whatever medium for communication they select. The older students appeared comfortable dividing the labor, addressing the project questions, and developing their presentation. A few of the younger groups

163

needed to be nudged with some pointed questions by the teachers, but they understood

the purpose of the project and the desired end state. Overall, this was a well-coordinated

effort that reinforced the purpose of the STEAM program and the generally enthusiastic

responses of the stakeholders to the data collection instruments in this dissertation.

Interpretation

Student Interest (Research Question 1)

The first research question sought to explore the influence of the STEAM

program in generating student interest in STEAM learning and the STEAM professions.

The input for this question derives from the first question of the teacher focus groups and

questions 6, 7, 8, and 12 from the student surveys. The responses from the teacher focus

groups regarding student interest in the STEAM learning and the STEAM professions

indicate that the program has awakened to students to the possibilities inherent in the

science, technology, engineering, arts, and mathematics professions. The teachers are

less certain about whether the program has influenced student career plans. As one

teacher (I91) pointed out, "I think middle school is kind of young to know what you want

to do."

Student responses to their survey mirror teacher responses to the focus group

question. In Questions 6 and 7, the students indicate their awareness of STEAM

professions has increased and many are open to taking more STEAM classes in high

school and college. Question 8 asks whether students are thinking about entering a

STEAM profession. Although more than half of the students either slightly or strongly

indicate interest in entering a STEAM profession, the response is not as uniformly

164

positive as the other interest questions. This is appropriate. Middle school is "kind of young" to be committing to an adult profession.

There is one notable difference between groups in the student survey. In Question 8, white students indicate they are more likely, statistically, to enter a STEAM profession than their African American counterparts. In their responses to the Question 1 on student interest in STEAM profession in the teacher focus groups, the teachers emphasize the school efforts to enfold the females in the STEAM culture. The Girls in Engineering program is the most remarked program. There is an absence of responses regarding school efforts to recruit minorities into the STEAM work force. These two indicators may provide the school an avenue to explore in the future evolution of the STEAM program.

Student Self-Efficacy (Research Question 2)

The second research question explores the influence of the school's STEAM program on promoting student self-efficacy, or confidence in their abilities. It also focuses on the program's influence on females and minorities, two explicit components of the Obama administration's "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009). Student self-efficacy was a component of the administrator interview, the teacher focus groups, and both surveys.

In both the administrator interview and the teacher focus groups, participants emphasized their perception that the students in the STEAM program have an increased confidence in their ability to tackle the challenges they encounter. In question 2 of the teacher focus groups, one of the teachers (R36) remarked on the positive differences between her seventh-grade students who have been in the program for a year and newly

165

transferred students. This positive sense of self-efficacy is also evident in the responses

to the teacher and student surveys. In the teacher survey, the teachers gave positive

responses to the questions on student problem solving, collaboration, and communication

(Figure 4.2). Similarly, the student survey responses to questions on problem solving,

collaboration, communication, and responsible use of technology were positive (Figure

4.5).

Table 4.5 presents the difference between female and male responses to the

survey questions. As previously remarked, there were few significant differences

between female and male responses. None of the differences were in questions focused

on student interest in STEAM or student sense of self-efficacy. In this school, females

are as confident in their abilities to solve problems, communicate, collaborate, and use

technology responsibly as their male counterparts.

Tables 4.6 and 4.7 present the differences between white students and African

American and Hispanic students, respectively. In these two comparisons, there are few

statistically significant differences in the responses of the subgroups. Combined with the

comparison of male and female students, these responses indicate a sense of parity

between the sexes and the races in the school regarding STEAM learning and STEAM

professions. Female students perceive themselves as competent as their male

counterparts. Likewise, African American and Hispanic students are equally sure of their

abilities as their white counterparts. Generally, the school's goal to instill confidence in

the efficacy of females and minorities is a success.

Teacher Confidence (Research Question 3)

The third research question seeks to discern whether professional development and participation in the STEAM program has influenced teacher efficacy. The input for this question comes primarily from Questions 4 and 6 in the teacher focus groups, and Questions 3 through 8 in the teacher survey (Appendix E). In the focus groups, the teachers projected ambivalence about the professional development they had received, both in the initial implementation of the program, and the ongoing training teachers new to the school receive. They reiterated this ambivalence in the teacher survey, Questions 3 and 4.

Despite their ambivalence towards the influence of professional development in developing teacher efficacy, the teachers did indicate they have growing confidence in their ability to provide the inquiry-based, collaborative, technology rich educational process in a STEM or STEAM program. In Question 6 of the teacher focus groups, the teachers explained this confidence comes from the practice they receive in the implementation of the program. As they teach, in their everyday classes and during the STEAM projects, they are making more connections between their content area and the STEAM professions. Additionally, half of the teachers in the focus groups indicated they have adopted a more hands-on, kinesthetic, and inquiry-based instructional style. The responses to survey questions 5 through 8 reflect this teacher confidence in their ability to provide appropriate instruction for the inquiry-based, student-centric learning favored by STEM and STEAM programs.

Although this confidence is not unanimous among the teachers, it does reflect the prevalent view of the faculty and the overall climate among the adults in the building.

167

This teacher confidence was evident in the classroom observations that occurred during the school-wide STEAM project. During these snapshots of the school program in action, the teachers served as facilitators for the learning process. The focus of the class periods was on the students and their interaction with the engineering design process and collaboration with each other.

Academic Achievement (Research Question 4)

The fourth research question addresses the influence of the STEAM program on the school's academic achievement. Judging by trend analysis, school achievement in math, English language arts, and science has grown since 2016. This is evident in Tables 4.1, 4.2, and 4.3, which illustrate school, school district, and statewide achievement on common standardized tests. The causes for school growth in academic achievement are not easily identifiable; however, the previous four school years coincide with the second, third, fourth, and fifth years in which the school has adopted the STEAM curriculum. The principal, a strong leader with a vision for success, has been the school leader during the implementation of the STEAM curriculum. She has been the transformational leader that Ferrara-Genao (2015) insists as a key component of an effective STEM/STEAM program. Further, the faculty has a common language, a consistent, long-term program, and the means to emphasize STEAM connections in every lesson.

While making STEAM connections in every lesson can create a burden for the teachers, their comments in the focus groups indicate that making these connections has influenced them to branch out from their traditional role as content area teachers. As one teacher (L77) said, "Not only that but having that deliberate focus on how the content we're teaching applies to those STEAM careers is very important. We're no longer

168

teaching in isolation with our different subjects." This common focus on STEAM connections, annual schoolwide STEAM boot camps, extracurricular activities devoted to STEAM, and an annual schoolwide STEAM project all contribute to a consistent message.

The data from statewide assessments supports the growth in student achievement over the last four years. During this same four-year period, the school leadership has remained in place, as has the STEAM program. Without attempting to establish a causal link between the STEAM program and academic achievement, it is probably safe to state that there is a positive association between the STEAM program with its consistent message and school academic achievement. This growth in academic achievement is consistent with other school programs that have implemented a STEM or STEAM curriculum with fidelity (Olivarez, 2012; Ferrara-Genao, 2015).

Summary

Chapter 4 began with a presentation of the study site, a rural middle school with a science, technology, engineering, arts, and mathematics (STEAM) program in its sixth year. Following this review, the data collection instruments were presented in the order in which the researcher collected them. In this case, the researcher began with an interview of the building principal, followed by focus groups with the school's faculty, and an electronic survey of the teachers regarding the school's STEAM program. Following this, the students took an electronic survey of their perception of the STEAM program. The final data item was observations of classrooms engaged in the school's annual, school wide, "walls down" STEAM project.

169

Together, these data collections instruments comprised the mixed methods program evaluation of the school's STEAM program. The focus of the evaluation was the research questions. These questions assessed student interest in STEAM, student sense of self-efficacy, teacher sense of self-efficacy, and the academic growth of the school since the inception of the STEAM program. The mapping of the data collection instruments is in Table 3.2 and is based on the STEM Common Measurement System (Saxton et al, 2014). This framework allowed the researcher to develop a comprehensive assessment of the four research questions.

The interview with the school principal presented a middle school with a strong administrator, who understands the school and strategic purpose of the STEAM initiative. The focus groups and teacher survey presented a dedicated faculty who understand their roles as facilitators in the inquiry-based, student-centered STEAM learning process. Overall, the teachers were cautiously optimistic about the students awakening to the challenges and opportunities of STEAM education and STEAM professions, and confident in their abilities to guide their students through the engineering design process. The student survey and classroom observations depicted a student body taking an interest in STEAM education and professions, and developing confidence in their ability to communicate, collaborate, solve problems, and use technology responsibly. What is particularly heartening about this student confidence is the similarity across responses of female students with male students, and minority students with the white students.

The school data from state tests of mathematics, science, and English language arts for the last four years show a steady improvement in the number of students who meet or exceed standards. While there may be no causal relationship between the

170

STEAM program and school academic achievement, it is one component in a successful school culture led by a strong administrator and a dedicated faculty that prides itself in being a magnet school in the district for STEAM learning. Chapter Five will summarize the program evaluation of the STEAM program in the target middle school and make recommendations for practice and research.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

Introduction

Based on the target school's performance in state tests of academic achievement for the last four school years (SCDE, 2019), the school has improved academically in math, science, and English language arts. In its sixth year of operation, the school's STEAM program appears to be flourishing and is an integral part of the school's academic program. For the most part, the data from the principal's interview, teacher focus groups, teacher and student surveys, and classroom observations indicate the STEAM program is successful and firmly embedded in the school's culture. With that in mind, this chapter examines practical and research recommendations for improving the school's STEAM program. Let us review the research questions for the study.

Research Questions

1. What is the STEAM program's impact on student interest in STEM/STEAM professions?

2. How has participation in the STEAM program influenced the self-efficacy of students in STEAM knowledge and skills, with a focus on females and minorities involved in the program?

3. How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students?

4. What is the STEAM program's influence on student achievement?

172

<center>**Discussion**</center>

The first three research questions derive from the Obama administration's 2009 "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009). Specifically, this nationwide initiative sought to increase STEM literacy, improve math and science education, and increase opportunities for females and minorities in STEM fields. From a recruitment and economic aspect, this national initiative translates to recruiting and training STEM/STEAM educators, and encouraging more young adults into the scientific, technological, engineering , and mathematical fields. Within a middle school, these three goals translate to students' perceived interest in STEM/STEAM education and professions, their sense of self-efficacy, and teachers' confidence in their ability to provide the student-centered, inquiry-based instruction that STEM/STEAM promotes.

The first research question asks whether the STEAM program has impacted student interest in STEM/STEAM professions. This is a cause and effect question that this evaluation, which takes a snapshot of student interest at one point in time, does not answer. What the data from the collection instruments does indicate is that the students are more interested than not in STEM/STEAM education and professions. Additionally, while the students may not overwhelmingly predict they will enter a STEM/STEAM profession, they are aware of the opportunities.

The second research question assesses whether the STEAM program has influenced student self-efficacy, particularly the self-efficacy of minorities and female students. This question requires initial data points with which to compare student efficacy, as depicted in the interviews, surveys, focus group, and classroom observations.

<center>173</center>

Unfortunately, there are no initial data points to use to assess the STEAM program's influence on student self-efficacy.

What the data collection instruments do indicate is that student self-efficacy is strong. In the student survey, the students expressed confidence in their ability to collaborate, communicate, solve problems, and use technology responsibly. Of interest, there was a parity of confidence between female and male students, and majority and minority students. This sense of student self-efficacy and parity between the sub-groups is evident in the other data collection instruments.

In the focus group interviews, one of the teachers (R36) commented on the difference between the thought processes of seventh graders who transferred into the school at the beginning of the year, and those seventh grade students who had experienced the engineering design process promoted by STEAM learning in their sixth grade year. The students with experience in STEAM learning were familiar with collaborating, solving open-ended problems, and communicating their results in a variety of methods. This difference in thinking is not a matter of ability. It is one of perception.

The third research question seeks to determine the impact of professional development on teacher confidence in providing STEAM learning to their students. Educators who teach the STEM/STEAM learners must be confident in their ability to facilitate the inquiry-based learning process. Contrary to the experience of many educators, they are not the center of instruction in the STEM/STEAM classroom. This requires restraint and the confidence of the teacher to let the students take the lead in the learning experience, particularly when the students fail. This ability to transfer control of the learning process to the students takes training and experience.

174

Like the questions on student interest in STEAM and student self-efficacy, there are no initial data points with which to compare teacher confidence in their abilities to provide inquiry-based, technology heavy, student-centric instruction. The teacher survey is a snapshot of teacher perception of their ability to provide competent STEAM instruction.

However, in the focus groups, several of the teachers indicated they were at the school during the initial professional develop, site visits, and book study the faculty experienced when they first became a STEAM school. There is anecdotal evidence of teachers' experience with professional development and its influence on their ability to provide STEAM instruction. Much of their confidence, teachers attribute to working together with their peers to make STEAM connections in their lessons and construct the school's "walls down" projects. What was very clear in the responses of the faculty was their understanding of the value of professional development, and their desire to receive regular professional development. In the words of one teacher (B92) regarding professional development, "I could still use some."

Although the administrator interview, focus groups, and surveys do not answer the cause and effect research questions, they do indicate that the middle school has achieved the three goals of the "Educate to Innovate" campaign. Students are aware of STEAM professions and educational opportunities, they are confident in their knowledge and skills, and there is parity of self-efficacy between sub-groups. Additionally, the teachers express confidence in their ability to facilitate the STEM/STEAM learning process.

175

What the school's performance on state assessments of mathematics, science, and English language arts for the last four years indicates is that while the school's STEAM program has matured and gelled, student academic achievement has also risen. There is not growth in every subject, every year, but the school experienced growth in the percent of students who met or exceeded expectations on each assessment during the four-year period, 2016 to 2019. There is insufficient evidence to establish a correlation between the advent of the STEAM program and the school's gains in academic achievement. This would answer the fourth research question on the STEAM program's impact on student achievement. However, it is not surprising that a school with an enterprising principal, a core of committed teachers, and a student body that has embraced the STEAM learning experience, has also experienced sustained academic achievement.

Going forward, the school will experience challenges in keeping the STEAM learning experience fresh, sustaining capability of the faculty, and maintaining a culture focused on inquiry-based learning. The following section lists recommendations for the school to put into practice, followed by recommendations for further research into STEM/STEAM learning.

<div align="center">

Implications and Recommendations

</div>

Recommendations for Practice

  Continue to focus on the extended, positive interactions between teachers and students. The success of the school's STEAM program depends on the productive relationships the students and teachers develop during the students' three years in the school. The responses from the student surveys indicated the students felt confident in being able to get help and encouragement from their teachers. This resulted in a student

body the researcher observed actively engaged and enthusiastic about the annual, "walls down," school-wide STEAM project. Therefore, it is essential to continue to focus on the extended, productive interactions between teachers and students while implementing the STEAM curriculum.

Research has indicated that parents and teachers are a significant factor in the decision of students to pursue STEM/STEAM education and professions. Sjaastad (2012) referred to these influential persons as "definers" and outlined three roles these people fulfill in the inspiration of young people. "Definers" assist students in defining STEAM, they often model STEAM careers, and they provide opportunities for students to interact with the STEAM professions. Griffin et al. (2014) focused their research on minority students and emphasized the importance of encouragement and the development of persistence. In effect, teachers become an integral part of the support systems (Museus & Liverman, 2010; Nakamoto & Bojorquez, 2017) for the young STEAM learners. By faithfully implementing the STEAM curriculum and activities, and developing productive, long-term relationships with students during the process, the faculty will continue to facilitate the growth of students in intellectual curiosity, scientific literacy (McNally, 2012), an understanding of their STEAM opportunities, and the perseverance, or grit (Duckworth, 2016), to pursue their dreams.

Implement longitudinal measures to track students following middle school. As students complete their tenure in the middle school, the faculty should consider collecting data on their graduates through high school, college, and into the work force. The STEM and STEAM education students begin in middle school becomes the talent "pipeline" (Jung, 2016) into the work force for computer specialists, engineers,

177

mathematicians, scientists, and artists. By recording student choices of programs of study and careers, and noting changes over time, the school can begin to determine the influence of their STEAM program on these choices. By design, a program evaluation will only assess a snapshot of the school's STEAM program, determining whether the curriculum and activities are impacting student interest in STEM/STEAM in the short term. Conversely, a longitudinal study of students who have left the program will provide information on whether the program has influenced the long-term choices of program graduates. At the least, the school should have the students take an entrance and exit poll of interest in STEAM learning and STEAM professions. This would enable them to track changes in student interest before and after they participate in the school's STEAM program.

Currently, the initial group of students who spent three years in the school's STEAM program are in their senior year of high school. If they are pursuing career and technology education after high school, it will begin as they graduate and depart for college next year. For the most part, students graduating the middle school feed into a single high school. It would be beneficial to establish a partnership with this high school to collect course and college selection data from this high school over the course of the next five to ten years to identify trends in student education and career selection. While there is certainly no easily identifiable causal relationship between the middle school STEAM program and student long-term choices of education and career, longitudinal trend analysis may establish some association between the two variables. It may not. Regardless, longitudinal data collection of student choices will potentially inform the future direction of the school STEAM program.

178

Continue to implement activities and curriculum for female and minority students. Currently, the school implements activities and curriculum that actively seek to include females in the STEAM program. In the administrator interview and teacher focus groups, the participants mentioned several instances of females taking a leading role in the STEAM program. The "Girls in Engineering" exploratory course in the school is an example of this, targeting female students and emphasizing STEAM education and STEAM professions.

Courses targeted on the inclusion of females and minorities have the potential to spark interest in STEM/STEAM among females and minorities, and to change the stereotypes these groups may have accepted. This "commitment to inclusion" (Green et al., 2006, p. 60) is emphasized in the literature (Toglia, 2013; Burgstahler, 2012) and is an important facet of the "Educate to Innovate" campaign (Office of the Press Secretary, The White House, 2009). The school should continue to develop programs to include minority and female students. It should also track the demographics of participation in extracurricular activities and STEAM-focused classes.

Based on the interview with the principal and the focus group sessions with the teachers, there does not appear to be a consolidated emphasis to integrate the minorities into the STEAM program; however, based on the results of the surveys and the observations from STEAM classes, this does not appear to be a need in the school. As it currently stands, the school's STEAM program is color-blind and open to females and males. While there is little difference in the appeal of STEAM training and STEAM professions among the genders or the races, many of the STEAM professions have little minority and female participation. The school would do well to emphasize female and

179

minority success in male and white dominated fields to keep this enthusiasm strong and provide hope for female and minority students.

The school might also explore mentoring programs for their minority students, particularly those students who struggle academically. In their meta-analysis of 320 surveys of STEM programs in higher education, Griffin et al. (2010) noted the importance of mentoring minority students in engineering, science, and math programs, programs with traditionally high failure rates. This mentoring and encouragement helped struggling minority students to develop the "grit" to succeed in these programs (Duckworth, 2016). If the minority students perceive they may be able to successfully accomplish a STEAM program of study, they may be encouraged to attempt such a program.

Invest in the professional development of the faculty. In her dissertation on successful middle school STEM programs, Ferrara-Genao (2015) concluded that invested and effective teachers are the key element in successfully implementing a STEM program. These dedicated professional educators become "definers" or role models for their students (Sjaastad, 2012). The key to developing these professional educators is training them to model, demonstrate, and explain the inquiry-based, technology-driven, student-centric learning the students will experience.

In the focus groups, the teachers indicated there is a STEAM boot camp in the school to introduce the new students to the program each year. In a similar vein, there is an orientation and introductory training for new teachers to the school. However, during the teacher responses to the questions on professional development questions, there was

180

some confusion on the nature of professional development on STEAM the school receives.

This is the sixth year of the STEAM program at the school. According to one of the teachers (L77) who has been at the school since the initiation of STEAM learning, the teachers received considerable training on STEAM instruction and developing a curriculum during the school's first two years as a STEAM school. Since then, professional development on STEAM has been introductory and related to the immediate implementation in the school and the classroom. Five teachers in the focus groups (A57, B92, Q10, I91, L77) indicated a desire for professional development on STEAM implementation. In a faculty of 14 teachers (now 17), this is a sizable group of teachers. At this point in the course of the school's life cycle as a STEAM school, a recommendation for practice is for the school to participate in professional development on STEAM implementation and curriculum building for the entire faculty.

While introductory training and professional learning communities keep the STEAM program running, whole faculty training would serve two purposes. It would officially introduce the STEAM concept to newcomers in a setting in which the veterans could share their experiences, and it would refresh the initial training of the veteran teachers. It might also serve as a bonding and networking opportunity for a faculty which has changed since the introduction of STEAM into the school. Comprehensive professional development as a faculty is not necessarily an annual requirement, but it is something to consider every three to four years as the faculty composition changes. Ferrara-Genao (2015) and Nakamoto and Bojorquez (2017) both emphasized the need for continuous professional development throughout the life cycle of a STEM or STEAM

program in a school. Professional development is a component of the STEM Common Measurement System (Saxton et al., 2014) as an ongoing piece of the program. This periodic training would serve the same purpose as preventive maintenance on a vehicle. It would adjust the timing, lubricate the fittings, and keep the vehicle running at peak performance.

Continue to create new, schoolwide STEAM projects each year. In discussions with the principal, the researcher learned that the school creates its own "walls down," schoolwide STEAM projects each year. One recommendation for practice is to continue creating these homegrown projects each year, even if it causes a delay in the implementation of the project. Creating new projects each year ensures the relevance of the projects, a key factor in catching the interest of middle school students (Dutta-Moscato, 2014). This practice also causes the faculty creating the project to experience some of the same challenges they want the students to experience in an inquiry-based, student-centered learning experience. The faculty will need to collaborate, communicate, and use technology effectively. They also might experience what the principal termed "struggle time," exercising their critical thinking and creative skills. This annual exercise in creating a schoolwide project will foster teacher buy-in to the STEAM experience and should facilitate their creation of relevant and suitably challenging projects for the students.

Continue to require teachers to make a STEAM connection in every lesson. Currently, teachers in the school are required to make a connection to STEAM professions or STEAM applications of lesson content for every lesson they teach. The principal and teachers mentioned this in the administrator interview and teacher focus

182

groups, respectively. The purpose is to establish relevance of the learning, a practice Toglia (2014) indicated is essential in STEM and STEAM learning. During the focus group discussions of implementing the inquiry-based, student-centered STEAM curriculum, the teachers mentioned their requirement to include a STEAM connection in every lesson. This practice caused them to conduct research into the applications of their lessons and collaborate with teachers of different disciplines. Being part of a collaborative team, teachers no longer felt they were teaching their subjects in isolation. Their lessons are integrated with STEAM professions, creating a connection for the students and their teachers. This practice takes time and sometimes inspiration, particularly at first, but it answers the eternal student question, "When are we ever going to use this?" This practice should continue going forward.

Recommendations for Research

   Research existing longitudinal studies of completers of STEM/STEAM programs. One of the recommendations for practice is to conduct a longitudinal study of program completers from the school. A longitudinal study would provide the school with an indication of program success and point out areas to improve in the existing STEAM program. However, there is no need to develop the data collection instruments of a longitudinal study in isolation. In the course of the program evaluation design and data collection, the researcher received permission to use the STEM Common Measurement System (Saxton et al., 2014) to organize the evaluation's data collection instruments and the observation tool from another program evaluation (Ferrara-Genao, 2015). President Obama initiated the current "Educate to Innovate" campaign in 2009. Sixth graders in the year 2009 are completing college in the next few years. There may be measures in

183

place to track trends in courses of study and career selection. A recommendation for research is to examine the data collection efforts of other STEM/STEAM schools or institutions with an interest in STEM or STEAM.

Schools like the University of Texas, with its UTeach STEM teacher certification program (Backes et al., 2016), may track trends in student education and career choices in order to validate their program. Likewise, regional education agencies, such as the Southern Regional Education Board (SREB, 2017), may track the progress of the programs they certify for STEM or STEAM education. Finally, middle schools or high schools that became STEM/STEAM schools in the wake of the "Educate to Innovate" campaign may be tracking their graduates once they leave the program. If any of these organizations have mechanisms for tracking their graduates through college and into their eventual career, it would be worthwhile to contact them and seek permission to use their data collection instruments.

Research the STEM/STEAM programs of similar schools. The target school in this study is a rural, middle school with a large minority and impoverished population. The STEAM program has minimal resources. The school does not operate under a federal or state grant to finance their program; nor has it asked school partners for funding to finance their program. Additionally, the projects the school has completed were all designed in-house by the teachers on a rotational basis. Different groups of teachers designed the projects from year-to-year. This process is time-intensive and has resulted in projects that lack consistency of quality and academic rigor. A recommendation for research is to identify STEM/STEAM schools with similar demographics to examine their curriculum, projects, and funding mechanisms. Kindred

184

schools may be willing to share curriculum, projects, and the means with which they finance their STEM/STEAM. This last piece, financing the program, is critical. If there are schools out there that have established viable means to finance their program, it would be beneficial to explore what they do and adapt it for the target school.

Research reasons why the African American students were less likely to enter STEAM professions then white students. In the student survey, the African American students indicated less preference to pursue STEAM professions than their white peers. This was the only statistically significant difference between sub-groups in the survey. The findings of this evaluation note the difference but do not propose a reason why it occurs. It would be worthwhile for the school to seek the reasons for this difference preparatory to developing a plan of action to close the gap between the races. Closing this gap is in accordance with the goals of the "Educate to Innovate" campaign and with the school's goal to create a color-blind program for nurturing prospective STEAM professionals. This research may involve looking into what similar schools have done to close the gaps in student aspiration and it may involve discussing with the African American students why they have less preference to enter STEAM professions. With these reasons in hand, it would help in creating a plan of action that helps these students begin to visualize themselves as prospective engineers, mathematicians, scientists, computer specialists, and artists. This is at the heart of the reasons for developing a STEM/STEAM program, in the school and in the country.

<div align="center">

Relevance to the Literature

</div>

This study was a practical application of the STEM Common Measurement System (Saxton et al., 2014), a theoretical construct, as a framework for evaluating a

185

STEM/STEAM program. This construct facilitated the organization of the program evaluation of the school's STEAM program and is a natural fit for future program evaluations of STEM or STEAM schools. It is an example of a content, inputs, process, and products (CIPP) conceptual model for a program evaluation in practice (Mertens & Wilson, 2012) and wholly appropriate for the evaluation task at hand.

As a program evaluation, the researcher reviewed the purpose and means available for data collection before deciding on an appropriate paradigm for the evaluation (Mertens & Wilson, 2012).   In this evaluation, the primary purpose was to assess an ongoing STEAM   program and provide pertinent feedback to the faculty and administration on the implementation. This emphasis on providing useful input to an ongoing STEAM program contributed to the decision to conduct a pragmatic, mixed methods evaluation. The result is an effective and efficient evaluation of an ongoing STEAM program with minimal intrusion of the program.

<div align="center">

Summary and Final Thoughts

</div>

This dissertation began with a discussion of the difference between STEM problem-based learning (PBL) and teacher-directed projects. Problem-based learning is student-centered, inquiry-based and open-ended rather than teacher directed and highly structured. Teacher directed projects tend to have one best answer and are often completed for fun. The Southern Region Education Board (SREB, 2017) described these entertaining but often irrelevant projects as "Edutainment."

The pragmatic, mixed methods program evaluation in this dissertation depicted a middle school in its sixth year of implementing a STEAM program that is striving to make the school one where problem-based learning is the norm rather than the exception.

They are not engaged in "Edutainment." The principal has been with the program since its inception and is a driving force behind the implementation of the walls down, annual STEAM projects, the numerous STEAM activities available at the school, and a school culture that continues to embrace STEAM learning. In her dissertation on middle schools successful in implementing a STEM curriculum, Ferrara-Genao (2015) emphasized the importance of strong administrators who champion the program. This is the case here.

The teachers are also instrumental in the success of the school's STEAM program. Their responses in the focus groups and the teacher survey indicate a faculty that generally buys into the culture required for STEAM learning to be successful. There are nay-sayers among the teachers, but they are a minority and they do not hold disproportional sway over their fellow teachers. Teacher responses to the focus group questions and survey items on student interest and efficacy indicate the teachers see a difference in student interest in STEAM and student confidence in their abilities. More importantly, the student responses to the school support questions in the student survey indicate the students believe in their teachers. In this environment of mutual respect between teachers and students, the STEAM program has flourished.

In response to the research questions, the students have developed an interest in STEAM learning and professions, and their self-efficacy is strong. With few exceptions, there are no statistically significant differences in student responses to interest and efficacy questions when comparing females and minorities to males and whites, respectively. The teachers are confident in their ability to teach the inquiry-based, student-centered, technology rich instruction required of STEAM learning. And finally, the school has grown academically over the last four years, as indicated on state testing.

187

REFERENCES

Almarode, J. T., Subotnik, R. F., Crowe, E., Tai, R. H., Lee, G. M., & Nowlin, F. (2014). Specialized high schools and talent search programs: Incubators for adolescents with high ability in STEM disciplines. *Journal of Advanced Academics, 25*(3), 307-331.

America Competes Act, 20 U. S. C. § 9801 *et seq.* (2007).

Avery, Z.K., & Reeve, E. M. (2013). Developing effective STEM professional development programs. *Journal of Technology Education, 25*(1), 55-69.

Backes, B., Goldhaber, D., Cade, W., Sullivan, K., & Dodson, M. (2016). *Can uteach? Assessing the relative effectiveness of STEM teachers.* National Center for Analysis of Longitudinal Data in Education Research Working Paper, 173.

Basham, J. D., & Marino, M. T. (2013). Understanding STEM education and supporting students through universal design for learning. *Teaching Exceptional Children, 45*(4), 8-15.

Beede, D. N., Julian, T. A., Langdon, D., McKittrick, G., Khan, B., & Doms, M. E. (2011). *Women in STEM: A gender gap to innovation*.

Blackburn, H. (2017). The status of women in STEM in higher education: A review of the literature 2007–2017. *Science & Technology Libraries*, *36*(3), 235-273.

Bloom, B. S., & Sosniak, L. A. (1985). *Developing talent in young people*. New York: Ballantine Books.

Boyce, A.S. (2017). Lessons learned using a values-engaged approach to attend to culture, diversity, and equity in a STEM program evaluation. *Evaluation & Program Planning*, *64*(2017), 33-43.

Burgstahler, S. (2012). *Universal design in education: Principles and applications.* Seattle: University of Washington. Retrieved from http://www.washington.edu/doit/universal-design-education-principles-and-application

Burrows, A., & Slater, T. (2015). A proposed integrated STEM framework for contemporary teacher preparation. *Teacher Education & Practice, 28*(2/3), 318-330.

Bybee, R.W. Advancing STEM education: A 2020 vision. *Technology & Engineering Teacher, 70*(1), 30-35.

Bybee, R.W. (2010). What is STEM education? *Science, 329*(5995), 996.

Carter, S. (2012). *Utilization-focused evaluation of a STEM enrichment program* (Doctoral dissertation). Retrieved from *ProQuest LLC*. http://gateway.proquest.com.pallas2.tcl.sc.edu/openurl?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&res_dat=xri:pqm&rft_dat=xri:pqdiss:3533980

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin*, *143*(1), 1-35.

Culture. (n.d.). In *Meriam-Webster online dictionary*. Retrieved October 26, 2017, from https://www.meriam-webster.com/dictionary/culture

189

Diversity. (n.d.). In *Meriam-Webster online dictionary*. Retrieved October 28, 2017, from

https://www.meriam-webster.com/dictionary/diversity

Duckworth, A. (2016). *Grit: The power of passion and persistence.* New York, New

York: Scribner.

Dutta-Moscato, J., Gopalakrishnan, V., Lotze, M. T., & Becich, M. J. (2014, March).

Creating a pipeline of talent for informatics:

Elementary and Secondary Education Act (ESEA) of 1965, 20 U. S. C. § 6301 *et seq.*

(1965).

English, L.D. (2017). Advancing elementary and middle school STEM education.

International Journal of Science and Mathematics Education, 15(1), 5-24.

Equity. (n.d.). In *Meriam-Webster online dictionary*. Retrieved October 28, 2017, from

https://www.meriam-webster.com/dictionary/equity

Every Student Succeeds Act (ESSA) of 2015, 20 U.S.C. § 6301 *et seq.* (2015).

Executive Office of the President: President's Council of Advisors on Science and

Technology. (2010). *Prepare and inspire: K-12 education in science, technology,*

engineering, and math (STEM) for America's future. Retrieved from

https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-

stem-ed-final.pdf

Ferrara-Genao, J. C. (2015). *The principal's perspective: Essential factors when*

implementing integrative STEM in middle school (Doctoral dissertation).

Retrieved from University of Southern California Digital Library

http://cdm15799.contentdm.oclc.org/cdm/ref/

collection/p15799coll3/id/587899

Gonzalez, H. B., & Kuenzi, J. J. (2012). *Science, technology, engineering, and mathematics (STEM) education: A primer.* Congressional Research Service, Library of Congress. Retrieved from https://www.upd.edu.ph/~updinfo/oct13/articles/R42642.pdf

Greene, J. C., DeStefano, L., Burgon, H., & Hall, J. (2006). An educative, values-engaged approach to evaluating STEM educational programs. *New Directions for Evaluation*, *2006*(109), 53-71.

Griffin, K. A., Perez II, D., Holmes, A. P. E., & Mayo, C. E. P. (2010). Investing in the future: The importance of faculty mentoring in the development of students of color in STEM. *New Directions for Institutional Research, 2010*(148), 5-15.

Herro, D., and Quigley, C. (2016). Innovating with STEAM in middle school classrooms: Remixing education. *On the Horizon, 24*(3), 190-204.

Hill, J. G., & Gruber, K. J. (2011). *Education and certification qualifications of departmentalized public high school teachers of core subjects: Evidence from the 2007-2008 schools and staffing survey* (NCES Report 2011-037). Retrieved from National Center for Education Statistics website: https://nces.ed.gov/pubs2011/2011317.pdf

Huck, S. W. (2012). *Reading statistics and research* (6th ed.). Boston, Massachusetts: Pearson Education, Inc.

International Society for Technology Education. (2018). *ISTE Standards for Students*. Retrieved from https://www.iste.org/standards/for-students

Jiang, Z., Doverspike, D., Zhao, J., Lam, P., & Menzemer, C. (2010). High school bridge
program: A multidisciplinary STEM research program. *Journal of STEM
Education: Innovations & Research*, *11*(1), 61-68.

Joint Committee on Standards for Educational Evaluation. (1994). *The program
evaluation standards: How to assess evaluations of educational programs (2nd
ed.)*. Thousand Oaks: Sage Publications.

Jolly, A. (2014). STEAM vs. STEM: Do the arts belong? *Education Week*. Retrieved
from http://www.edweek.org/tm/articles/2014/11/18/ctq-jollystem-vs-steam.html

Jung, Y. J. (2014). STEM education and sustainable growth in regions: Lessons learned
from the US WIRED program evaluation. *World Technopolis Review, 3*(3), 153-
164.

Katzenmeyer, C., & Lawrenz, F. (2006). National Science Foundation perspectives on
the nature of STEM program evaluation. *New Directions for Evaluation,
2006*(109), 7-18.

King, C. M., Lancaster, P. E., DeFrance, N. L., Melin, J. A., & Cleveland, R. (2013).
Curricular and pedagogical imperatives for fostering effective STEM teacher
preparation. *Teacher Education and Practice*, *26*(4), 706-720.

Kolvoord, B., Puffenbarger, R., McGhee, R., Miller, R. J., Overway, K., Phillips, K., & ...
Brown, J. (2016). Bridging the valley: Recruiting and retaining STEM majors.
Journal of STEM Education: Innovations and Research, *17*(4), 8-18.

Lam, P., Doverspike, D., Zhao, J., Zhe, J., & Menzemer, C. (2008). An evaluation of a
STEM program for middle school students on learning disability related IEPs.
Journal of STEM Education: Innovations & Research, *9*(1/2), 21-29.

Lawrenz, F., & Huffman, D. (2006). Methodological pluralism: The gold standard of STEM evaluation. *New Directions for Evaluation, 2006*(109), 19-34.

Lesseig, K., Slavit, D., Nelson, T. H., & Seidel, R. (2016). Supporting middle school teachers' implementation of STEM design challenges. *School Science & Mathematics, 116*(4), 177-188.

McDonald, C.V. (2016). STEM education: A review of the contribution of the disciplines of science, technology, engineering, and mathematics. *Science Education International*, *27*(4), 530-569.

McDonnell, L. M., & Weatherford, M. S. (2013). Organized interests and the common core. *Educational Researcher*, *42*(9), 488-497.

McNally, T. (2012). Innovative teaching and technology in the service of science: Recruiting the next generation of STEM students. *Journal of the Scholarship of Teaching and Learning*, *12*(1), 49-58.

Mertens, D. M., & Hopson, R. K. (2006). Advancing evaluation of STEM efforts through attention to diversity and culture. *New Directions for Evaluation, 2006*(109), 35-51.

Mertens, D. M., & Wilson, A. T. (2012). *Program evaluation theory and practice: A comprehensive guide.* New York: The Guilford Press.

Milner, D. I., Horan, J. J., & Tracey, T. J. G. (2014). Development and evaluation of STEM interest and self-efficacy tests. *Journal of Career Assessment, 22*(4), 642-653.

Museus, S. D., & Liverman, D. (2010). High-performing institutions and their

implications for studying underrepresented minority students in STEM. *New

Directions in Institutional Research, 2010*(148), 17-27.

Museus, S. D., Palmer, R. T., Davis, R. J., & Maramba, D. C. (2011). Special Issue:

Racial and Ethnic Minority Students' Success in STEM Education. *ASHE Higher

Education Report*, *36*(6), 1-140.

Mythopoesis. (n.d.). In *Meriam-Webster online dictionary*. Retrieved March 11, 2018,

from https://www.meriam-webster.com/dictionary/mythopoesis

Nakamoto, J., & Bojorquez, J. C. (2017). Pathways to STEM initiative (PSI): Evaluation

report for an investing in innovation (I3) development grant. *WestEd*.

National Coalition for Women and Girls in Education. (2008). *Title IX at 35: Beyond the

headlines*. Retrieved from http://ncwge.org/PDF/TitleIXat35.pdf

National Defense Education Act of 1958, Pub. L. No. 85-864, § 101, 72 Stat. 1580

(1958).

New Ellenton Middle STEAM Middle School. (2016). *2016-2017 NEMS STEAM

brochure*. Retrieved from https://www.acpsd.net/Page/20553

New Ellen STEAM Magnet Middle School website. (2019). Retrieved from

https://www.acpsd.net/Page/20553

Office of the Press Secretary, The White House. (2009). President Obama launches

"educate to innovate" campaign for excellence in science, technology,

engineering & math (STEM) education. Retrieved from

https://obamawhitehouse.archives.gov/the-press-office/president-obama-launches-

educate-innovate-campaign-excellence-science-technology-en

194

Olivarez, N. (2012). *The impact of a STEM program on academic achievement of eighth grade students in a South Texas middle school* (Doctoral Dissertation, Texas A&M University-Corpus Christi).

Novit, R. (2013, May 26). Dugar returns to New Ellenton as principal. *Aiken Standard*. Retrieved from https://www.aikenstandard.com/

Page, C. A., Lewis, C. W., Autenrieth, R. L., & Butler-Purry, K. L. (2013). Enrichment experiences in engineering (E3) 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. *Journal of STEM Education: Innovations & Research*, *14*(3), 27-33.

Perez, M., & Romero, P. (2014). Secondary STEM teacher preparation as a top priority for the university of the future: National uteach replication as a strategic initiative. *The Journal of the World Universities Forum, 6*(4), 21-36.

Quigley, C. F., Herro, D., & Jamil, F. M. (2017). Developing a conceptual model of STEAM teaching practices. *School Science and Mathematics*, *117*(1-2), 1-12.

Ransom, C. (2015). Interview with President Barack Obama. *Popular Science, 288*(2). Retrieved from http://www.popsci.com/features/interview-with-president-barack-obama/

Reiss, M. J., & Mujtaba, T. (2017). Should we embed careers education in STEM lessons? *Curriculum Journal, 28*(1), 137-150.

Sanders, M. E. (2009). STEM, STEM education, STEMmania. *Technology Teacher, 68*(4), 20-26.

195

Saxton, E., Burns, R., Holveck, S., Kelley, S., Prince, D., Rigelman, N, & Skinner, E. A. (2014). A common measurement system for K-12 STEM education: Adopting an educational evaluation methodology that elevates theoretical foundations and systems thinking. *Studies in Educational Evaluation*, *40,* 18-35.

Schuster, D., Buckwalter, J., Marrs, K., Pritchett, S., Sebens, J., & Hiatt, B. (2012). Aligning university-based teacher preparation and new STEM teacher support. *Science Educator*, *21*(2), 39-44.

Sithole, A., Chiyaka, E. T., McCarthy, P., Mupinga, D. M., Bucklein, B. K., & Kibirige, J. (2017). Student attraction, persistence, and retention in STEM Programs: Successes and continuing challenges. *Higher Education Studies*, *7*(1), 46-59.

Sjaastad, J. (2012). Sources of inspiration: The role of significant persons in young people's choice of science in higher education. *International Journal of Science Education*, *34*(10), 1615-1636.

South Carolina Department of Education website. (2019). *SC school report card*. Retrieved from https://screportcards.ed.sc.gov/

South Carolina Education Oversight Committee. (2017). *Profile of the South Carolina graduate*. Retrieved from http://www.eoc.sc.gov/Home/Profile%20of%20the%20 Graduate/Profile%20of%20the%20SC%20Graduate.pdf

Southern Regional Education Board. (2017). *Advanced career: What modern career and technical education looks like*. Retrieved from https://www.sreb.org/advanced-career

Southern Regional Education Board. (2017). *College or career? Why not both*. Retrieved from https://www.sreb.org/sites/main/files/file-attachments/stem_pbl_pinellas.pdf

STEM Education Act of 2015. 42. U. S. C. § 1861. *et seq.* (2015).

STEM Education Coordination Act of 2009, H. Res. 1709, 111th Cong., 111 Cong. Rec. (2009) (enacted).

Stufflebeam, D. L. (1999). *Program evaluations metaevaluation checklist*. Retrieved from Western Michigan University Evaluation Center website: http://www.wmich.edu/sites /default/files/attachments/u350/2014/program_metaeval_short.pdf

Stufflebeam, D. L. (2001). The metaevaluation imperative. *American Journal of Evaluation, 22*(2), 183-209.

Subotnik, R. F., Tai, R. H., Rickoff, R., & Almarode, J. (2009). Specialized public high schools of science, mathematics, and technology and the STEM pipeline: What do we know now and what will we know in 5 years? *Roeper Review*, *32*(1), 7-16.

Toglia, T.V. (2013). Gender equity issues in CTE and STEM education: Economic and social implications. *Tech Directions, 72*(7), 14-17.

Tsui, L. (2009). Recruiting females into male dominated programs: Effective strategies and approaches. *Journal of College Admission, 203*, 8-13.

Tsui, L., Cosentino, C., Clewell, B. C., Deterding, N., Gilfenbaum, E. M., Page, E., & West, C. (2008). *Producing women engineers: A study of undergraduate engineering programs for women*. Submitted to the National Science Foundation, August 2008.

United States Department of Justice. (2015). *Overview of Title IX of the Education Amendments of 1972*. Retrieved from https://www.justice.gov/crt/overview-title-ix-education-amendments-1972-20-usc-1681-et-seq

van den Kieboom, L. A., McNew-Birren, J. C., Eckman, E. W., & Silver-Thorn, M. B. (2013). Field experience as the centerpiece of an integrated model for STEM teacher preparation. *Teacher Education and Practice*, *26*(2), 341-357.

Walters, J., & McNeely, C. L. (2010). Recasting Title IX: Addressing gender equity in the science, technology, engineering, and mathematics professoriate. *Review of Policy Research*, *27*(3), 317-332.

Wells, J. G. (2016). I-STEM ed exemplar: Implementation of the PIRPOSAL model. *Technology and Engineering Teacher, 76*(2), 16-23.

Wissehr, C., Concannon, J., & Barrow, L. H. (2011). Looking back at the sputnik era and its impact on science education. *School Science & Mathematics, 111*(7), 368-375.

Wood, L. (2016, October 11). New Ellenton students save Earth with STEAM power. *Aiken Standard*. Retrieved from https://www.aikenstandard.com/

Wood, L. (2017, December 3). New Ellenton middle students diagnose 'mystery disease.' *Aiken Standard*. Retrieved from https://www.aikenstandard.com/

Wood, L. (2018, August 18). New school year: District's redistricting plan goes into effect. *Aiken Standard*. Retrieved from https://www.aikenstandard.com/

Zhe, Z., Doverspike, D., Zhao, J., Lam, P., & Menzemer, C. (2010). High school bridge program: A multidisciplinary STEM research program. *Journal of STEM Education: Innovations & Research, 11*(1), 61-68.

APPENDIX A

DISTRICT APPROVAL OF RESEARCH PROPOSAL

AIKEN COUNTY
PUBLIC SCHOOLS

Guidelines and Procedures for Conducting Research Affiliated with Aiken County Schools

This document is intended to provide an overview regarding the policies, procedures and approval processes for conducting any type of research within the Aiken County School District (ACPSD).

The Aiken County School District is committed to upholding the highest standards in educational research, including full compliance with ethical and legal codes of conduct involving human subjects. The following guidelines and approval process applies to all teachers, staff, students, other personnel, or researchers outside of the Aiken County School District interested in conducting any type of research either within the District or in any Aiken County school.

Ethical Responsibility

Any person, group or organization engaged in research within the Aiken County School District or in any one of the District's schools, are expected to meet the highest standards of integrity, accuracy, objectivity and intellectual honesty. This includes appropriate regard for human subjects, and full compliance with local, state and federal laws.

Researchers are expected to be knowledgeable of, and comply with, the appropriate ethical codes that govern education research. These include the code of ethics outlined by the *American Educational Research Association (AERA)* and those by the Society for Research in Child Development, both of which provide guidance to those conducting educational research.

Confidentiality/Privacy and Access

The Family Educational Rights and Privacy Act (FERPA) (20 U.S.C. § 1232g; 34 CFR Part 99) is a Federal law that protects the privacy of student education records. The law applies to all schools that receive funds under an applicable program of the U.S. Department of Education. The Aiken County School District is the custodian of confidential, proprietary and private information. Individuals who have access to such information are expected to be familiar and to comply with applicable laws, District policies, directives and agreements pertaining to access, use, protection and disclosure of such information. Please see the resource section listed below for complete information on FERPA policies.

Aiken County School District Employees

Student/School Based Research to Improve Instructional Practices

Teachers may gather and analyze data at any time if the data are being used solely for the improvement of their own professional practice and if the collection of such data would be part of ordinary instructional procedures for their own students. Research of this nature should have the approval of the school Principal, but does not require District approval.

Research Conducted as part of a College or University Degree Program or Class

Most often, research conducted by District employees is part of a requirement for a class or degree program falls under the category of *action research*. Mills (2003) defined action research as *"any systematic inquiry conducted by teachers, administrators, counselors, or others with a vested interest in the teaching and learning process, for the purpose of gathering data about how their particular schools operate, how they teach, and how students learn"* (p. 5).

It is the responsibility of the individual conducting the research to work closely with their professor to determine if the proposed research project 1) involves a systematic investigation, including research development, testing and evaluation, designed to develop or to contribute to generalizable knowledge, or 2) is necessary to fulfill requirements for a master's thesis, doctoral dissertation, or other research requirements of the University. If so, the research will likely require approval from the University's Institutional Review Board (IRB). Anything beyond action research that involves human subjects, will require approval from the University's IRB. A human subject is defined as: *A living individual about*

Rev 9/2016

199

whom an investigator conducting research obtains 1) data through intervention or interaction with the individual or 2) identifiable private information.

The Aiken County School District expects college and university faculty members to work with their students to develop, review, edit and obtain institutional approval of proposals *before* they are submitted to the district for review. Individuals who are submitting proposals to meet requirements for a degree program at a college or university must submit documentation that their proposals have been reviewed by the institutional review board (IRB) of the college or university and either approved or granted exempt status by the IRB. The granting of exempt status by an institutional review board does *not* relieve the researcher of the ethical responsibility to obtain informed consent from participants.

Researchers Outside of the Aiken County School District

The Aiken County School District will work to accommodate researchers from outside the district if their proposals meet district criteria. The district requires that educational research projects conform to ethical standards. Therefore, the district requires researchers, including its own employees, to obtain written parent and/or student permission when using student data and/or work samples in class presentations, academic papers, conference presentations, publications and similar activities. The District will review research proposals that *meet the following approval criteria*:

- The research does not interfere with the educational programs of the district.
- The research respects the privacy, informed consent and due process rights of students and employees.
- The researcher agrees to provide the district with a copy of the completed research.
- These procedures and criteria are in place to protect students and employees of the district. While the district welcomes research studies, it is important to note that failure to adhere to district policy and procedures will result in denial of the proposal.

Researchers outside of the Aiken County School District must also undergo a mandatory criminal background check required by District policy. Researchers must complete the volunteer application which may be found at http://www.acpsd.net/cms/lib011/SC02209457/Centricity/Domain/116/SLED.pdf

Procedures to Submit a Research Project for Review

After reviewing this document and the critical resource information listed below, a researcher may complete the *Application Request for Research Project* and submit it to the Office of Accountability and Assessment for review either via fax (803) 641-2636 or email to kolin@acpsd.net

After the application is reviewed, you will be notified via email at the address listed on the application.

Critical Resources and Information for all those conducting research in Aiken County Schools

- AERA Code of Ethics
  http://www.aera.net/Portals/38/docs/About_AERA/CodeOfEthics(1).pdf
- Office for Human Research Protections IRB Guidelines
  http://www.hhs.gov/ohrp/
- Online Research Ethics Course:
  http://ori.dhhs.gov/education/products/montana_round1/research_ethics.html
- NIH online training course Introduction to the Responsible Conduct of Research
  http://researchethics.od.nih.gov/
- Society for Research in Child Development
  http://www.srcd.org/index.php?option=com_content&task=view&id=68
- Family Educational Rights and Privacy Act (FERPA)
  http://www2.ed.gov/policy/gen/guid/fpco/index.html

Rev 9/2016

Application Request for Research Project

NAME: Warren Wintrode	DATE OF PROPOSAL: 11-28-17
School/Location: Aiken County Public Schools	Principal/Supervisor Shunte Dugar
Email address: wwintrode@acpsd.net	University Professor: Dr. Susan Bon

SCHOOL(S), CLASSROOM or LOCATION IN WHICH PROJECT IS BEING CONDUCTED:

New Ellenton Middle School (NEMS)

APPROVAL RECEIVED FROM PRINCIPAL OR IMMEDIATE SUPERVISOR ☑ YES ☐ NO	RESEARCH START DATE: AUG 2018
	ESTIMATED COMPLETION DATE: DEC 2018

Research Project Description
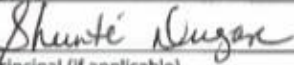
1. Title of Research Project:

Program Evaluation of STEAM Program at NEMS

2. Describe the primary purpose of the research as well as the measurable objectives of the project.
Examples: "The aim of this study is to _____ (Determine/Measure/Gather information on/ Investigate the consequences/Test the theory/Analyze the impact/Develop deeper understanding of _____.

The aim of this study is to determine the impact of the science, technology, engineering, arts, and mathematics (STEAM) on student interest in STEAM professions, their self-efficacy in critical thinking, collaboration, and communication, and teacher efficacy in providing inquiry-based, student-centered instruction. The research questions:

- How do students who have participated in the STEAM program perceive their interest in STEAM professions and self-efficacy in STEAM knowledge and skills?
- How has participation in the STEAM program influenced the self-efficacy of females and minorities involved in the program?
- How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students?

3. Provide a brief description of the research and how it will address improvement of educational policy, programs or practices:

My proposal is to conduct a program evaluation of the STEAM program at New Ellenton Middle School, with the participation of the faculty and administration. This will occur during the 2018-19 school year. The end state of the study is an assessment of the STEAM program effectiveness, and potentially some recommendations for improving the program.

4. How does the Research Project align with the strategic mission and vision of the ACPSD, a specific school or classroom? If a section is not applicable to your Research Project, indicate N/A.
District/School strategic plan and educational goals to improve student achievement:

☑ Research-based strategies related to improving districts, schools, curriculum, instruction, assessment, and Improving learning for all students:

☐ Improvement of learning for all students in the targeted student population(s):

☑ Standards-based instruction and assessment, (SC State Standards, College-Career Ready etc.)

Rev 3/2016

- ☐ Professional development and support for instructional or support staff:
- ☐ Supervision and evaluation of instructional staff (and non-instructional staff, if applicable):
- ☑ Diverse learning needs of students:
- ☑ Use of technologies designed to enhance teaching and learning,
- ☑ Creating a safe, nurturing and orderly school environment that is conducive to learning for all students
- ☐ Engaging Parents, Community or Business partners

Data Requests: Please describe in detail any data or information that you are requesting from the District. This would include requests to administer surveys, conduct observations etc. Please be as specific as possible.

I would like to obtain the following information from the District:

- Student survey on the STEAM program (focus on interest and efficacy, 12 items)
- Teacher survey on the STEAM program (focus on interest, efficacy, student supports, and professional development, 12 items)
- Focus group with the teachers (focus on interest, efficacy, student supports, and professional development, 9 questions)
- Interviews with administration
- School report card data, and artifacts from the STEAM program.

Other Relevant Comments:

I will conduct this research with the participation and cooperation of NEMS faculty and staff. I will preview all data collection instruments with the stakeholders and adjust them accordingly.

My signature below certifies that:

- I have received a copy of the *Guidelines and Procedures for Conducting Research Affiliated with Aiken County Schools* and that I will comply fully with the policies and procedures outlined as part of my research
- I have reviewed all relevant policies and procedures as outlined in that document related to responsible conduct in research including those related to ethical conduct and confidentiality.
- I understand that while working as a researcher under the supervision of an Aiken County School District employee, I may have access to records and files that contain confidential information and that it is the employer's obligation to protect the rights of these files and/or individuals and that
- I will follow the operating practices and procedures required while handling these records and will not inappropriately access or disclose this information.
- I acknowledge that if I misrepresent or omit any information as requested on this application I have jeopardized my continued association with Aiken County School District and is cause for forfeiture of consideration

Researcher Name: **Warren Wintrode**
Print or Type name

Researcher Signature _Warren Wintrode_   Date 11-28-17

Reviewed by:

Signature: _Shunté Dugan_   Date: 12/19/17
Principal (if applicable)

Signature: * _Katebli_   Date: 2/27/2018
Director, Office of Accountability & Assessment or Chief Officer of Administration

Disposition: APPROVED   DENIED

* please prepare parent letter regarding student surveys 9/2016

Kate Olin

Hi Warren,

I reviewed your research request last night. I have only one area that I request that you address. I know it is technically a program evaluation rather than research but it does request the involvement of students. What does your program chair say about IRB approval? At minimum, please prepare a letter to parents of any students that you want to participate in the survey. Just a general introduction, rationale and letting them know participation is voluntary. Please let me know if you have any questions.

Thank you.

Kate Olin, Director
Office of Accountability & Assessment
Aiken County Public Schools
kolin@acpsd.net
803-641-2609

AIKEN COUNTY
PUBLIC SCHOOLS

The mission of Aiken County Public Schools, the emerging premier school district, is to cultivate future-ready students to serve our evolving community and world through an innovative, literacy-focused school system distinguished by rigorous, personalized learning opportunities; highly effective, service-driven professionals; and mutually-beneficial partnerships.

1

Date

Parents,

My name is Warren Wintrode and am an employee of Aiken County Public Schools. I am working with the faculty and staff of New Ellenton STEAM Magnet Middle School to evaluate the science, technology, engineering, arts, and mathematics (STEAM) program at the school. Every child at New Ellenton Middle participates in the STEAM program, learning about technical professions and developing skills that promote life-long learning, problem solving, working as part of a team, speaking, and writing. The purpose of the evaluation is to learn about the program and use this information to improve the learning experience for our children.

As part of the evaluation, I would like to have all of the students at the school take a brief, 13-question survey to get information on their thoughts about the STEAM program. Specifically, it asks whether students are more interested in STEAM than before they began the program. It also asks whether the students feel more confident in their learning skills since beginning the program. Participation is voluntary. The survey is anonymous. It will not collect any identifiable information about your child. If you would not like your child to participate in the survey, please sign the "opt out" below and have your child return it to the front office. Thank you.

Warren Wintrode
Math Content Interventionist
Aiken County Public Schools

....

I would prefer that my child, _____, not take the STEAM program
survey.   (Print student name)

_____   _____
(Signature of parent)   (Date)

APPENDIX B

IRB APPROVAL OF RESEARCH PROPOSAL

UNIVERSITY OF
SOUTH CAROLINA

OFFICE OF RESEARCH COMPLIANCE

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH
DECLARATION of NOT RESEARCH

Warren Wintrode
College of Education
Department of Education Leadership & Policies / Educational Administration
Wardlaw
Columbia, SC 29208

Re: Pro00079102

Dear Mr. Wintrode:

This is to certify that research study entitled *Program Evaluation of a Middle School STEAM Program* was reviewed on **6/27/2018** by the Office of Research Compliance, which is an administrative office that supports the University of South Carolina Institutional Review Board (USC IRB). The Office of Research Compliance, on behalf of the Institutional Review Board, has determined that the referenced research study is not subject to the Protection of Human Subject Regulations in accordance with the Code of Federal Regulations 45 CFR 46 et. seq.

No further oversight by the USC IRB is required. However, the investigator should inform the Office of Research Compliance prior to making any substantive changes in the research methods, as this may alter the status of the project and require another review.

If you have questions, contact Arlene McWhorter at arlenem@sc.edu or (803) 777-7095.

Sincerely,

Lisa M. Johnson
ORC Assistant Director
and IRB Manager

University of South Carolina ● 1600 Hampton Street, Suite 414 ● Columbia, South Carolina 29208 ● 803-777-7095
An Equal Opportunity Institution

205

www.manaraa.com

APPENDIX C

STEAM GOALS AND IMPLEMENTATION FOCUS GROUP GUIDE

Introduction

The science, technology, engineering, arts, and mathematics (STEAM) program at this school is a school-wide, cross-curricular program designed to introduce our students to science, technology, engineering, arts, and mathematics (STEAM) professions and engage them in real-world applications of the engineering design process. With your help, I have embarked on a program evaluation of the STEAM program at this school, designed to identify the goals of the program, characterize the strengths and areas for improvement in program implementation, and determine whether the program is meeting its goals.

This focus group will be approximately 30 minutes long. We will gather the information from the group in two methods, through taping and observing the focus group session. The tape-recording of the focus-group will be only for analysis; the names of participants will not be used in any reports. Your input to this process is very important; however, if you are uncomfortable speaking, you are not required to participate. Do you have any questions?

Ground rules:

1. The ideas shared here are confidential and your participation is voluntary. If you are not comfortable participating, you may excuse yourself. If you choose to participate, you do not have to answer every question, but I hope you will share your thoughts.

2. Keep comments focused on the implementation of the STEAM program within the school and the implications for the students in the future.

3. As I mentioned, our discussion will be tape-recorded; so please speak loudly enough for the tape-recorder to pick up your voice.

4. For the tape recorder to pick up your voice, one person should speak at a time. Please do not interrupt other teachers when they are speaking.

5. Address statements to the entire group even when you are responding to the comment of an individual; avoid conversations with your neighbors because this will limit the information that goes into our discussion and distract other group members.

6. You do not have address your comments to me. We hope to have an open discussion about the strengths of the STEAM program and areas for improvement. I am here to ask questions and keep us on track.

7. In our discussion, feel free to make comments that are negative as well as positive. All opinions need to be shared. We are <u>not</u> trying to get everyone to agree on an issue; instead we want to hear all viewpoints.

8. At times I may have to interrupt you. I am not trying to be rude; I am trying to assure that everyone is heard and that in our limited time we cover a certain amount of material.

9. If you feel that you are speaking for the group, please indicate so. I will attempt to clarify by asking questions such as "Is this how everyone feels?" Please respect each other's right to disagree or offer a different perspective.

Do you have any questions about the procedures?

Questions:

1. From your observations, have students who have participated in the STEAM program become more interested in the STEAM professions?

2. How has student perception of their self-efficacy in STEAM knowledge and skills changed since their involvement in the STEAM program?

3. How has participation in the STEAM program influenced the interest and self-efficacy of females and minorities involved in the program?

4. How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students?

5. What are your current and future needs for professional development?

6. Has implementing the inquiry-based, student-centered STEAM curriculum caused you to adjust your instructional practices, during the STEAM projects and in your regular classes? If so, in what manner have you changed your instruction?

7. What are your challenges in implementing effective STEAM instruction?

8. What is your plan for collecting and analyzing student data, in the short term, and as students exit the program (through high school and beyond)? How will you use the data you collect?

Close: Again, thank you for your attention and participation. Your input will help clarify the program goals and definition of success.

APPENDIX D

STEAM SURVEY FOR STUDENTS

Please complete the survey below. Your participation is voluntary, and your responses are anonymous. The questions ask for your impressions of the Science, Technology, Engineering, Arts, and Mathematics (STEAM) program at the school. Place a check in one box for each question with the most accurate response.

Statement: The Science, Technology, Engineering, Arts, and Mathematics, or STEAM, program within your school is part of a nationwide campaign sponsored by the president to promote science and math education in our nation's public schools. This campaign promotes a program of study that is student-centered and based on inquiry, problem solving, working in teams, and technology use. The goal of the campaign is to promote student interest in STEM and STEAM, and increase the numbers of scientists, engineers, mathematicians, and computer scientists in our workforce. For middle school students, the STEAM program is intended to introduce you to STEM and STEAM professions and encourage you to participate in STEM and STEAM activities and further studies. Your answers to this survey will help your teachers and principal assess the effectiveness of the program in promoting student interest in STEM and STEAM studies and professions. It will also check to see if you think the program is helping you develop your confidence in your abilities to problem solve, work in teams, and communicate verbally and in writing. Please take your time with the survey. Read each question carefully, and answer what is asked. There is no right or wrong answer for a question, and your responses are anonymous. Your answers will assist the teachers and principal in designing the program in the future.

What is your gender?	Female ☐	Male ☐	
What is your grade?	6th ☐	7th ☐	8th ☐
What is your race?	Black ☐	Hispanic ☐	White ☐	Other ☐

1. Have you completed a STEAM project with your classmates while at NEMS?	Yes □	No □		
2. STEAM education has helped me improve my **ability to work together with my classmates**.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4
3. STEAM education has helped me improve my **communication skills.**	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4
4. STEAM education has NOT helped me improve my **ability to write in complete, grammatically correct sentences**.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4
5. STEAM education has helped me improve my **ability to solve problems**.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4
6. I have learned about professions in science, technology, engineering, arts, and math that I did not know before.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4
7. I DO NOT want to take **more STEAM classes in high school and college.**	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4
8. I am thinking about entering a **STEAM profession**.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4
9. I can get help from my teachers in math and science if I need it.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4

10. Working on the STEAM projects, I have become better at **completing my assignments**.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4
11. My teachers have encouraged me when I struggled in science, or math, or with a STEAM project.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4
12. I DO NOT participate in a STEAM-related activity (Future City, MATH COUNTS, Cyber Patriot, academic team).	Yes ☐	No ☐		
13. Working on the STEAM projects, I have developed **responsible use of technology.**	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4
14. The technology guarantees, and STEAM projects, have helped me **deepen my use of technology.**	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4
15. Overall, participating in the STEAM program has been a positive experience.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4

APPENDIX E

STEAM SURVEY FOR TEACHERS

Please complete the survey below. Your participation is voluntary, and your responses are anonymous. The questions ask for your impressions of the Science, Technology, Engineering, Arts, and Math (STEAM) program at the school. Read each question carefully and place a check in one box for each question with the most accurate response.

1. Have you received STEM/STEAM training prior to teaching at this school?	Yes ☐	No ☐				
2. Have you participated in a STEM/ STEAM program before teaching at this school?	Yes ☐	No ☐				
3. The STEM training I received at the beginning of our time as a STEAM school was beneficial.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4		Didn't receive initial training ☐
4. The ongoing STEAM professional development we receive during the school year is relevant to our STEAM program.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4		Have not participated in ongoing training ☐
5. I DO NOT feel competent to facilitate the cross-curricular, inquiry-based learning process in STEAM education.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4		

6. I am comfortable providing and facilitating the students' technology guarantees.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4	
7. Participating in a STEAM program has motivated me to adapt and refine my normal classroom instruction.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4	
8. I have become more interested in a STEAM field because of participation in the STEAM program.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4	
9. I have provided extra help/tutoring to students struggling with STEAM material.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4	
10. I have provided encouragement to students struggling with STEAM material.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4	
11. We receive sufficient support from the school district to implement the STEAM program.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4	
12. Our partner enterprises have been gracious in sharing their time, knowledge, and enthusiasm for their professions.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4	Do not interact with partners □
13. The STEAM curriculum has NOT brought an improvement in student critical thinking skills.	Strongly disagree □ 1	Slightly disagree □ 2	Slightly agree □ 3	Strongly agree □ 4	

14. The STEAM curriculum has brought an improvement in student communication skills.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4	
15. The STEAM program has brought an improvement in student collaboration skills.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4	
16. The parents have been supportive of their children's' requirements for the STEAM program's project-based learning.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4	Have not interacted with parents ☐
17. We have a sufficient plan to collect data on program implementation and adjust our program accordingly.	Strongly disagree ☐ 1	Slightly disagree ☐ 2	Slightly agree ☐ 3	Strongly agree ☐ 4	Unaware of data collection plan ☐

APPENDIX F

INTERVIEW WITH SCHOOL ADMINISTRATOR

Introduction

Good morning/afternoon. Thank you for allowing me to conduct a program evaluation of the science, technology, engineering, arts, and math (STEAM) program at your school, and for agreeing to meet with me today. The purpose of the interview is to collect information on program implementation. I have anticipated an hour to complete the interview. During the interview, I will ask questions on the following topics:

- Curriculum, instructional practices, and assessment
- Partnerships and career education
- Professional development (initial and ongoing)
- Faculty self-efficacy
- Student supports (academic, emotional, and social)
- Student self-efficacy and perseverance
- Recruitment
- Data collection, analysis, and program modification

With your permission, I will tape the interview. (Pause for permission). Thank you. To ensure fidelity of the data, I will read the questions verbatim. You have the questions before you. After the interview, I will transcribe the questions and answers. I will provide you a copy of the transcription for clarification before I incorporate the interview into the body of data for the program evaluation. Do you have any questions? (Pause for questions). Let's begin.

Questions

1. What are the goals of the STEAM program and why has the school become a STEAM school?

2. How do you make sure the students know what STEAM is and the reasons they are in a STEAM program?

3. From your perspective, have students who have participated in the STEAM program become more interested in the STEAM professions?

214

4. How has student perception of their self-efficacy in STEAM knowledge and skills changed since their involvement in the STEAM program? Has there been a change in the perceived self-efficacy of females and minorities involved in the program?

5. What interventions does the school employ to increase student knowledge, ability, and persistence (self-efficacy)?

6. How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students? What are your current and future needs for professional development?

7. Has participation in the professional development, and in implementing the STEAM curriculum, influenced your teachers to adjust their instructional practices? If so, in what manner and in what circumstances have they adjusted their instruction?

8. What are the challenges in implementing an effective STEAM program? Is district and state support available and adequate?

9. Has the implementation of the STEAM program improved student achievement in science and math? Does the data support this?

10. What is your plan for collecting and analyzing student data? Do you plan to track students through high school and beyond? How will you use the data you collect?

CLASSROOM OBSERVATION PROTOCOL

Date of Observation: _____ Day of Week: _____

Observation Start Time: _____ Grade Level: _____ Number of students: _____

School District:
_____

School Name:
_____

Teacher Participation Letter Identification: _____

Subject Taught: _____ Class Period: _____ Class/Activity minutes: _____

Topic of Lesson/Activity:

During the administrator interview, teacher focus group, and student and teacher surveys, the focus has been to gather data on teacher and student perception of student interest, student self-efficacy, and teacher efficacy. The purpose of this observation protocol (Ferrara-Genao, 2015, 157-160) is to document STEAM activities in the middle school. The intent of the observation is to discern whether student and teacher perception matches their actual conduct during STEAM activities in the school.

Middle School Classroom Observation Protocol

Research Questions
RQ1: What is the STEAM program's impact on student interest in STEM/STEAM professions?
RQ2: How has participation in the STEAM program influenced the self-efficacy of students in STEAM knowledge and skills, with a focus on females and minorities involved in the program?
RQ3: How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students?
RQ4: What is the STEAM program's influence on student achievement?

Integrated STEAM Classroom Environment	
- Description - Number student desks/ seats - Seat arrangement - Seat arrangement impact on participants interactions and movements - Equipment - Technology available - Documents/artifacts (number and type) - Student products - Materials - Print rich walls - Projects displayed - Other - Added notes	(Take a picture/video of classroom BEFORE students enter) ____ Computer(s) ____ Projector ____ Doc Camera ____ iPods ____ iPads ____ SMART Phones ____ Internet video ____ Visuals ____ Audio ____ Internet ____ Websites ____ PowerPoints Other _____

217

Integrated STEAM Lesson/Activities/Interactions	
I. Technology • What technology is used?	____ Computer(s) ____ Projector ____ Doc Camera ____ iPods ____ iPads ____ SMART Phones ____ Internet video ____ Visuals ____ Audio ____ Internet ____ Websites ____ PowerPoints Other _____
• Who is using the technology?	____ Teacher ____ Students ____ Other
II. Strategies • How is technology used? • What is the purpose of technology in activity? • How is the teacher checking for understanding? • Are the students using organizers, guidelines, or procedures? • Does the activity require collaboration? • What level of rigor, critical thinking is required? • Does the activity require communication (written and verbal)? • What is the literacy requirement - reading, charts, graphs, tables, etc.?	Teacher Efficacy Evident: ____ Yes ____ No Student Efficacy Evident: ____ Yes ____ No
III. Student Interest • Number of students • Student-student interactions • Student-teacher interactions • Active participants • Passive participants Describe conversations	Student Interest Evident: ____ Yes ____ No

218

Integrated STEAM Lesson/Activities/Interactions	
IV. STEAM Integration • Use of the Engineering Design Process • Describe use of Science, Technology, Engineering, Arts, and Mathematics • Student Inquiry • Multiple representations • Problem-based • Student-centered • Technology-rich	STEAM Elements Evident: ____ Yes ____No
Other Notes/Observations	

APPENDIX H

PERMISSION TO USE COPYRIGHTED MATERIALS

ELSEVIER LICENSE
TERMS AND CONDITIONS

Nov 29, 2017

This Agreement between Aiken County Public Schools ("You") and Elsevier ("Elsevier") consists of your license details and the terms and conditions provided by Elsevier and Copyright Clearance Center.

License Number	4238170710159
License date	Nov 29, 2017
Licensed Content Publisher	Elsevier
Licensed Content Publication	Studies in Educational Evaluation
Licensed Content Title	A Common Measurement System for K-12 STEM education: Adopting an educational evaluation methodology that elevates theoretical foundations and systems thinking
Licensed Content Author	Emily Saxton, Robin Burns, Susan Holveck, Sybil Kelley, Daniel Prince, Nicole Rigelman, Ellen A. Skinner
Licensed Content Date	Mar 1, 2014
Licensed Content Volume	40
Licensed Content Issue	n/a

220

Licensed Content Pages	18
Start Page	18
End Page	35
Type of Use	reuse in a thesis/dissertation
Portion	figures/tables/illustrations
Number of figures/tables/illustrations	1
Format	both print and electronic
Are you the author of this Elsevier article?	No
Will you be translating?	No
Original figure numbers	2
Title of your thesis/dissertation	Program Evaluation of the STEAM Program at a Middle School
Expected completion date	Jan 2019
Estimated size (number of pages)	125
Requestor Location	Aiken County Public Schools 950 Murrah Avenue

AIKEN, SC 29803 United States Attn: Aiken County Public Schools |
| Publisher Tax ID | 98-0397604 |
| Total | 0.00 USD |

221

Warren Wintrode <wwintrode@gmail.com>   Nov 28 (1 day ago)

to ccox, pzline

My name is Warren Wintrode. I am doctoral student in Educational Leadership at the University of South Carolina. I am working on my dissertation on STEM educational implementation at a middle school and would like permission to include a figure from your journal in my dissertation. The figure is the "iSTEM framework of tiered integration of STEM disciplines." The article it appears in has the following bibliographical information:

Burrows, A., & Slater, T. (2015). A proposed integrated STEM framework for contemporary teacher preparation. *Teacher Education & Practice, 28(2/3)*, 318-330.

The figure is on page 324.

Thank you.

Warren Wintrode

Patricia Zline   4:32 pm (4 hours ago)

to me

Good Afternoon Warren,

Thank you for your email. Yes you have permission to reuse this figure in your dissertation. Permission is nonexclusive. Please cite by title, author and publisher. Permission is for your dissertation only, including deposit in a dissertation archive. If you should decide to publish at a later date, you will have to reclear this use.

Best

Patricia
Patricia Zline
Rights and Permissions Assistant
ROWMAN &
LITTLEFIELD
4501 Forbes Blvd, Suite 200
Lanham, Maryland 20706 USA
pzline@rowman.com
301-459-3366 ext. 5420   301-429-5748 fax
www.rowman.com

222

Auburndale Intermediate School
1255 River Rd
Corona, CA 92880
☎**: 951.736.3231**
www.aisbulldogpride.com
Corona-Norco Unified School District

APPENDIX I

TRANSCRIPT OF ADMINISTRATOR INTERVIEW

Question 1: What are the goals of the STEAM program and why has the school become a STEAM school?

Principal response:

> Well, I'm going to be honest. The initial reason why we became a STEAM school was to increase our enrollment. That was the initial purpose for the district recognizing us, or naming us, as a STEAM school, but of course it has evolved way beyond that now. It has grown roots; it has rooted here as a fundamental part of our day and everything that we do.

> But the reason we became a STEAM school is to basically have a school without walls. To help students make references and to understand the importance of things they are learning in math and what it looks like in science and how its relative to English. What happened in the eighteenth century or in ancient Egypt? How all of that came about. Why is it important to me?

> And looking at that, even with that, bringing that to the twenty first century. Making them prepared for the twenty first century and all the jobs. What's out there for them. Making sure that we broaden their horizons in that aspect. They understand STEAM jobs and what's out there for them. Jobs that haven't even been created yet. A lot of employers are having difficulties finding people who are able to fill those positions.

> The goal of our STEAM program, again, is to broaden the horizon of our students and help them to understand and deepen their knowledge. And deepen the roots of their standards. And make sure they really understand science and math and English. And understand fundamentally how they all interact with each other to grow them.

Question 2: How do you make sure the students know what STEAM is and the reasons they are in a STEAM program?

225

Principal response:

> We do have a comprehensive STEAM program. Some schools have a separate program that students can be a part of. Our students, when they walk in, they're STEAM students, all of them. How we make that students know what STEAM is, is that every year we have a boot camp. We start with a boot camp. It starts in September and it talks about what STEAM is, STEAM looks like, the principles of STEAM. We talk about the metacognition piece, reflecting, thinking about your own thinking, growing them personally as students, helping students take ownership in their learning. Growing in that aspect.

> We, as a STEAM school, our focus is technology. That's the driving force of our school. We have certain principles, when you're a student as a sixth grader, when they leave sixth grade, they have this skill set, the technology guarantees. We borrowed from the ISTE (International Society for Technology in Education) standards. Those fundamental things, they are coached through our three-week STEAM boot camp that all of our teachers teach during advisory. We have a non-instructional period each day. We teach that for thirty minutes and the culminating activity is a mini-STEAM project that culminates our STEAM boot camp, every year.

> This year what we did, we felt that seventh and eighth grade were seeing the same thing over and over and were ready for a step up. Sixth grade had the generic – this is what you do. The seventh and eighth grade we focused more on the aspect of the technology guarantees. We also talked about the fundamentals of STEAM and what that is because we recognize that we also have new students that enter in. Everybody does boot camp. We all move together as a school.

Question 3: From your perspective, have students who have participated in the STEAM program become more interested in the STEAM professions?

Principal response:

> Yes. I do think so, with our – as a STEAM school we are an AdvancEd STEM school. We have not sought out any STEAM accreditations, but we are a STEM-accredited school.

> One of the fundamentals of AdvancEd is that we are supposed to do outreach for those demographics that are underserved in the STEAM professions. Those are minorities, people with disabilities, and women, or girls. To answer that, we do have Girls in Engineering class. We bring in all sorts of engineers, we take field trips, we do all kinds of things. We have Cyber Patriots. That's a competition for high school and middle

226

school students across the nation, where they are finding areas of weaknesses in the coding and the prevention of hacking. We do things like that to bring in and expose our kids.

And also, our career development facilitator, our career counselor, they take STEAM field trips through him. We have a career each month that we focus on, and we bring in speakers. We just had a career day just recently. We bring in speakers. We try to (Have you found your Hispanic, female engineer yet?) We're working on it.

SEED Day, I found the Women in Engineering Association and so I got the contact, and so I asked her point blank. I need some African American, women engineers. Most importantly, I have an increasing population of female, Hispanic girls, and I want them to see somebody that looks like them. That's so powerful.

Question 4: How has student perception of their self-efficacy in STEAM knowledge and skills changed since their involvement in the STEAM program? Has there been a change in the perceived self-efficacy of females and minorities involved in the program?

Principal response:

Of course. Our last year, Cyber Patriots was our Girls in Engineering group. It was our sixth grade Girls in Engineering group. (Wow). They placed in the Cyber Patriots, first time out of the block. They are very confident. They are active in their academics. They are doing well.

I do believe over time you see the STEAM skills, see that skill set, build that confidence and self-efficacy, and that self-concept in our students. Especially in our eighth-grade students, even when we do school-wide STEAM projects. You can tell our kids that have been here three years. That have done it for three years. Even some of the judges have said that we shouldn't judge school wide. That we should judge by grade level. (But you never know. Like you said, last year's great Cyber Patriot girls. You never know.) You never know. But you can definitely tell that the self-efficacy and self-concept improved over time. It does.

Question 5: What interventions does the school employ to increase student knowledge, ability, and persistence (self-efficacy)?

Principal response:

When it comes to academics, we have Catch Up Café. And Catch Up Café, we invented that, along with our advisory. A lot of times in advisory, we have different things going on. We invented Catch Up Café for those students who have missing work, missing homework, class work,

227

whatever the case may be. They take their lunch, eat it in a classroom with a teacher, and they catch up on their work. We also, we have tutors coming in to assist students.

And then, personally, as a school, I meet with grade levels, students alone. What I mean alone is no teacher. (Right). And we're in Vegas, it's just me and the students, and the guidance counselor, and the assistant principal. That's when we have our relationship. I build that rapport with them and they can tell me what stumbling blocks are in their way. I can remove those. We just had one of those today.

I do believe, I think it's powerful to build relationships with students. When students know that you care. I think students these days have to understand the why. I think as adults we miss that when we – that's a disservice – when we brush it off and say, "You do what I tell you to do because I'm the adult." And not give them the why.

My first benchmarks for social studies, they're looking pretty good. I can tell you that I went on the news and I talked to them. I told them why they were doing it. I helped them to understand why I needed them to do well. I tried to make it to every class that was giving a benchmark. We had mints for the kids, to keep them stimulated. And I told them, I set goals. I set my expectation. "I need you to do this." And then, of course, you've got to dangle the carrot, so I told them I'd feed them. All kids love food. And I told them, "We are going to celebrate."

I think it is important for us to bring that full circle. You set your expectations. You monitor them. You do all these things, but at the end of the day you have to celebrate. (Right). So, I'm looking forward to my remaining benchmarks being high as well.

Question 6: How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students? What are your current and future needs for professional development?

Principal response:

Initially, I think it has blown teacher confidence through the roof, especially teachers who were not confident in technology. Using technology as a dictionary versus as a tool to extend knowledge, deepen knowledge, for lack of a better word. But professionally I think we have taken it to another level. Teachers' confidence is through the roof. I have teachers who were very resistant, who are now a little bit more on board. I won't say a hundred percent, but they are right there.

228

When they are speaking to their kids, they are referencing the technology guarantees. They're talking about the meta-cognition. They're bringing all of that. They're talking about what's going on in their math classes. They're talking about what they may see in art. Using, even, the other side of their brain to bring differentiation and to deepen student learning as well. They may be talking about what's in math. It's that walls-down aspect.

(There was some initial PD that you all did, to say "This is what we're doing and where we're going?"). Well, I think the first thing we did was start with a book study. We had to understand it first. We had to understand it in its simplest terms. We had to understand what it looks like. I think you get something in your head, but you have to understand what it looks like in my class, for my content, for my students. And then what I need to know to employ this.

We started with a book study. We did that. I did not start with the whole school. I started with a faithful few. We had a small group of people who were ready to get on board. We did school visits. We did a lot of school visits, to see what it looks like. To talk about how did they evolve to that level. What were some of their stumbling blocks, and things of that nature? Did it affect test scores? And then we came back here. Then we said, "This is what we have. This is what we learned. This is who we are. What do we want it to look like?" And how should it look operating at its highest level.

I'm excited from whence we've come, but we're still on that road of discovery. It always evolves. (So, what do they need to go to the next level? What do you think?) I think now what we need to do is stay on top of the ISTE standards and deepen, broaden our knowledge about how technology can be used in the classroom.

Question 7: Has participation in the professional development, and in implementing the STEAM curriculum, influenced your teachers to adjust their instructional practices? If so, in what manner and in what circumstances have they adjusted their instruction?

Principal response:

I think the language of their instruction has adjusted. I think the language and the verbiage. They are now talking about what's going on in each other's classrooms. They are talking about how what you do in one class is relevant in another. Not only that, another thing I have added in our lesson plans, not only do we plan our EQ, LO, and differentiation, we plan a STEAM connection.

229

And so, our STEAM connection, it talks about what's the real-world relevancy. How does my learning objective today relate to the real world? Essentially, I even tell with our instructional framework, we have to have an activator or lesson importance. The STEAM connection is your lesson importance. It tells you why this is important, why you need to learn Algebra 1, specifically. It's not just activating prior learning. It's really with my demographics, my kids need to see the why in it.

Question 8: What are the challenges in implementing an effective STEAM program? Is district and state support available and adequate?

Principal response:

The challenges are that it's a fully comprehensive program. It's not just something that you do. It's not just a moment in time. It's something that you have to work on constantly and you have to stay ahead of it. And it's fully involved. You have a program that's comprehensive and fully involved, and you have district initiatives that you have to work out at the same time. (Oh, I see). Sometimes it can become too much. Sometimes it can become too much if I'm speaking honestly.

The state and district support, we do get district support. I don't so much get state support. In art, my art teacher has applied for the ADC grant, arts and basic curriculum, that's a distinguished arts program, grant. So, we get that from the state department. So, it leverages our fine arts piece of the program.

Question 9: Has the implementation of the STEAM program improved student achievement in science and math? Does the data support this?

Principal response:

Yeah, the data supports it. Laughter. Our data supports it. (The standardized test scores, do you see any differences in say math, science, English, their reading?) I would say it's the ability to analyze and interpret models. That research aspect and asking the questions to deepen their understanding. When you're dealing with the engineering process, that's an ongoing process, and you have to constantly, it's a constant improvement process. So, I think it builds stamina and grit, for lack of a better word.

During our grade level meetings today, a student said to me, "I don't like it when a teacher tells me when I ask a question, to ask my neighbor." And I had to explain to that student that it's called "struggle time." (Right) That sometimes if we just give it to you, then you will sit there, and you will just get. You're not actively participating in your education.

230

Sometimes struggling to figure it out, thinking about putting those connections together, asking your neighbor, seeing what they're doing, and pulling it together. That's more than a teacher would ever tell you. You would get more out of that than that teacher just giving you the answer. (That pain that you're feeling in your brain is your muscle growing.) And your dendrites firing, you know what I'm saying.

I think, as educators, we have to be explicit in telling our students why we do what we do. I will make sure I take that to the teacher the kid was referring to. That, if you want your kids to struggle successfully, you have to explain that method that you're doing. Otherwise, they'll just think that you're being smart, and curt. Does that make sense? "No guys, what we're doing is called struggle time. I need you to refer to your notes, to ask your neighbor. I need you to try to figure this out. Then I promise you, we are going to reconvene and then we're going to work through this together. But I need you to develop some grit, to be able to struggle through this and try to figure it out. And I have prizes for the ones who have …"

It gives them that – they understand it – so they'll dive in the means behind the madness. I think sometimes we miss those little things that can take us over. I think if that teacher had said, "This is what we're doing. This is why we're doing it. I need you to either look in your notes, ask a neighbor, or do this. We'll come back in five minutes. You should have the answer."

Question 10: What is your plan for collecting and analyzing student data? Do you plan to track students through high school and beyond? How will you use the data you collect?

Principal response:

Just student data? I track student data all the time. We have our lead and lag data. State assessments. Our Edmentum data. Where our kids are right then and informing us of their current strengths and weaknesses. We use data all the time. RI, reading inventory, math inventory to see where you are. Put goals in place when we conference with students. So, we're constantly collecting and analyzing student data. (Which year was the first year the students had gone through three years of the program? This is the fourth or fifth year you've been doing this?)

This is my sixth year. My first year we just explored. We've been five years in the program. (You've had kids out of the program for two years, so are you looking at longitudinal out of the school stuff?) I haven't. I haven't tracked them that far. It's difficult when you don't have

231

control. When you're leaning on someone else to give you that information. Maybe that's something my STEAM facilitators and I can look at and develop. (I'm just kind of curious. Are we getting more kids to go to CATE? Are we getting kids who are in a couple of years leaving high school, going on, and taking physics-type stuff or engineering? Is it paying off in the long run?) I would like to say it does, but I do not have evidence of that. I don't know unless I honestly go over there and get that data. If I get that data. Does that make sense?

And the skill set, to build that twenty first century skill set, those soft skills, that they need. Those are things that we employ all the time, the collaboration and communication skills. Those kinds of things, being able to work together like that, build those soft skills. No, but that will be something that as we go on as a STEAM school that we need to be able to track. And in the short term, track it even in the short term. A career assessment at the beginning of the school year and then after we employ all of our curriculum and things of that nature. Seeing if anything changes by the end of their year. And do it each year, and we can look at it longitudinal, sixth, seventh, and eighth, did it evolve each year.

APPENDIX J

TRANSCRIPT OF TEACHER FOCUS GROUPS

Question 1: From your observations, have students who have participated in the STEAM program become more interested in the STEAM professions?

Teacher responses:

A57: I definitely think they're more exposed to a variety of STEAM professions. (OK). I think a lot of them already had an idea of what they want to be or what they want to do before coming in. We're at least showing them other things, other career paths.

(Any other thoughts?)

I91: I think middle school is kind of young to know what you want to do. They may have seen something that they did not realize, as you said, was a potential as a career. So, I think that was a door that was open to them. But as far as what I'm going to become, I think that's kind of a broad idea for middle schoolers. (OK).

L77: I feel the same way. I predominately work with sixth graders in my classes, so that exposure I feel is very important. I am not really seeing any minds change as far as my observations, but again, at the age level that they are that exposure can have a very large impact because further down the line when they are about careers, they'll think back on those different professions that they were exposed to. (OK. Good. Ma'am?).

X58: From my observations, I would say yes, because students that have participated in the STEAM program have become a little bit more aware of the different jobs and careers that we have out there, especially for women. Most men go into the field of mathematics or engineering for one, even technology, but we have a program called Girls in Engineering. So, girls are carrying hammers and power tools and things like that. And they're building! I had an eighth-grade group come into my class. I needed a hangar to hang aprons. They were in my classroom with drills and they created this prototype I guess you would call to hang aprons. So, we are very proud, my art classes are very proud of our door hangar that they created for us.

233

R36: I agree with that. I teach seventh grade Girls in Engineering. In my everyday classes, I don't hear as much, but with that group of girls I do hear it. In our last parent conference, two of the parents said as a result of them being sixth grade Girls in Engineering and now seventh grade engineers, their girls are now talking about being engineers where one had another interest. Two parents. The second parent confirmed, and I was like, "Oh my God." They are taking it in. So, I do hear that interest, not only in our students, but in our parents.

(Anything else?)

Q10: Well, I concur with all that's been said so far. With the Girls in Engineering, they also created, I needed, I have headphones in my classroom. I needed a stand to put my headphones on. They have done a great job in getting it together. I don't hear it too much in my science class. I mean we do a lot of STEAM-related projects. You know with science you do incorporate the math portion as well as the ELA portion. To see that they're taking it a step further in crewing(?) up certain creations to fit your needs, I applaud that effort as well.

B92: I'm pretty new. In terms of the STEAM program, are we looking at just our curriculum as a whole or, like, the extra activities that we do? (Everything). I know that from my Intro to Coding class, there's been a lot interest in that. They're getting pretty creative with it and they're using the skills on their own to apply it to themselves. I feel like that's a really good opportunity to have that type of course, and it is female, male, all age groups and they seem to be really enjoying that. Kind of understanding how that can help them beyond here. (OK).

G99: Me personally, I don't think our students realized how many professions there were out there or STEAM-related. I don't know if it's necessarily changed their minds, but it has opened up their eyes to all the different aspects of STEAM and what they are doing to prepare themselves for the future.

J38: I think too, STEAM is in almost any profession anymore. I feel like after working with Miss Kearse last year, with guidance and doing everything with that, the career highlight stuff, there were things I learned that STEAM is incorporated in more things than we thought. So, it's just kind of a new way of looking at the same old stuff.

Question 2: How has student perception of their self-efficacy in STEAM knowledge and skills changed since their involvement in the STEAM program?

234

Teacher responses:

R36: I see a difference in our students that transfer in, being a seventh-grade teacher. My first clue that that student was not with us in the sixth grade is their way of thinking, their responses to things, or even their response to our club day. They have a different perspective or different ideal, a different train of thought from our students that have been here, and this is their second year. I find, I'm often hearing our seventh graders telling those students what they did last year or reflecting on the difference. I've heard some transfer students talking about how things are so different, but they're liking it. They're liking the change.

X58: I'll just add to what she said. I see confidence in art when it comes to presenting. They're not just presenting in ELA, they're presenting in art, presenting in math, in science and things like that. It's getting better and better.

G99: I think they have a better understanding of the way that the world works and the type of future that they're going into. Going into this twenty first century, learners' aspects that we know how to use technology not only appropriately also effectively. I think that that has helped individualize that a little bit more clearly.

J38: (In response to a comment that the STEAM process may be hindering learners) I would agree with that. The engineering design process is "you can start anywhere, be anywhere." In case you don't maybe have that thought process. It can be kind of overwhelming. They're creative but they don't know how to start. The advanced student may be a little more capable of that. (OK).

Y89: I see a positive impact on students, as far as their confidence with STEAM. Some of the students who don't perform well academically, when they do the STEAM clubs, they succeed. They do really well, and it gives them that sense of accomplishment that they don't always get in their classes I notice.

Question 3: How has participation in the STEAM program influenced the interest and self-efficacy of females and minorities involved in the program?

Teacher responses:

A57: Well we have classes for girls in engineering so that's specific to the female population. Some of the male students the other day were asking me, "Why don't we have a Males in Engineering, or why can't it just be engineering class?" So, they see that as a … whatever, it just left my brain.

235

I91: We survey the children to see what types of specials that they would like to be in and there was enough interest in the Girls in Engineering that it has been expanded from just sixth grade to sixth, seventh, and eighth. So, I kind of think that speaks for itself that there is the excitement in it, the involvement in it, the girls wanting to continue doing it. I think that's definitely a good representation.

L77: Looking at those who sign up for my Future Cities program, which fits with our STEAM. I get a lot of females that join that program and they do exceptionally well. They show a lot of interest in it. They are usually the ones that go on to be the speakers at the Future Cities competition, in front of the judges. And so, I think it has a very powerful, positive impact for that group.

G99: Well, I teach a class of Girls in Engineering and at the beginning of the year, coming in, they did not want to be there. They're not even looking into going into engineering, why can't they just be in Art. They realized a lot of the stuff that we're doing, like when we built the headphone stands. They've never used a power tool before and they started fighting over power tools, because they wanted to use them. Using just PVC cutters to cut a piece of PVC, you'd be amazed at the cooperation between them. Just working together to get it done. There were several teachers that we built them for, and I don't think any of the teachers had a problem with the way that they looked or the outcome. Anything like that obviously boosted their confidence, especially when they get to say, "I made that. This is mine." And it's just those girls.

(Any other thoughts?)

J38: We did Cyber Patriots. I taught Girls in Engineering last year and we did Cyber Patriots, dealing in cyber security. Our girls were basically "voluntold" to do it, but I think that they definitely got something out of it. I think they learned some new things and I think even now of going back to becoming more interested. I think there's definitely one student who would head that way, more so than just being able to learn about that. I think that empowered them. They now can help their classmates with better passwords, and they know terminology the other kids don't. So, kind of the "We did that."

R36: I don't hear much on minorities, but females I've seen an interest. (OK). But I can't say it's been one group opposed to another. As a whole, I've heard/seen females take an interest in the program. All of my math students, I've seen, when it comes to their struggle with the math skills. If I say, "Well, just apply the engineering process," then the first thing that some of them will respond is, "If I didn't get it, just try

236

something else, just try something else." To me, that's them implementing what we've embedded in them.

(Anything else?)

Q10: Well, something comes to mind when we're doing our science fair. They're using that STEAM process that they've been taught through boot camp to come up with, not just because they're doing this grade level science when you're choosing a project. They're looking beyond. I encourage them to think about a real-world problem and how you can solve that problem. So, I see a lot of what we're doing is influencing that aspect as well. (OK).

Question 4: How has professional development and participation in the STEAM program impacted teacher confidence in providing STEAM education to their students?

Teacher responses:

G99: I don't know if I speak for everybody else in the school, but I definitely speak for myself. It has definitely impacted my teaching in a more positive light. Just because I get to do things with the STEAM and with the incorporation that I would never do in a basic classroom. Spending more time talking about why we're going to use this and actually showing more of the why we're going to use this to students I think impacts their lives daily. And they get that question of why, how, when answered a lot more, I feel, in my classroom than they would in other classrooms that are not STEAM-connected.

A57: Since I've been here, we haven't done any type of (professional development) specific to STEAM. We've done the literacy framework, the instructional framework, and we've done stuff relating to student behavior. That might have been at my old school, but we haven't done anything specifically STEAM. We do talk about it in PLCs, can we do inter-disciplinary things, but nothing STEAM-specific that I can think of.

X58: I know with me, I found that I was already teaching STEAM. I just wasn't making that connection to the core subjects when I was teaching it. For instance, if I'm teaching ceramics and we're putting pieces in the kiln, I never really spoke on the scientific part of how the heat effects the chemicals of the glaze, and this is why the glaze turns colors. Things like that. Until I went through the training in STEAM.

(Other comments on professional development?)

B92: I could still use some. (Laughter).

237

R36: I think mine has come from coaching; I say coaching. I'm call it bending the ear, I'm often bending the ear. I'm often going to Mrs. Dugar when I get lost or confused about something. I can't say that's come through district professional development, but in-house development made a difference because I still struggle with how to make the connection between STEAM and my math lesson. (OK). I know what STEAM is. I get the concepts, but sometimes it's hard for me to make it real-world and break it down to that middle school, math, struggling level. But conversation, that one on one conversation helps being the only seventh grade math teacher. So often, I'm going to Mrs. Dugar and asking how or what. (OK). I call that more coaching than professional development.

Y89: I think, for me, it's a little bit easier to implement the STEAM activities in a math class. When I was at my previous, it always felt like such a long, involved process that we usually would skip over it. But here, it's a little easier to do something smaller that's STEAM-related so it just seems more within reach at this school, when I want to do something like that.

Question 5: What are your current and future needs for professional development?

Teacher responses:

R36: I think if I could professional development to what I call my taught skill, my seventh-grade math skills applied to my struggling students. It may be my background. I can make the STEAM connection, but I'm often told that it's over my students' heads. Then I'm struggling with how do I break it down and get it to them, to convey to them what I'm thinking and what I'm saying and what are my thoughts on it. It makes sense and it's true, but that does no good if they can't understand it

B92: Even just how we can make them make the connections rather. I feel like when we can get them seeing and kind of bring that into class, because they're the ones going through the curriculum. It would be really cool to start seeing them saying, "Oh, that's like we did in science." Having them kind of make those connections, rather than us kind of feeding it to them. "Here's how it's connected." As I was thinking here, maybe the teachers can be collaborating more but maybe that's us doing the work. Maybe we can figure out how we can facilitate them making those connections.

(OK. Other thoughts?)

X58: I think it will be neat if, I know a lot of times we meet as a group, but when you think about exploratory, we're always meeting as a group to go over things about literacy. How it should go into ELA. I'm sitting

there. Would you like art in your lesson? (Agreement from the other three teachers). But I do think that if we are going to cover STEAM, it needs to be not just everyone implementing technology, everyone implementing mathematics. I also think that everyone should pool in the arts aspect. If we're going to be STEAM and not STEM.

Q10: That's probably where we need those professional developments so that we know how to tie that all in. So, we're comfortable because some of our conversation about they're not really good at art but they can illustrate their point because some students are fantastic. So how could we help them to understand it using the arts? Then make it real-world so they can understand it's not so far off. It's like their visualizing what it is that we're trying to express to them. Maybe we need more in terms of how we can incorporate all that, so it flows.

B92: I think the best-case scenario could be that school could represent what's happening in the outside world more. So rather than having boxes of English, math, science, art, why not have real world topics. Something like engineering naturally is incorporating math and design and technology. So, have more STEAM projects rather than doing our own subjects. Teaching it through one lens. Kind of like your STEAM projects, your mini projects that you do for two weeks, but if we blew that up bigger. This is kind of like, down the road.

Q10: We have done that, because you're new. Every semester we've had a project where it's across …

B92: But I'm saying, what if education looked like that as a whole. (Agreement from Q10).

R36: Can I ask something? Is what she described more a project-based than STEAM-based (model)? It seems to me what (B92) is describing is more project-based than STEAM-based? Does that make sense? It seems to me what (B92) is describing is project-based.

B92: Is it project-based? I'm probably going off.

X58: I guess it can be project-based if it's not tied into science and engineering, or mathematics.

R36: What she's describing sounds more project-based learning. (Agreement from other teachers). Because my understanding is that is that most of teachers I've seen, we all do incorporate each one of those components, but my incorporation of art is not teaching art, not tying that art class into the math class. My vision of incorporating art doesn't meet the criteria of that STEAM project, just because I let them use this or that,

239

the same technology. I use a lot of technology in math; however, I don't make that academic connection with technology and math. Because they're using technology, it doesn't make it STEAM. Part of my struggles is not that I don't use the components of STEAM in math class but I'm not tying it so that the students get the full picture of this is STEAM. (Agreement from art teacher). So, I use it all, but I don't tie it and make that connection that guides when using STEAM. (Right).

I91: I don't think we've ever really had a professional development, have we?

L77: We had a lot of professional development during the first and second year of doing the STEAM program. That's when we did the book analysis. That's where we had a large amount of professional development in it. Where there was a push to attend the classes. And now it's smoothed out. But I know, especially for the newer teachers as well as those ones who still need that professional development, we should keep that as a high focus. I know that for me, I've done a lot of external things in regard to college classes. I can see from the perspective of a teacher who has not done something on their own needing that same amount of professional development.

A57: New teachers get almost like a boot camp themselves before school starts.

L77: Oh, I was not aware of that.

A57: They go through a book and the process. They started last year.

J38: I would like professional development more for content area because I'm music and we're a little bit more of a smaller pool of people. I would just like to be able to do that, be able to collaborate with people that teach the same thing that I do. There are only a few people in the building that teach music or art, and it would be nice if I could do that. (OK).

Question 6: Has implementing the inquiry-based, student-centered STEAM curriculum caused you to adjust your instructional practices, during the STEAM projects and in your regular classes? If so, in what manner have you changed your instruction?

Teacher responses:

I91: I know that every day, in part of our lessons, we … your STEAM connection. So, teachers refer to your LO, your EQ, and you refer to your STEAM connection, which ties into your standard. That's something that we've added to it. (OK).

240

L77: Not only that but having that deliberate focus on how the content we're teaching applies to those STEAM careers is very important. We're no longer teaching in isolation with our different subjects. We're always integrating in, "These are careers that this subject matter applies to. These are the other subjects and how they are integrated with the subject matter that we have in our class."

R36: I think the concept has caused me, given me reason to be more hands-on, more interactive, more kinesthetic. There's more visual. I'm less auditory with the teaching. I'm doing more illustrating, modeling.

X58: When I'm creating my lesson plans, I look more in detail through my research. Sometimes I text her (the science teacher in the group), sometimes, "Okay, what are you doing in science? How can I tie this in?" So, I guess I'm a little bit more aware of what I'm teaching and what subject I'm pulling in. Because we do have to have STEAM connections with each lesson. It can be tough at times. I don't know a lot about science. I try to ask other people.

Q10: Well, science is a lot to do with inquiry. So, I try to be more inquiry-driven with my students. Also, we try to incorporate a lot of kinesthetic modeling because especially when we talk about astronomy and special eighth grade standards. Sometimes you have to bring that model in. (Sure). The concept is so abstract that you need something so that they can see it, I guess, to understand the information. I think with science we do; I do try to incorporate a lot of those inquiry-based and a lot more to do with kinesthetic activity.

(Anything else?)

B92: I'm the computer science teacher. I think that we do a lot with the skills that connect to all of the different components of STEAM. So, it's not usually too much of a stretch. I think it would be helpful if I was able to get more in the loop of what's happening in other classes. Sometimes you get so in your own little bubble trying to do your thing in the classroom that sometimes it's hard. I'd like to understand more so that I could be making that much more connection to the other parts of STEAM.

Question 7: What are your challenges in implementing effective STEAM instruction?

Teacher responses:

A57: I think one of our challenges is we only tend to focus on it like once a month when we do our STEAM club. It's not a constant year-to-year thing unless we do a STEAM project in the middle of the year. Or like

241

we'll do Boot Camp and it just those couple weeks of bam-bam-bam, here it is, and it kind of fizzles out until the next STEAM club. So, consistency, for me, is a struggle. (OK).

Y89: The standards, we're held, as far as teaching our standard. We have to teach our standard just like any other school, but then we have additional responsibilities with STEAM. So, trying to make sure you have enough time to do what you're essentially hired for, and also incorporating the STEAM, I think, is a challenge for me. (OK).

X58: I just think we need more practice. I think practice would help, me anyways.

Q10: And time is important. (All of the teachers in the group agree). That's important.

R36: I think I would like the knowledge of how to implement the STEAM concept, as I shared earlier. I understand what STEAM is and I understand how to implement it and tie it so that the connection is made with my students or the students make the connection without me verbally telling them. They memorize it. I tell my students and they memorize it, and they can give it back. But if they could go in depth with it. I'm not confident in saying they could. They just know what Miss (R36) told them but they don't know it. They just know because they've memorized, because they hear it all the time. They've been trained. Know your STEAM connection. Know this, know that, so they've memorized and not know it. I'm not sure if they've learned it. (Agreement of other teachers).

B92: That's something I've noticed, even with the technology guarantees. They know there's certain activities that I've uploaded to certain folders, but I'm not sure they understand the why, the significance of what they're trying to demonstrate. I think that they're doing things. I just don't know how in depth do they actually understand why it is that we did STEAM boot camp. Why it is that we do these things because they're like, "Are we still doing boot camp?" That was their reaction in advisory. "Are we still doing it?" So, it seems like maybe to them it's just another thing that we talk about. I don't know if they understand why it's important, or the purpose, or how it applies.

R36: I think our challenge is learning how to get them to make that connection. (OK).

B92: Or how to make it even meaningful to them. Why does it matter that we're a STEAM school? (OK).

G99: Time and money.

242

E63: I know it's hard for the library with everyone having computers there's no need for people to come to the library to use my expertise. So instead of students receiving instruction on how to properly use technology from someone who still is learning herself, but overall knows how to do it. Teachers are not coming in because they all have computers. My role in that aspect is not being used. I feel like I just sit in the library and check out books. In my professional development for being a librarian, that's not what I'm being told I should be doing. (Sure). It's not the only thing, but they don't have time to come to the library. That's nothing against you all. There's just no time to be the kind of librarian I'd like to be.

Question 8: What is your plan for collecting and analyzing student data, in the short term, and as students exit the program (through high school and beyond)? How will you use the data you collect?

Teacher responses:

R36: I think that technology guarantee, as a school, that's something that we're doing, that's our data. That's our documentation. I think what we do with it, as each group of students move on, we learn what needs to be changed, what was good, what was not.

X58: In eighth grade, I think you've already met with them, they do an exit interview. (OK). I'm actually doing a digital portfolio this year, where the students have to include their personal critique with their artwork. It goes into a folder that they can pull up in high school. The only issue is I have to get with the (high school) teacher to see if he can continue their portfolio. That's just having the time to meet with others in your field.

I91: I have no idea about high school and how you would get that.

Y89: I know here they're eighth grade. They have technology guarantees. So, throughout their middle school career there are things that they must be able to do. And then their eighth-grade year, before they exit, they have to present all of their findings. They keep a portfolio in Schoology and they present it to a board. Now as far as what we do with that data … I'm sure it's used.

I91: I think the STEAM team used it to kind of guide what we're going to do the next year. And I think from last year where they did it, how we are approaching setting up our portfolios and where we're attacking the sixth graders. So, I can definitely see how the STEAM has taken the data they

collected from last year. Once they do leave our middle school, I'm not sure if the district follows it through.

Y89: I would guess with the graduations and plans, the IGPs. They're able to choose their interest for the high school. I know my son chose engineering as one course that he's taking. So, I guess through the IGP they're collecting data from the students too. They're looking at their interests they might have developed here. (Anything else?)

G99: Well the students are collecting their own data that they're going to share at the end of the year through an exit conference where they have to prove to us that they are technology-ready, STEAM-ready, really just ready to move on to their next level. Through high school and beyond, that's going to be quite a bit more difficult for us because when our kids leave us it's not necessarily that they're going to our feeder high school. It may be that they're going here, there, everywhere in the county, leaving the state, because we are so close to Georgia. We do have several kids who leave the state after leaving our school.

APPENDIX K

CLASSROOM OBSERVATIONS

The school hallways are festooned with posters, pictures, bulletin boards, and other decorations that expound on the fact (school name) is a STEAM school. STEAM projects decorate the bookcases in the media center. When entering the school, it is impossible not to realize that this school promotes STEAM learning.

On this day, I conduct two observations of classes working on Project IMPACT: Educate, Empower, Elevate. This is the annual school-wide, STEAM project in the school. The purpose of the project is for groups of students to work on solutions to society-wide problems. One of the students informs me that the topics include preventing animal cruelty, homelessness, gun violence, bullying, pollution, and mental health. There are other topics. Students choose their topic and are assigned to a teacher overseeing the effort on that topic.

In their topical groups, the students work in groups of four. Within the group of four, the students assign themselves responsibilities: task manager, materials manager, time manager, or document manager. They orient their work to answer specific questions in a graphic organizer they receive from the teacher.

- What is the problem?
- What do you know about the problem (locally, nationally, and globally)? You will need to conduct research to support your topic being a problem.
- What steps will you take to address your problem and positively impact your community (it must be a reasonable and realistic solution)? What reliable research is there to support your solution?
- What obstacles do you foresee? How can you overcome them?
- What materials will you need to develop your solution?
- Who can help make your solution a reality?
- How will you communicate your solution to your target audience?
- Why have you chosen this method of communication?
- What impact do you anticipate your work will have on your community?

During these observations, the students have been working together several days and are in the process of creating their communication product.

245

Observation One.

The teacher begins class by explaining the timeline until the students present their projects. The topics in this classroom are preventing animal cruelty. The students are organized in desk clusters of three or four, with laptops available to every student. The teacher informs the class that she can provide help with MLA citations, embedding videos, or other technical aspects of student presentations. Otherwise, students are on their own. The students who have chosen this group are mainly seventh and eighth graders, which makes the teacher's hands-off attitude understandable. After two or three years of working in groups on a variety of STEAM and classroom projects, these students appear capable of the self-direction necessary for inquiry-based learning. The teacher in this classroom is more technical coordinator than facilitator of the inquiry. During this observation, the groups finalized their product and determined the assignments for the out brief, scheduled to occur the following week to a panel of professionals.

The presentation format is up to the students. They can create a PowerPoint, a flyer, a poster, a radio broadcast, a public service announcement video, or other means to illustrate their message. Of the six groups in the first classroom, five are making PowerPoint presentations. One is making a flyer using Canva. Conversing with the principal prior to leaving the building, she informed the researcher that there are groups in the building that are creating videos and other less common means of delivering the message. However, most groups in the two observed classes opted with familiar, and comfortable, means of presentation – PowerPoint.

Observation Two.

At 2:45, halfway through the day's activity period, the researcher changed classrooms. In the second classroom, the topic was homelessness. The teacher moved from group to group, asking tough questions. "What is your solution?" "Should you define homelessness for your audience? What is homelessness?" She is using the questions students are provided in the graphic organizer to stimulate them to completely address their problems.

There are four groups in this classroom. Two groups are making PowerPoint presentations and two are making posters.

At 3:03, teacher calls for attention. She addresses task managers, telling them on the next day (there are two more days for the group to work), they need to identify what they will need to work on. She follows this up by going from task manager to task manager, asking their priority for the next day of work.

At 3:06, teacher directs students to shut down their computers and put away their materials.

The class period ends at 3:10.