

An In-Depth Focus on An Emerging STEM School, A Community-Based Framework for
STEM Integration, and Fostering Students' STEM Interest

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Dedication

I would like to dedicate this dissertation to the underserved children of today, especially young girls and students of color as well as their teachers. Our future is in your hands. May we all work together to educate our children to the best of our ability by continuing to expand their minds and peak their curiosity to endless possibilities. May we have the courage to do everything we can so that *all* children are educated with fairness, equity and justice. May our children realize and actualize their fullest potentials.

Abstract

The fields of science, technology, engineering, and mathematics (STEM) have been and continue to be dominated by White men (Corbett & Hill, 2015). Women and students of color are underrepresented in post-high school STEM majors and careers in relation to the current demographics of the United States population (Corbett & Hill, 2015). The middle school years mark a decline in interest and positive attitudes toward STEM (Riegle-Crumb, Moore, & Ramos-Wada, 2010). Researchers argue that teaching and learning through STEM integration and the creation of STEM schools, particularly in areas with a high population of under-represented students, could ameliorate this situation. This three-paper dissertation focused on an urban, community middle school located in the Midwestern United States working to develop a STEM focus. The first paper is a case study that explored the factors that impact how teachers and administrators work to develop as an emerging STEM school. The second paper develops a conceptual framework for STEM integration which takes an inclusive approach and incorporates social justice, community strengths and expertise, and personal relevance, and explores the implementation of this conceptual framework. The third paper focuses specifically on ways to foster STEM interest in female students through their participation in inclusive, integrated STEM units. Overarching themes from the three studies include the need for: (i) an inclusive approach to STEM integration; (ii) STEM integration with community connections; and (iii) awareness of social justice-related issues in STEM that promote gender and racial equity in STEM education.

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Chapter 1: Introduction

STEM (science, technology, engineering, and mathematics) is an increasingly important issue in education today given increasing concerns about the United States losing its competitive position in STEM fields and the need to prepare more scientists, technologists, engineers, and mathematicians. The concern stems from the increasing demand for STEM workers, as the number of STEM jobs grew much faster than the number of non-STEM jobs over the last decade (24.4 percent versus 4 percent, respectively) (Noonan, 2017). If the current trend continues, the United States will not be able to meet the need for STEM jobs with its own workers. Thus, in order for the United States to remain an economic and political world leader in scientific and technological innovations in an increasingly global economy, it is imperative to prepare its young citizens in STEM (President's Council of Advisors on Science and Technology [PCAST], 2010; Thomas & Williams, 2010).

STEM workforce demands are further complicated as the students who major in STEM fields and enter STEM careers do not reflect current demographics of the United States population. Despite some progress in gender and racial equity for women and people of color in STEM careers, STEM fields have historically been and continue to be dominated by White men, particularly in engineering, computer sciences, and physics (National Science Foundation [NSF], 2015). Female students and students of color are underrepresented in post-high school STEM majors (Corbett & Hill, 2010). Women of color are especially underrepresented in STEM fields (NSF, 2015). For example, in 2013, only 12 percent of working engineers in the United States were women (Corbett & Hill,

2015) and while Black and Hispanic women make up 15.5 percent of the general population in the United States (United States Census Bureau, 2010), they constitute only 4 percent of computer professionals and less than 2 percent of engineers (Corbett & Hill, 2015).

The underrepresentation of women and people of color in STEM demonstrates a need for intervention and research into fostering STEM interest in female students and students of color. Students' attitudes about STEM influence their future career choices (Riegle-Crumb, Moore, & Ramos-Wada, 2010). Girls of color, in particular, tend to become less interested in STEM as they transition from elementary to high school and college, and then on to jobs and careers (Riegle-Crumb et al., 2010; Turner et al., 2008). As girls' career aspirations are largely formed by the age of thirteen (Lindahl, 2007), the middle school years have been identified as a critical time when female students lose interest in STEM topics. No difference was found by gender in STEM attitudes among fourth-grade students, but by eighth grade, more White boys and fewer girls, especially girls of color, were interested in STEM fields (Riegle-Crumb et al., 2010). Furthermore, in a national sample of high school seniors, Xie and Shauman (2003) found that female students were 60 percent less likely to pursue a STEM career compared to male students.

To ensure that all students have the capacity to pursue STEM careers, educators need to find ways to increase interest for a broader audience of students. In order to cultivate an interest in STEM, students should be encouraged to identify with STEM, establish a positive attitude toward STEM education, and understand potential STEM career paths (Thomas & Williams, 2010). A positive STEM identity is linked to STEM

career aspirations. One way to promote the development of a STEM-related identity is through STEM integration, a student-centered, holistic approach for merging some or all four STEM subjects into one class, unit, or lesson that is based on connections between STEM subjects and real-world problems (Moore, et al, 2014b; Honey, Pearson, & Schweingruber, 2014).

Historically, STEM programming has focused its attention on creating opportunities for gifted and talented students (Thomas & Williams, 2010). More recent efforts have made a strong case for a more inclusive approach to STEM education. An inclusive approach could provide all students with the chance to learn about opportunities and gain the experiences needed to enter a STEM field (Honey et al., 2014). It could also support an increasing diversity in the STEM fields. Increasing interest and opportunities in STEM careers for female students and students of color would also serve to ameliorate the predicted future employee shortages in STEM fields.

This three-paper dissertation is part of a two-year grant in which researchers from a large Midwestern university studied the development of STEM programming at five secondary schools within the same urban, public school district in close proximity to the university. Paper one of this dissertation is a case study about one of the five schools, Falconer Middle School (pseudonym), and its development as a new and emerging STEM school throughout the first year of the larger two-year study, Falconer's second year as a self-identified STEM school. Paper two describes a community-based framework for STEM integration that incorporates personal relevance and community strengths and expertise to promote STEM for all students. Two integrated STEM units

developed by a team of STEM teachers at Falconer are featured in this study to illustrate the implementation of the conceptual framework. Lastly, paper three is a single-embedded case study examining how, if at all, implementation of integrated STEM curricula helps to foster STEM interest in girls at Falconer. Through an in-depth focus on one emerging STEM school, its curriculum development and the fostering of STEM interest in its students -- particularly its females and students -- this dissertation aims to find ways to support all student populations in their success in STEM by improving STEM literacy and STEM interest.

Organization of Dissertation

This three-paper dissertation is composed of five chapters. The first chapter provided a brief overview of the three papers of the dissertation. The second, third, and fourth chapters are composed of the first, second, and third papers, respectively. Finally, the fifth chapter is a summary of the three papers and includes a discussion of the common themes across the entire dissertation.

Chapter 2 - *Factors that Impact STEM Programming Development at a Newly Emerging STEM School* - explores the process of becoming a STEM school. This study uses the Critical Components of Inclusive STEM High Schools put forth by Lynch et al. (2017) as a guide in examining Falconer Middle School's STEM programming development.

Chapter 3 - *A Community-Based Conceptual Framework for STEM Integration and the Development of Integrated STEM Curricula at a Newly Emerging STEM School* - describes the development of a conceptual framework for STEM integration. Two

integrated STEM units are featured in this study, exemplifying how the framework incorporates cultural relevance, inclusiveness, community strengths and expertise, and community change.

Chapter 4 - *Fostering STEM Interest in Female Students through STEM*

Integration at a Developing STEM Middle School - illuminated ways that a community-embedded STEM integration experience helps to foster STEM interest in middle school girls at a developing STEM school.

Chapter 5 describes the over-arching themes across all three papers of this dissertation and recommendations for future research.

Chapter 2: Factors that Impact Development of STEM Programming at a Newly Emerging STEM School

Introduction

STEM education has become a prominent issue over the last ten years because of the growing shortages in the STEM workforce (Noonan, 2017; Vilorio, 2014). Currently, United States students lack proficiency and interest in STEM compared to other nations (PCAST, 2010), and even those who are proficient are moving away from STEM careers. In order for the United States to continue to be an economic and political world leader in scientific and technological innovations and meet its current workforce needs, it is imperative to prepare students in STEM and motivate more young citizens to pursue careers in STEM fields (National Academies of Sciences, Engineering, & Medicine, 2007; PCAST, 2010; Thomas & Williams, 2010).

Unfortunately, the number of students who major in STEM fields and who enter STEM careers do not reflect current demographics of the United States population. Despite progress in gender and racial equity in STEM careers, most STEM fields continue to be dominated by White men, particularly in engineering, computer sciences, and physics (NSF, 2015). Female students and students of color are under-represented in the population of college graduates with STEM majors and careers in STEM fields (Corbett & Hill, 2010). If the United States is to meet its workforce needs and continue to thrive as a leader in STEM, it is critical that more women and under-represented students consider STEM careers.

In an effort to increase the number of students pursuing STEM careers, national reports have recommended the creation of a minimum of 200 inclusive STEM high schools and 800 STEM elementary and middle schools over the next decade (PCAST, 2010). In addition, recent efforts have focused on a more inclusive approach to STEM education in order to provide *all* students with the chance to learn about opportunities and gain the experiences needed to enter a STEM field (Honey, et al., 2014). Thus, to increase STEM accessibility for underserved populations, policymakers call for STEM schools in areas of high poverty and under-represented populations. In response, the number of self-identified STEM schools has increased across the United States. However, the quality of these schools is unclear and the research base for understanding qualities of STEM schools is under-developed.

The existing literature on STEM schools has primarily focused on well-established STEM high schools (e.g. Lynch et al, 2017). Little research exists on the process of becoming an inclusive STEM school and STEM programming development. There has also been minimal attention given to research of the development of STEM middle schools, despite middle school being a critical period in career and STEM identity (Blackhurst & Auger, 2008; Gibbons & Borders, 2010; Jackson et al., 2011; Riegler-Crumb et al., 2010). Thus, this study contributes to the literature by focusing on an emerging STEM middle school and understanding the factors that impact STEM programming development. The following research question guided this study: *In what ways do teachers and administrators work to develop as an emerging STEM school?*

Literature Review

STEM Schools

Multiple definitions and types of STEM schools exist in the literature (Robelen, 2011). Some STEM schools simply offer a traditional curriculum with more mathematics and science offerings. Others put more emphasis on project-based learning or occupational themes such as biotechnology (Robelen, 2011). Limited criteria exists to guide schools who wish to be considered STEM schools. Only ten states offer specific policies for becoming a STEM school. In addition, there is limited national policy for becoming a STEM school (Carmichael, 2017; Nevada STEM Hub, 2019; Utah STEM Action Center, 2019).

The National Consortium for Secondary STEM Schools [NCSSSS] (NCSSSS, 2019), formed in 1988, worked closely with the United States Congress to define the term “STEM-focused specialty school” in the Every Student Succeeds Act (ESSA) passed by the United States Congress in 2015 (United States Department of Education, 2018). The NCSSSS defined STEM schools as “those that prepare students to be leaders in global innovation by engaging them in rigorous, relevant, and integrated learning experiences, with a science, technology, engineering, and mathematics focus and specialization that includes authentic research school-wide” (NCSSSS, 2019). Any self-identified non-profit STEM school that shares in its vision, mission, and its beliefs and fulfills certain criteria is welcome to apply to become a member of NCSSSS. This criteria includes “(a) hav[ing] a science, technology, engineering and mathematics focus; (b) requir[ing] students to take advanced course offerings in STEM areas; (c) includ[ing] authentic research and/or

project-based focus school-wide; (d) maintain[ing] affiliations with local colleges/universities/research facilities/etc; and (d) students participating in external STEM related competitions” (NCSSSS, 2019). At present, 100 STEM schools are members of NCSSSS (NCSSSS, 2019), yet many more STEM schools exist across the United States as NCSSSS guidelines are not a requirement. Based on NCSSSS research and other previous studies, the STEM School Registry defined a “STEM secondary school as a stand-alone school, school-within-a-school, or program providing secondary students (grades 9-12) with coursework that prepares them for higher education in science, technology, engineering, or mathematics fields” (Means, Confrey, House & Bhanot, 2008). In 2008, the registry contained 315 public STEM high schools, representing only one percent of all public United States high schools (Means, Confrey, House, & Bhanot, 2008). This number has since grown, following the PCAST report in 2010 that recommended more STEM schools. However, given the lack of clear criteria for becoming a STEM school, it is difficult to determine the number of quality STEM schools in the United States.

The Committee on Highly Successful Schools or Programs for K-12 STEM Education (National Research Council [NRC], 2012) identified three different STEM school types: (1) *selective STEM high schools*, (2) *STEM-focused technical and career readiness schools*, and (3) *inclusive STEM high schools*. Formulated around the STEM disciplines, *selective STEM high schools* have extremely selective admissions criteria. Most often, *STEM-focused technical and career readiness schools* are programs within career academies and comprehensive high schools. *Inclusive STEM high schools* have no

selective entrance criteria and aim to educate students from under-represented groups and provide access to authentic STEM programming for *all* students. Given the need to diversify the STEM workforce and the focus of this study on an urban public school, this paper focuses on *inclusive STEM schools*.

Inclusive STEM Schools

Inclusive STEM schools have been defined as “open-enrollment schools with a strong focus on preparing under-represented students (e.g., Blacks, Hispanics, female students, and students from low-income families) for advanced STEM education studies and careers” (Peters-Burton, Lynch, Behrend, & Means, 2014, p. 64). Inclusive STEM schools provide “more STEM learning opportunities than in a conventional school” (Robelen, 2011, p. 18) and “a richer set of resources and a requirement that goes beyond the minimum in math and science” (Robelen, 2011, p. 18). In a study that examined ten STEM high schools, Scott (2012) found common characteristics among inclusive STEM schools such as more rigorous requirements, more STEM content in core courses, real world problem-solving, work-related experiences and internships, and more students from under-represented groups, such as female students, students of color, immigrants, and students with low socioeconomic status. These inclusive STEM schools showed promise for attracting a broader student population to STEM fields, and when given the opportunity and support, many students (not only the gifted and talented) can be successful in STEM (Scott, 2012).

STEM Integration

Further problematizing the development of clear definitions for STEM schools is

the lack of consensus on a definition for STEM integration (Heil, Pearson, & Burger, 2013; Honey et al., 2014). Integrated STEM has been described as the intentional integration of: (a) all STEM subjects as one integrative subject matter (Dugger, 2013); (b) all STEM subjects *and* other non-STEM subjects (Boe, 2015); (c) two or more STEM subjects (Moore et al., 2014b), or one or more STEM subjects enhanced with other non-STEM school subjects (Sanders, 2009); and (d) content of one STEM domain into the content of the other three domains [e.g. engineering integrated into science, math, and technology courses] (Dugger, 2013).

Despite these variations in definitions, there are several common elements across models of STEM integration. These include: (a) the inclusion of an engaging, real-world context (Kelly & Knowles, 2016; Moore et al., 2014b); (b) explicit connections between science, technology, engineering, and mathematics and modeling them as they would be used in STEM careers (Honey et al., 2014); (c) the intentional development of 21st century competencies (NRC, 2012); and (d) an emphasis on student-centered pedagogies such as providing a robust learning environment for social interaction and teamwork among groups of students that has been shown to increase interest in STEM (Kelly & Knowles, 2016; NRC, 2012).

Middle School Focus

While much of the STEM school literature is focused on STEM high schools, middle school is a pivotal time for the development and education of students. According to the National Middle School Association (2010), “young people undergo more rapid and profound personal changes between the ages 10 and 15 than at any other time in their

life” (p. 6). Female students’ career aspirations are largely formed by the age of thirteen (Lindahl, 2007). Middle school students, female students and students of color in particular, demonstrate low interest in careers and academics related to STEM compared to interest in other fields (Denson & Hill, 2010; Rogers, 2009). Thus, it is important for researchers to focus on fostering STEM interest at the middle school level.

Conceptual Framework

Given the lack of literature on STEM middle schools, this study drew on the literature on successful STEM high schools for conceptual grounding. Lynch et al. (2017) reported a core set of critical components (CC) that were found to be important for exemplary inclusive STEM high schools (ISHSs). The critical components are detailed in Table 2.1. Since this study explores an emerging STEM middle school, CC6, early college-level coursework, was not included in the analysis for this study.

Table 2.1

Critical Components for Inclusive STEM High Schools (Lynch et al., 2017)

Critical Component	Definition
CC1. STEM-Focused Curriculum for All	Rigorous courses in all four STEM disciplines, or, engineering and technology are explicitly, intentionally integrated into STEM subjects and non-STEM subjects in preparation for college.
CC2. Reform Instructional Strategies and Project-Based Learning	STEM classes emphasize instructional practices informed by research for active teaching and learning, immersing students in STEM content, processes, habits of mind and skills. Opportunities for project-based learning are encouraged and measured by performance-based assessment practices that have an authentic fit with STEM disciplines.
CC3. Integrated, Innovative Technology Use	The school's use of technology connects students with information systems, models, databases and research; teachers; mentors; and STEM-related social networking resources.
CC4. STEM-rich, Informal Experiences	Learning spills into areas regarded as "informal STEM education" and includes apprenticeships, mentoring, social networks, and engaging in STEM activities outside of school. As a result, the relationships between students, teachers, and knowledge are altered and hierarchies flatten.
CC5. Connections with Business, Industry, and the World of Work	The school boundaries extend beyond the school by creating partnerships with business and industry. The school environment intentionally reflects the workplace; students have the opportunity to think like professionals.
CC6. College Level Coursework (Not used in this study)	The school schedule is flexible, providing opportunities for students to take classes at institutions of higher education (IHE) or online.
CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff	Teachers are highly qualified and have advanced STEM content knowledge and/or practical experience in STEM careers. There are in-house opportunities for professional development, collaboration, and interactions with STEM professionals in the field.
CC8. Inclusive STEM Mission	The school's stated goals are to prepare students for STEM, with emphasis on recruiting students from under-represented groups.

CC9. Flexible and Autonomous Administration	The school has autonomy from the school district to address the goals of its innovative STEM program. The school may have partnerships with charter networks and non-governmental organizations that provide leverage, expertise, leadership, and resources for the school.
CC10. Supports for Under-represented Students	The school provides supports (tutoring, advisories, and special classes during and outside of school hours) for students to strengthen their STEM content and skills and to prepare them for STEM college majors.
CC11. Data Driven Decision Making for Continuous Improvement	The school community supports continuous improvement through data systems that inform future learning, teaching strategies, student supports, professional development, and resource allocation.
CC12. Innovative and Responsive Leadership	The school leadership is proactive and continuously addresses the needs of teachers, students, and the greater community through innovative solutions, open communication, and uplifting leadership.
CC13. Positive School Community and Culture of High Expectations for All	ISHSs have culture of high expectations for students and staff, and a school environment where students and staff feel a sense of personal, intellectual, and socio-emotional safety.
CC14. Agency and Choice	Students choose to attend a STEM-focused high school and understand the challenges that will be involved and develop a sense of purpose coherent with the school mission, committed to a different approach to high school due to its STEM focus.

Context of Study

This study occurred at Falconer Middle School during the 2016-2017 school year, its second year as a newly emerging STEM school. This study was part of a larger research study designed to support and research the process of developing STEM programming within middle schools in an urban, public school district located in the Midwestern United States. At each school in the larger study, a STEM teacher team was created and provided with professional development support, including a STEM fellow

(graduate student in STEM education) who helped the team to develop and implement STEM strategies and curricula. More details are provided in the case study.

Falconer's Neighborhood and Community

Falconer Middle School is located in a diverse, working-class neighborhood. Around the time of this study, the neighborhood had the highest rate of housing foreclosures in the city (Horsley, 2007), and approximately 50 percent of the students in the neighborhood attended local schools (Hawkins, 2007). Within the past 12 years, the city's Board of Education decided to close several middle and elementary schools, including Falconer. Due to the efforts of the community residents, Falconer re-opened its doors in September 2015 as a community school with a STEAM focus. (The "A" in STEAM stands for art. Art, music, and dance teachers were all members of the original STEAM team at Falconer. Thus, in reference to the work at Falconer during the first year of the grant, the term "STEAM" is used in describing the STEAM team, STEAM coordinator, and STEAM night. Otherwise, the term "STEM" is used in reference to other research and when referring to the larger grant work. For example, each graduate student, including the one assigned to Falconer is referred to as a STEM fellow. Also, in terms of the work at Falconer in the second year of the grant, the terms STEM team, STEM coordinator, and STEM showcase were used. This is because during year two, Falconer focused on core seventh-grade courses and engineering for STEM programming development. Art, dance, and music teachers were no longer a part of the STEM team.)

As a neighborhood school, any student is allowed to attend Falconer, which makes it inclusive. However, only students who live in the neighborhood and assigned zone are provided with free transportation to and from Falconer. So, students who live in the school neighborhood attend Falconer. They could choose to go elsewhere, but they

would have to find their own transportation, which is not possible for most Falconer students. From the CCs of ISHS put forth by Lynch et al. (2017), CC 14 is not part of Falconer Middle School. CC 14, Agency and Choice, states that students choose to attend a STEM-focused high school. In reality, students who live near Falconer do not have agency and choice in deciding where to attend school. They do not choose to go to Falconer, and thus, it is not an inclusive school in that sense.

At the time of this study, a total of 397 sixth, seventh, and eighth graders made up the entire student population at Falconer Middle School (State Report Card, 2018). The student population of Falconer was 72.3 percent Black, 17.6 percent Hispanic, 1.8 percent White, 2.0 percent Asian, 3.0 percent American Indian/Alaska Native, 0.5 percent Native Hawaiian/Pacific Islander, and 2.8 percent two or more races. The percentage of the student population at Falconer Middle School who filed paperwork to qualify for free/reduced lunch was 87.9 percent. The percentage of Falconer students who were English learners was 10.8 percent, and the percentage of Falconer students who received special education services was 27.7 percent. At Falconer, 7.1 percent of its students were homeless (State Report Card, 2018). According to the 2018 State Comprehensive Assessments reports, 12.2 percent of Falconer students were proficient in mathematics, 18.7 percent were proficient in reading, and 7.8 percent were proficient in science (State Report Card, 2018).

Methodology

The goal of this research was to describe the ways in which teachers and administrators worked to develop as an emerging STEM middle school. Thus, case study

was chosen as the methodology for this study (Yin, 2014). The Critical Components (CCs) of Inclusive STEM High Schools (ISHSs) (Lynch et al, 2017) were used as a guide to examine the development of STEM at Falconer, and how, if at all, each critical component played a part, or could play a part, in the development of an inclusive, urban STEM school.

Data Collection

Data collection occurred in the first year of the larger project and included (i) audio recordings and memos from STEAM team meetings in summer 2016 and academic year (2016-17); (ii) pre and post semi-structured interviews with teachers, the STEAM coordinator and the principal; (iii) audio-recordings and memos from weekly planning meetings with the STEAM coordinator; and (iv) teachers' written reflections on the implementation of the STEAM integrated units. In addition, focus groups were conducted to discuss the critical components data with the teachers in March and September 2017. A timeline for the data collection is shown in Figure 2.1.

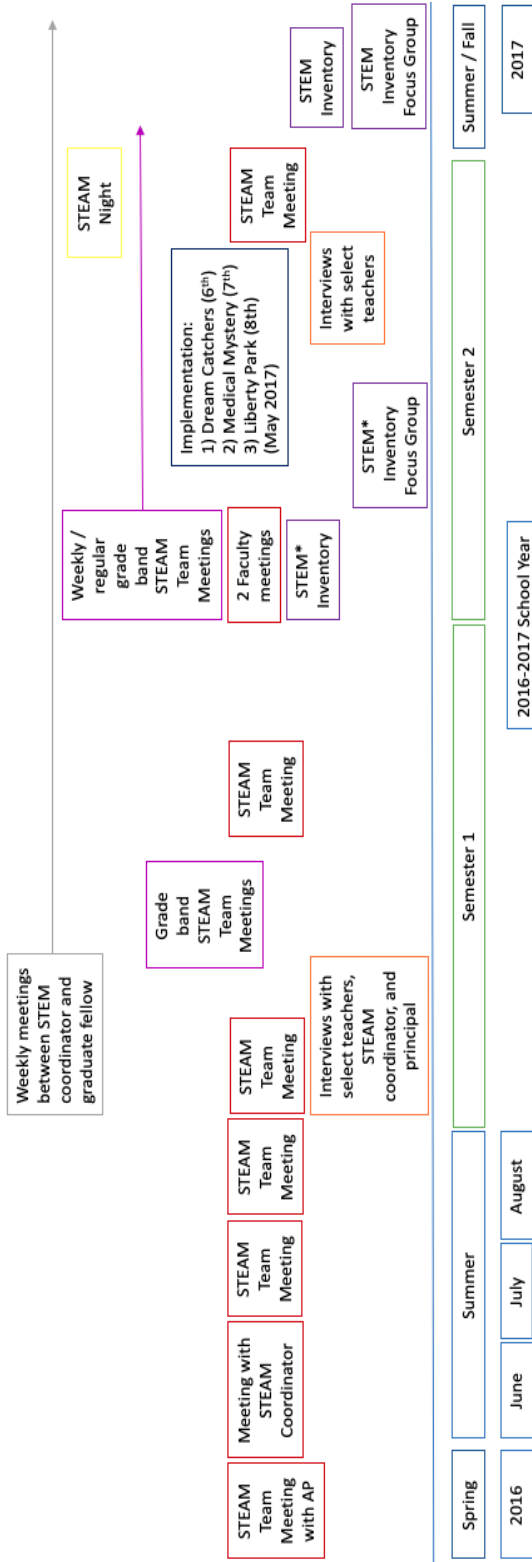


Figure 2.1 Timeline of Data Collection. The STEAM Inventory and the STEAM Inventory Focus Groups were part of the larger study. They took place at each of the four schools, including Falconer. Falconer was the only STEAM-focused school with a STEAM team, STEAM coordinator, and STEAM night. The other schools had STEAM teams, etc.

Focus Group 1. March 2017, a select group of STEAM team teachers participated in a focus group to discuss the 14 critical components of inclusive STEM high schools (ISHS) (Lynch et al., 2017) in relation to Falconer Middle School. The focus group included Ms. Hat, Mr. Ram, Mr. Lint, and Ms. Betty. (See Table 2.2). The focus group was facilitated by the STEM fellow/author. The teachers were asked to rank the critical components by level of importance, and they discussed the presence or absence of each of the components at Falconer.

Focus Group 2. In September 2017, at the beginning of the second school year of the grant, the STEM fellow conducted a focus group with the new STEM team. This included the core content seventh-grade teachers - Mr. Lint (science), Mr. Stop (social studies), Ms. Clay (English Language Arts [ELA]), and Ms. Van (mathematics). (See Table 2.2). Through the focus groups, the author was able to further examine the progress in STEM programming development, implementation, and STEM integration at Falconer during the first year and see how they planned to move forward in the second year.

Interviews. The STEM fellow conducted several interviews throughout the study at Falconer. At the beginning of the school year, Principal Charge was interviewed about Falconer's history, reputation, evolution and challenges. In addition, Ms. Charge was asked to describe her personal and/or professional mission for Falconer and what it means to be a STEAM school. In order to get an initial sense of the current STEAM programming at Falconer, the STEM fellow chose one teacher leader and two teachers on the STEAM team to interview. The STEAM Coordinator; Ms. Betty; the sixth through eighth-grade English as a second language (ESL) teacher, Mr. Bart; and the sixth-grade

science teacher, Mr. Suit; were interviewed at the beginning of the school year. During the third quarter, Ms. Betty and Mr. Bart were interviewed again. Mr. Suit left after quarter two, so he was not interviewed again. Instead, Mr. Lint, the seventh-grade science teacher, was interviewed. The interviewees were asked to describe what STEAM means in their own words, what STEAM looks like in practice, and how a STEAM-focused school might look different from traditional schooling. They were also asked to describe their leadership roles, how their roles may have changed over time, their participation in building a STEAM focus at Falconer, and the benefits to the community and students in becoming a STEAM-focused school. For a complete list of interview questions, see Appendix A.

Data Analysis

The 14 critical components for inclusive STEM high schools (Lynch et al., 2017) were used as a conceptual framework in writing a case study of the development of STEAM programming at Falconer Middle School. Audio recordings of focus groups, interviews and select meetings were transcribed and revisited, along with weekly memos and meeting notes. Evidence and extent of the presence of each of the critical components and the role that each critical component played in the development of Falconer was detailed across all data sources.

The Case of Falconer Middle School

Falconer's Decision to Become a STEAM School

Following recent school closings in the neighborhood, the school district expected a surge in enrollment and supported a movement towards neighborhood-based schooling

(Jacobson, 2015). The local community was “instrumental” in reopening Falconer, recognizing that “[Noether] High School (pseudonym), a public school that is located in the same neighborhood as Falconer, needed a strong, viable feeder school” (Ms. Charge, pre-interview). When Ms. Charge was tasked to reopen the school, she “requested and wanted Falconer to have a STEAM [science, technology, engineering, arts, mathematics] focus” (Ms. Charge, pre-interview).

Mission. Falconer’s mission statement could be found on Falconer’s website prior to opening, and still exists there at present (Falconer’s website, July 2019). Falconer’s mission is “to implement strategies to engage awesome minds to be prepared for success in high school and college.” Furthermore:

[Falconer] is a community school providing a STEAM (science, technology, engineering, arts and mathematics) focused education to prepare students to attend and be successful in [Noether] High School's [STEM] programs. The [Falconer] staff is highly skilled and excited to help your child learn, grow, and excel. We believe that our students’ preparation for success is not only enhanced throughout the school day but also after school with our extracurricular and athletic opportunities (Falconer’s website, July 2019).

Hiring staff. Ms. Charge was given the unique opportunity to hand-pick her staff. She wanted to hire a team that was “willing to look at the whole child,” not just focus on the content they were teaching. She hired a staff that was willing to do “whatever it took for our kids to be successful” (Ms. Charge, pre-interview). Ms. Charge purposefully selected a staff that represented the diversity of the community. Out of the 37 teachers, 20

were teachers of color. This is notable because in the state where Falconer is located, 96 percent of the public K-12 teachers are White (Coalition to Increase Teachers of Color and American Indian Teachers in [State], 2019). Ms. Charge also hired eight new teachers and several teachers without any experience in STEM or in leadership. The STEAM coordinator, Ms. Betty, had practical experience in a STEM career, STEM teaching, and STEM leadership. She also had advanced STEM content knowledge and was enrolled in a PhD program in STEM education. Two other teachers had advanced STEM content knowledge. Mr. Lint, the seventh-grade life science teacher had a bachelor's degree in biology, and Ms. Van, the seventh-grade mathematics teachers had a bachelor's degree in mathematics. Both Mr. Lint and Ms. Van were first-year teachers with minimal STEM or leadership experience. Additionally, two teachers left during the school year. The eighth-grade mathematics teacher, Mr. Top, left after the first quarter, and the sixth-grade science teacher, Mr. Suit, left after the second quarter. Both positions were filled with several different substitute teachers, each staying for 1-2 weeks at a time, for the remainder of the school-year.

Hiring a STEAM coordinator. Two weeks before Falconer opened its doors, Ms. Betty was hired as Falconer's STEAM coordinator. Ms. Betty led Falconer's STEAM programming development and STEAM team and was essential to this process. Ms. Betty was the only staff member with STEM leadership experience. She was initially hired primarily as a STEAM coordinator. However, Ms. Betty, due to her leadership and STEM expertise, soon began teaching nearly a full teaching load and took on many other responsibilities at Falconer, including co-facilitator of professional development (PD),

science team lead, instructional leadership team member, grant writer, push-in support for new science teachers, and part of the hiring committee. She taught the only STEM and engineering courses at Falconer and provided afterschool STEM enrichment programs such as robotics, Rube Goldberg, coding, and astronomy.

Appointing Falconer’s STEAM team. In spring 2015, Falconer started their partnership with a local university as part of the larger research project. The district STEM coordinators met with Ms. Charge to introduce the larger grant opportunity and she agreed for Falconer to participate. This process started with the creation of a school STEAM team. Assistant Principal (AP) Jake was heavily involved in Falconer’s STEAM initiative. He was present at the initial grant meetings that took place in spring 2016 prior to this study. Seventeen team members were selected by AP Jake, with further input from Ms. Betty. Teachers were selected based on their STEAM interest and content area. Mr. Jake aspired to have representation from each grade band, core subject area (math, science, ELA, social studies), elective (engineering, art, dance, music, AVID¹) and special education. Ms. Betty was tasked to approach each of the selected teachers to inform them about the STEAM team. Mr. Jake left the school at the end of spring 2016 and from this point on, Ms. Betty took over the STEAM team and STEAM programming development at Falconer. Table 2.2 includes a list of the original STEAM team members plus others who joined the STEAM team later.

¹ AVID is the acronym for Advancement Via Individual Determination. AVID is a program that offers courses from elementary, middle, high school and college that prepares students for college and helps students improve their learning and academic performance schoolwide (<https://www.AVID.org>, 2018)

Table 2.2

Participants

Pseudonym	Subject taught/Role at Falconer
Mr. Suit	6 th grade science; STEAM team member, 6 th grade band; terms 1 & 2 only
Ms. Hat	6 th grade math teacher; STEAM team member, 6 th grade band
Mr. Will	6 th grade social studies, 6 th grade band
Ms. Robin	6 th grade ELA, 6 th grade band
Mr. Lint	7 th grade science; STEAM team member, 7 th grade band
Ms. Van	7 th grade mathematics; 7 th grade band
Mr. Stop	7 th grade social studies; 7 th grade band
Ms. Clay	7 th grade ELA; STEAM team member, 7 th grade band
Ms. Volt	8 th grade science; STEAM team member, 8 th grade band
Mr. Top	8 th grade mathematics; STEAM team member, 8 th grade band; term 1 and part of term 2 only
Ms. Clean	8 th grade ELA; STEAM team member, 8 th grade band
Mr. Mayor	8 th grade social studies; STEAM team member, 8 th grade band
Mr. Ram	7 th and 8 th grade AVID teacher; STEAM team member, 7 th grade band
Mr. Blue	6 th grade mathematics special education; STEAM team member; push in and pull out; 6 th grade band
Mr. Stray	6 th -8 th grade science and mathematics special education/support for students with emotional behavioral disorders (EBD)
Mr. Bart	6 th -8 th grade English as a Second Language (ESL) teacher; STEAM team member, 8 th grade band
Ms. Hen	6 th -8 th grade Literacy Specialist; STEAM team member
Ms. Steen	6 th -8 th grade art; STEAM team member, 8 th grade band

Ms. Puck	6 th -8 th grade dance, STEAM team member
Ms. Hill	6 th -8 th grade choir; STEAM team member
Ms. Betty	STEAM coordinator; 6 th -8 th grade engineering/STEM teacher; after school instructor in coding, astronomy, and robotics

Administration and STEAM. Mr. Jake was replaced by Ms. Bell as the AP at the beginning of the 2016-2017 school year. Neither Ms. Charge nor Ms. Ball were able to attend any STEAM team meetings, STEM professional development or STEM events that were part of the larger study throughout the school year. They also were unable to collaborate with district STEM coordinators. Their intention was to be more involved in STEAM programming, but their focus was needed elsewhere. At the time of this study, as a new school, Falconer was still working to develop structures of a well-functioning school. This included trying to establish an effective behavioral support system, school leadership, and building a positive school community and school culture. Thus, the only administrator that was able to be heavily involved in the STEAM initiatives throughout the study was Ms. Betty, the STEAM coordinator.

Falconer’s STEAM Programming Development through the Work of the STEAM Coordinator and STEAM Team

Mission. Ms. Betty met with the STEAM team for a two full days in the summer of 2016. During the summer meetings, the STEAM team worked together to modify their school’s goals and mission and create a collective STEAM mission and goals for the STEAM team. This began with Ms. Betty leading a discussion in defining STEAM. Together, they came up with several attributes of what they thought about STEAM at

Falconer which evolved into their mission for Falconer. The STEAM team's final mission statement was written as the following: "[Falconer] Middle School uses a cohesive integrated STEAM education to further develop our [community's] students' innovative talents, problem-solving abilities, and 21st Century skills set in order to actualize the agency to influence the community and the world" (Falconer STEAM team, August 2016).

Goals. The team also agreed upon the goals for the school year. In order to fulfill their mission, the STEAM team decided to focus on developing curriculum. The school had some autonomy from the school district which allowed them to address their STEAM programming goals of developing and implementing integrated STEAM curricula. The Falconer teachers were not required to follow the district pacing guide and focused instruction, as long as they taught the state content standards for their discipline. They were also not required to give the district interim assessments and were allowed to create their own assessments.

Overall, most of the instruction at Falconer was traditional, lecture-based, and teacher-centered. However, the STEAM team worked to introduce reform instructional strategies and project-based learning through the development of the integrated STEM units. They decided to work in grade band teams - sixth, seventh, and eighth. Their goals were to develop and implement one integrated STEM unit per grade band and hold a STEAM Night at the end of the school year for students to present their work to the community.

The STEAM team members had very little experience in STEM, STEM integration, or developing STEM curricula. Thus, in order to help them come up with ideas for units and with integration, Ms. Betty decided to ask the teachers to begin by looking at their current lesson plans and student work and discuss them within their grade bands. Teachers then would take turns presenting their student work and lesson ideas to the rest of their teams. Together, the team would decide if, and how, the lesson could be “STEAMified,” a term they coined to describe how STEAM and other subjects could be integrated into a lesson. At another STEAM meeting that fall, in order to exemplify the process, Mr. Ram, Ms. Steen, and Ms. Hill, presented their lessons to be STEAMified by the whole team. In this way, teachers from other teams could do the same on their own and practice integrating multiple subjects into one lesson or unit.

STEAM Curriculum. From the words of Ms. Betty, “*Franklin is set up as a traditional school, but we don’t have to be...Teachers are in the driver’s seat.*” Ms. Betty and the STEAM team had the autonomy and agency to begin to develop a STEAM focus at Falconer. All students were required to take a quarter-long STEM course in sixth grade, unless they took band or choir. In seventh and eighth grade, semester-long STEM courses such as Design & Modeling and Robotics were optional. In addition, students had extra-curricular STEM opportunities through Falconer’s afterschool programming. Students who were not proficient in reading and/or mathematics were required to stay after school four days a week for enrichment coursework, unless a parent or guardian excused their child from attending. Academic after school programs included

tutoring/homework help, astronomy, robotics, coding, and Guise and Gems (hands-on STEM activities).

Each grade band attempted to develop a unit that aligned with the STEAM team's mission and goals. Grade band teams met regularly throughout the rest of the school year to design and plan an inclusive interdisciplinary unit. STEAM and core content (mathematics, science, ELA, and social studies) were integrated into one unit for sixth grade (Dream Catchers), another unit for seventh grade (Medical Mystery) and a unit for eighth grade (Liberty Playground) (see Table 2.3). Each unit was implemented during the school day during the fourth quarter. The following sections describe how each grade band decided on a unit theme and developed their integrated STEAM unit.

Table 2.3

Integrated STEAM Units

Unit	Description
Dream Catchers	Sixth-grade students told various Native American stories, learned about the state’s Ojibwe history, read Native American literature, and created dream catchers.
Medical Mystery	Seventh-grade students were challenged to try to identify the cause of death of a victim of a medical mystery. They learned about basic anatomy and physiology and performed a virtual autopsy of their patient. They also learned about various forensic topics including DNA techniques, autopsies, blood type, fingerprinting, and microscopes. Students created presentations and wrote essays about the forensic topics and their claim, evidence and reasoning behind the medical mystery. Students displayed their evidence of how they solved the medical mystery. They also created maps of the crime activity in the local neighborhood.
Liberty Playground	Eighth- grade students partnered with community members to redesign Liberty Playground, a local park near Falconer Middle School. Students created and conducted surveys for community outreach and researched local parks and local history. They learned about the community connection to the Mississippi watershed and flooding in the park and created scaled models of the park redesign. Students wrote essays and created slide presentations which they presented to the school and the community. Students worked side by side with the local designer, artist and architect of the park redesign.

Sixth Grade – Dream Catchers. The sixth-grade team spent several meetings brainstorming ideas for their STEM unit. They initially decided on a space theme in which students would build a rocket in their science class, connect with a local astronaut,

read the book *Rocket Boys*, and watch the movie *October Sky*. This was heavily driven by the sixth-grade science teacher, Mr. Suit. But, after he left at the end of the second quarter, the team was no longer confident to pursue this theme for their unit without him.

At the beginning of the third quarter, two morning faculty meetings were devoted to developing the integrated STEAM units. During this time, the sixth-grade team decided instead on a Native American theme. In social studies during the fall, students had learned about the history of Ojibwe in their state. They also learned about the art of storytelling in their ELA classes. In the fourth quarter, Mr. Will and Ms. Robin briefly revisited the history of Ojibwe and storytelling with the sixth-graders. They decided that they would learn about dream catchers (also the name of the unit) but due to classroom management issues, sixth grade teachers decided to only allow students who they thought were well-behaved to create dream catchers. Without a science teacher in the sixth-grade band, the unit lacked science integration. During the STEAM Night at the end of the school year, the dream catchers were put on display and two girls dressed in native costumes and demonstrated the art of storytelling.

Seventh Grade – Medical Mystery. Both Mr. Lint, the seventh-grade life science teacher, and Mr. Top, the eighth-grade mathematics teacher, participated in Project-Lead-The-Way (PLTW) curriculum training during the summer of 2016. Ms. Betty suggested that the seventh and eighth-grade bands further modify the PLTW units from their trainings by integrating STEM and other content areas. Mr. Lint agreed. Mr. Top also agreed, but he left after the first term, so the eighth-grade teachers needed to find another theme.

Mr. Lint met weekly with Ms. Betty during the third quarter and planned out the first of three science units of the Medical Mystery PLTW curriculum. They decided that most of the implementation would take place in Mr. Lint's science class. Mr. Lint introduced the students to a medical mystery, which begins with the mysterious death of a patient. Students were asked to research the cause of death and try to figure out if the patient was murdered. Students learned about basic anatomy and physiology, including the circulatory system, blood types and body temperature. They performed a virtual autopsy online. In the fourth term, just a few weeks before the STEAM Night, the rest of the seventh-grade team met with Ms. Betty and the STEAM fellow. As a team, they added to the curriculum and discussed how ELA, mathematics, and social studies would be integrated into Medical Mystery. As part of their final project for the curriculum, the students were asked to write a report summarizing their evidence and reasoning behind how the patient died. They wrote this essay as part of their ELA class with Ms. Clay. Mr. Lint and Ms. Clay met separately and created a two-part grading rubric for this assignment, one for science content and the other for ELA content, including writing and justifying their reasoning. Students were asked to create a presentation board to summarize their final research project. In social studies, Mr. Stop asked each student to research a forensics tool or process that was used to solve the medical mystery. Because the patient may have been the victim of a crime, Ms. Van tried to connect the unit to the community by asking her students to create a map of the crime in the neighborhood in math class. Students displayed their boards and presented their research during the community STEAM Night at the end of the school year.

Eighth Grade - Liberty Playground. During the morning faculty meeting at the beginning of term three, the STEM Fellow started to work with the eighth-grade team and continued to do so throughout the remainder of the school year. When asked for their ideas or a project theme, Ms. Steen suggested for the team to help in the redesign of a local park near the school, Liberty Playground, for their STEAM unit. Ms. Steen was the local artist assigned to the community project. She personally knew all of the community members involved. The rest of the team agreed, and they met weekly with the STEM fellow to plan the unit.

In ELA, Ms. Clean asked each student to write an essay about their thoughts about redesigning the park. Many wrote about violence in the community and how creating a safe place in the community could help to reduce crime. Some students interviewed community members about their role in the project and wrote about what they learned from their interviews. Groups of students surveyed all Falconer students from each grade level in order to find out what students wanted to gain from the park redesign. In Mr. Mayor's social studies class, each student conducted research and presented a google slides presentation on the history of parks, the history of their neighborhood, and what they hoped to see in the park redesign. In Ms. Volt's science class, students learned about the connection between the watershed of the Mississippi River and the community, including the park and redesign.

Ms. Steen initiated Falconer's development of partnerships with the local businesses and professionals that were hired to redesign Liberty Playground. Through the eighth-grade Liberty Playground Unit, students worked side by side the local architect,

designer, and artist who were hired to redesign the park. Together, in Ms. Steen's art class, they designed and created three-dimensional models of Liberty Park. The students had the opportunity to think and work like professional artists, designers, and architects. Students interviewed these professionals about the work that they do. Students were able to play a part in making a difference in their neighborhood by helping to redesign Liberty Playground.

Decisions moving forward into year two of the grant. At the end of Falconer's second school year and the first year of the grant, Ms. Betty and Ms. Charge decided to approach STEM curriculum development differently and focus only on the seventh grade the following year. Once the seventh-grade gained more experience and leadership, STEM programming development within other two grades could follow in the future.

The seventh-grade team met four full days over the summer 2017 and began planning out their lessons for the coming year. This process began by displaying standards for each discipline on a wall. Related standards from the core disciplines that could be taught in parallel or within the same unit would be moved next to one another. Once this was established, the teachers were able to collectively plan and schedule their lessons. The team also established common seventh-grade norms, which included common practices and behavioral expectations across all seventh-grade content areas and classrooms. While not directly related to STEM, as a new school, teachers felt that establishing a common culture was a necessary foundation in which STEM integration could build upon.

They also decided that it was important to connect STEM learning to the community and to students' lived experiences. They decided to create four integrated STEM units, one per quarter, and include standards from each quarter: 1) MidWest Metal Unit; 2) Civil War Soldier Unit; 3) Race and Genetics; and 4) Medical Mystery . Each unit would integrate science, mathematics, ELA, social studies and engineering and include a Community Connections day that would bring together students, teachers and community members for a full-day STEM learning event. Implementation of each unit would occur during the school day at the end of each quarter, and all seventh graders would participate. The team agreed to participate in structured meeting times each week during the school year to plan the units.

Findings

The findings from this study are presented by critical components drawing on the different data sources to describe how, if at all, each critical component was incorporated into the process of becoming a STEM school. As a reminder, CC6 was not included because of our focus on a STEM middle school. A summary of how the teachers used each CC is provided in Table 2.4.

Table 2.4

Presence/Absence of Critical Components at Falconer

Critical Component	Presence/Absence of CC at Falconer
CC1. STEM Focused Curriculum for All	<ul style="list-style-type: none"> one integrated STEM unit for each grade band implemented during the school day during term 4 (See Table 2.3).
CC2. Reform Instructional Strategies and Project-Based Learning	<ul style="list-style-type: none"> most instruction at Falconer was traditional, lecture-based, and teacher-centered. The STEAM team worked to introduce reform instructional strategies and project-based learning through the development of the integrated STEM units for each grade.
CC3. Integrated, Innovative Technology Use	<ul style="list-style-type: none"> technology is present at Falconer (Chromebooks, iPads, Apple computer labs, and 3D printers) not a focus of Falconer’s STEAM team. Technology was not necessarily used in student-centered ways to promote STEM during the time of this study.
CC4. STEM-rich, Informal Experiences	<ul style="list-style-type: none"> provided after school by individual teachers (not the product of collaboration among teachers like the integrated STEAM units). eg. astronomy, robotics, coding, hands-on STEM activities programs provide a space for students to create social networks and engage in STEM outside of the regular school day.
CC5. Connections with Business, Industry, and the World of Work	<ul style="list-style-type: none"> partnerships with local businesses and professionals through eighth-grade STEAM unit, Liberty Playground eg. architect, designer and artist hired to redesign local park
CC6. College Level Coursework	<ul style="list-style-type: none"> Not used in this study

CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff	<ul style="list-style-type: none"> • diverse staff • many new teachers; a few uncertified • staff lacked STEM leadership experience, practical experience in STEM fields (except for STEM coordinator) • few staff had advanced STEM content knowledge • one math and one science teacher left during the second quarter and replaced by substitutes • no whole school STEM professional development
CC8. Inclusive STEM Mission	<ul style="list-style-type: none"> • STEAM team created a mission and vision
CC9. Flexible and Autonomous Administration	<ul style="list-style-type: none"> • teachers not required to follow the district pacing guide and focused instruction or to use district interim assessments • teachers were able to develop integrated STEM units
CC10. Supports for Under-represented Students	<ul style="list-style-type: none"> • afterschool academic enrichment (eg. tutoring, astronomy, robotics, coding, and hands-on STEM activities) • Explore courses to improve proficiency in math and reading, during the school day • Math tutoring during the school day
CC11. Data Driven Decision Making for Continuous Improvement	<ul style="list-style-type: none"> • not a strong presence during the time of this study • Efforts to use data to inform administrative decisions at Falconer were in development.
CC12. Innovative and Responsive Leadership	<ul style="list-style-type: none"> • lacked principal and assistant principal (AP) leadership in STEAM initiatives • STEM coordinator led all STEAM initiatives • former AP initially appointed all STEAM team members
CC13. Positive School Community and Culture of High Expectations for All	<ul style="list-style-type: none"> • not strongly present yet at the time of this study. As a new school, Falconer was working to build a positive school community and culture.
CC14. Agency and Choice	<ul style="list-style-type: none"> • Falconer is a community school with a STEAM focus • Students don't choose to attend Falconer- it is attended by students who live in the school neighborhood.

After examining how, if at all, each critical component was incorporated into Falconer's process of becoming a STEM school, there were three themes that emerged from this study. These themes include: (a) Limited STEM Curriculum for all Students;

(b) Leadership and Teacher Agency; and (c) Hiring a Diverse, yet Underqualified Teaching Staff.

Limited STEM Curriculum For All Students

The first theme that emerged from this study was curriculum. While the school had a STEM teacher, Ms. Betty, who offered STEM classes during the school day, there was no other curricular focus on STEM. Even with the sixth-grade quarter-long STEM class, not all students took STEM if they were in band or choir. Seventh graders could choose to take a semester-long Design & Modeling course, and eighth-graders could opt to enroll in semester-long Robotics, but none of these courses were required. Thus, Ms. Betty charged the STEAM team with creating inclusive, integrated STEM units that would incorporate teachers and content from across the core subjects.

Overall, STEM curriculum development was not a priority, particularly for the sixth and seventh-grade band teams, and the quality of the sixth- and seventh- grade band STEAM units could have been better. Even though teachers did not have to follow the district pacing guide and instruction, the teachers decided to wait until the fourth term to implement their STEAM unit, after the state-required assessments in reading (sixth through eighth grade), mathematics (sixth through eighth grade) and, science (eighth-grade only). After its first year, Falconer's first priority of the School Improvement Plan (SIP) was to improve students' mathematics and reading proficiency levels for the state-required assessments ([Falconer] School Improvement Plan, 2016], which were very low. This meant that preparing their students for the state assessments was their top priority.

The seventh-grade team did not meet as a whole team to plan their unit until after the state assessments. There was little collaboration. Only Mr. Lint met with Ms. Betty to plan the unit prior to the fourth quarter. Mr. Lint did not spend much time preparing and was not able to implement the whole curriculum as originally planned. He stopped meeting with Ms. Betty. The other seventh-grade team members spent minimal time towards the end of the fourth quarter planning and preparing to implement their part of the unit. Mr. Stop (social studies), Ms. Clay (ELA), and Ms. Van (mathematics) each assigned a short project that was related to the main theme, which took five days of in-class work time for students to complete.

Overall, there was minimal effort towards integration and collaboration amongst the sixth-grade band. Without a science teacher, they did not integrate science into their unit. In addition, the team struggled with managing behavior among the sixth-grade students. In the fourth quarter, only select students who were well-behaved were actually allowed to create dream catchers. Rather than teaching new content, teachers revisited the history of Ojibwe in their state and story-telling.

Content from both of the sixth and seventh-grade units were related to standards that were taught during the school year, but there was little connection to most of the students' lived experiences or to the community. In contrast, the eighth-grade unit, Liberty Playground, was a product of meaningful collaboration that purposefully connected content from multiple disciplines into an integrated unit. Students were also able to make meaningful connections to their own community and work closely with community members and make a difference in their shared community. Below is an

excerpt from a student's essay about Liberty Playground that he wrote in Ms. Clean's ELA class:

Violence is a common thing in North Minneapolis. It affects us all in some way. Some families lose members to shootings, stabbings and kidnappings. People are afraid to let their children outside by themselves because of this stuff. Things have been like this for quite some time, and we all hope it will stop. [Liberty Playground] may have the potential to change things in our community. [Liberty Playground] can bring our community together. It can allow us to interact with other people without worrying about being killed-at least that's what we are hoping. [Liberty Playground] can bring the possibilities of a safer community.

Leadership and Teacher Agency

Leadership. The second theme that emerged from this study was leadership and agency. Through Ms. Betty's leadership, the team created the STEAM mission for Falconer, set yearly goals, and created a plan to achieve their goals. She led and supported the work of the three grade bands, and each team was able to develop and implement an integrated unit during the fourth quarter. She organized a successful STEAM night at the end of the school year. The lack of leadership and STEM experience amongst the staff other than Ms. Betty made it challenging to develop STEM programming. Also, with many new teachers and teacher turn-over at a new school, STEM programming was not the priority of most staff members.

Unfortunately, Principal Charge and AP Bell were not able to provide much leadership and support for Falconer's STEAM team and were minimally involved in STEAM programming development. Prior to the beginning of the school year, Ms. Charge was able to commit her time and energy to STEM programming development before other things needed her attention. Once school began, she needed to focus on developing behavioral support, strong leadership, and a positive school culture. The STEAM team teachers also found it difficult to focus on STEAM programming development. Teachers were working to build their own classroom culture and establish behavioral management systems within their own classrooms. Thus, it was difficult for the STEM coordinator to motivate teachers to fully invest their time and energy in the work.

Teacher Agency. The lack of administrative involvement in the STEAM programming development turned out to be a positive factor for Falconer's STEM initiative. It gave Falconer's STEAM team teachers the agency to make collective decisions that impacted STEAM programming development. Grade band teams of teachers were given common planning time to meet regularly during the school day. If they met outside of the school day, the larger grant was able to monetarily compensate teachers for their time. Each grade band was given the autonomy to create inclusive, multidisciplinary units to be implemented during the school day and were not mandated to follow a set curriculum. The principal also allowed teachers to alter the regular school schedule during the implementation of the STEAM units. For example, the entire eighth-

grade class met in the cafeteria one morning to work with local professionals to create plans for the redesign of the park.

Lack of administrative leadership and support and an inexperienced staff also led to other issues. New teachers struggled with creating their own assessments. Teachers could use district assessments if they chose to, but many teachers struggled with analyzing both their own and district assessments. Thus, many teachers were unable to present assessment data, and there was no system in place to monitor student progress throughout the school year.

Hiring a Diverse but Underqualified Teaching Staff.

The third theme that emerged from this study was related to staffing. Overall, Falconer did not have well-prepared STEM teachers and lacked STEM leadership. Ms. Charge hired a staff that represented the diversity of the community. This included many new teachers with little STEM or leadership experience and a few that lacked teacher certification. Due to recent budget cuts in the district, Ms. Charge had tough choices to make. She may have had the opportunity to choose her staff, but she had a limited budget to pay her staff. She was committed to providing a STEAM-focused education which included extra elective staff members, including art, dance, choir, band, AVID, engineering, Chinese and Spanish teachers. The limited budget had to account for these extra electives. Also, she many have been pressured from the district to hire a diverse staff. These circumstances may have led Ms. Charge to hire many new and inexperienced teachers.

The lack of STEM leadership and STEM experience created challenges for developing integrated STEM curricula at Falconer. With minimal expertise in STEM and leadership, the STEAM team was unable to fully utilize the autonomy and agency given to them by the administration. Ultimately, Ms. Betty and the STEM fellow had to lead the STEAM curriculum development rather than teachers.

Staff turn-over among STEAM team members further made curricular work problematic. The sixth- and the eighth-grade teams each lost one core content teacher in the first semester. Both of these teachers had planned to lead their teams. The sixth-grade team had done a good amount of planning for their space/rocket -themed unit during the first semester. But, without Mr. Suit in the second semester, they were no longer able to continue to develop this unit. This was frustrating for the sixth-grade band, and the team lost momentum.

In a similar way, the eighth-grade team was supposed to be led by Mr. Top, the eighth-grade mathematics teacher, who had attended an aerospace PLTW training the previous summer. Thus, aerospace was going to be their unit theme, and the eighth-grade team had planned on modifying the PLTW unit. When Mr. Top left at the beginning of quarter two, he was also replaced by a substitute teacher. The eighth-grade band also had to come up with a new theme. The team lost their mathematics teacher, making it more difficult to create a STEAM unit that integrated mathematics content.

The substitute teachers did not have any content background in the courses they taught, nor did they stay long in their positions. Falconer had a difficult time finding replacements for the positions they lost. The sixth-grade science and eighth-grade

mathematics courses both ended up being taught by several different substitute teachers for the remainder of the school year. Each substitute teacher stayed for just one to two weeks. The lack of a consistent team of teachers in two grade bands added to the difficulty of establishing behavioral norms and a sense of community and culture within each grade and throughout the school. Thus, grade band teams had a more difficult time focusing on curriculum development.

Discussion and Implications

Falconer - A Community School Working to Develop a STEAM Focus

Perhaps Falconer was not ready to build its STEM capacity in its first few years as a new school. Ms. Charge may have had all the intentions of developing STEM programming during the first few years, but as time went by and other issues took priority, Ms. Charge found it more and more difficult to build a STEM program and build a solid school foundation at the same time. Ms. Charge chose to open up a school that she self-identified as a STEAM school. Similarly, many struggling schools self-identify as STEM schools. They add the label of a STEM school in order to attract more students, but with little STEM foresight or preparation (Lynch et al, 2017). This appears to be what happened with Falconer. In the state in which Falconer resides, there were no specific criteria for becoming a STEM school. Thus, Falconer was able to label itself as a STEM school.

Falconer lacked the foundation of a well-functioning school. A STEM school must be built upon the foundation of a well-functioning school with an established school culture and community, which Falconer was still working to develop. As a new school, Falconer was struggling to develop a school culture, behavioral management system, and effective leadership. It was difficult for the administration to focus on building STEM without a sound foundation in place. This parallels previous research. For example, Eisenhart et al., (2015) found that “trying to focus on STEM without other components of a well-functioning school is not likely to produce the desirable outcomes that the STEM school movement intends, and may contribute instead, to the already considerable

problem of struggling schools” (p.786). This was the case for Falconer, which prematurely self-identified as a STEM school. CC9- Flexible and Autonomous Administration; and CC10- Supports for Under-represented Students (Lynch et al., 2017). Three of these four were found to be crucial to Falconer’s STEM programming development: CCs 1, 7 and 9, in this study.

CC1. STEM-Focused Curriculum For All

Prior to this study, STEM curricular opportunities at Falconer were limited to three elective STEM classes. Also, there was limited integration of STEM disciplines at Falconer within the core classes. Thus, the STEAM teams agreed to focus on developing STEM curriculum. The addition of a single integrated STEM unit at the end of the school year per grade band to otherwise traditional and subject-focused instruction constituted a move towards increasing the availability of STEM curriculum as called for in CC1.

All students should have opportunities to participate in STEM-focused curriculum throughout the school year, but at Falconer, this was not the case. Even though the initial goal of the STEAM team was to create inclusive units, in the end, not all students were allowed to participate. For example, as in the case of the sixth-grade Dream Catchers unit, teachers only allowed well-behaved students to create dream catchers. As for the Liberty Playground unit, some eighth-grade students were not allowed to work with the architects and designers during the morning workshop in the cafeteria due to poor behavior. All seventh-grade students were able to participate in all of the implementation of the Medical Mystery unit. Other than the year-end STEM units which introduced some

reform instructional strategies and project-based learning, most of the instruction was traditional at Falconer (CC2).

CC7. Well-Prepared STEM Teachers and Professionalized Teaching Staff

Falconer would have benefitted from having more well-prepared STEM teachers rather than a young staff with minimal leadership skills, STEM experience and expertise. In this way, the teachers may have had an easier time collaborating and integrating STEM throughout the school year and utilizing this freedom. Regardless of staff background, on-going STEM professional development is necessary in building a STEM school and continuing to improve STEM programming to meet the needs of staff and students. Falconer would benefit from continuing whole-staff, STEM-focused, professional development.

Ms. Betty joined the Falconer team two weeks prior to its opening. Falconer would have benefited from Ms. Betty's STEM leadership, experience and expertise perhaps a year prior to opening during the planning stages of the school. Ms. Betty supported Falconer in many ways that were unrelated to the STEAM programming development. This included being on the hiring committee, being a member of the instructional leadership team, co-facilitating professional development, writing grants for Falconer, and serving as the science lead. She also taught nearly a full load during the school day and four days after school. Her many roles helped Falconer in several areas. However, if she was able to focus on her position as a STEM coordinator rather than having the other responsibilities that were far beyond a full work-load, she could have helped STEM programming to further develop at Falconer. .

CC9. Leadership Needed at Falconer

In each of the STEM schools from Lynch et al.'s (2017) study, leadership was distributed among administrators and teachers, and at times, students and community members, creating a more flattened hierarchy (Gronn, 2009; Spillane, 2006), which helped to create and sustain a well-functioning, innovative STEM school (Spillane, Lynch, & Ford, 2016). There was open communication amongst the school community. Proactive leadership continuously addressed students' and teachers' needs, and the school's mission and STEM focus was promoted.

Falconer would benefit from working towards building a similar leadership model. But this takes time. It is important to keep in mind that the schools in Lynch et al.'s (2017) study were well-established, exemplary STEM schools. With time, schools like Falconer could grow as a new school in order to develop their STEM program in this way. At Falconer, new teachers would gain experience and develop leadership skills. In order for Falconer's leadership to develop in this way, its administration needs to be involved in STEM programming development and promote the STEAM team's mission along with the STEAM team and the rest of the school.

Even though Ms. Charge was unable to be directly involved in Falconer's STEAM programming during the first year of the grant, She did contribute positively to the work of the STEAM team. She gave the STEAM team members regular common planning time to develop integrated STEM curricula. She did not mandate Falconer teachers to follow district curricular requirements. Teachers had the freedom to create

their own curricula and assessments. This allowed STEAM team grade bands to collaborate and develop integrated STEAM curricula.

The Need for STEM School Guidelines

Increasing the number of STEM schools is one way to broaden the population of students who participate in STEM. It can be implied from this study that this must be done in a purposeful way. There must be specific guidelines to follow in becoming a STEM school.

Without guidelines and policies, any school can self-identify as a STEM school. The lack of established guidelines in becoming a STEM school can be problematic. If the goal is to increase and diversify the population of students participating in STEM, it is imperative that STEM be accessible for any student who chooses to participate in STEM. However, if any school such as Falconer can become a STEM school by name only without any requirements, we cannot be sure that STEM schools are providing quality STEM education for *all* students.

Conclusion

This study focused on the journey of Falconer Middle School as an emerging STEM school and the factors that impact its STEM programming development. For those who wish to create a STEM school, the 14 critical components put forth by Lynch et al. (2017) could be used to as a guide, paying close attention to CC's 1, 7, and 9. CC1- STEM-Focused Curriculum For All; CC7- Well-Prepared STEM Teachers and Professionalized Teaching Staff; CC9- Flexible and Autonomous Administration. These three CCs are the foundation of any successful STEM school.

Hiring a staff with STEM expertise, experience and leadership should be one of the first steps in developing a STEM school (CC 7). Administration should give agency to their teachers, including common planning time and flexibility in scheduling, just as Falconer did (CC 9). However, administration must also support their teachers and be directly involved with STEM programming development. CC12, Innovative and Responsive Leadership, states that “the school leadership is proactive and continuously addresses the needs of teachers, students, and the greater community through innovative solutions, open communication, and uplifting leadership” (Lynch et al, 2017, p. 719) Unfortunately, CC12 was not present at Falconer, but much needed. Administration should attend to the needs their staff and provide on-going STEM professional development for the entire staff, including the administration. There must be open communication amongst administration and staff. Administration and teachers need to work together to develop and sustain a STEM program with shared leadership responsibilities.

The creation of inclusive STEM middle schools is one possible way to increase and diversify the population of students who participate in STEM and promote STEM-literacy for all students. Middle school is a time in students’ lives that is critical to improving students’ attitudes and interests in STEM as they begin to think about their career paths and develop their STEM identities (Blackhurst & Auger, 2008; Gibbons & Borders, 2010; Jackson et al., 2011). A focus on STEM in middle school would increase STEM interest in a broader population of students and lead to a larger and broader population of students who pursue STEM majors and careers. More research is needed to

create and study the development of more STEM middle schools, and establish ways to evaluate STEM programs in order to ensure that all students who participate in STEM receive a quality STEM education.

STEM school criteria is necessary in all states so that not just any school can identify as a STEM school. Perhaps CCs 1,7, and 9, the most important critical components, should be part of the mandatory criteria of all STEM schools in the state that Falconer resides. All students at all STEM schools should engage in STEM-focused curricula throughout the school year. All staff should participate in STEM professional development that prepares them to teach STEM (CC7). Administration should work with teachers and share leadership roles. (CC 9). It should be mandatory that all STEM schools are inclusive. Beginning with these most important CCs is a good place to start in setting STEM school criteria as well as becoming a STEM school.

Chapter 3: A Community-Based Conceptual Framework for STEM Integration and the Development of Integrated STEM Curricula at a Newly Emerging STEM School

Introduction

Over the past decade, there have been urgent calls to improve K-12 STEM education in the United States in order to alleviate the shortage of STEM workers to fill the growing STEM field jobs. These calls have generated new approaches to teaching and learning, such as integrated STEM, strategies to improve STEM interest in young citizens, and ways to potentially broaden and diversify the population of students who pursue STEM careers. As a new approach, STEM integration has many definitions (Heil, et al., 2013; Honey et al., 2014). However, various models of STEM agree on certain components: (a) an emphasis on student-centered pedagogies (Bransford, Brown, and Cocking, 2000; ; Furner & Kumar, 2007; Smith, Sheppard, Johnson, & Johnson, 2005; Stinson, Harkness, Meyer, & Stallworth, 2009; Wang, Moore, Roehrig, & Park, 2011); (b) connecting STEM subjects and real-world problems (Kelly & Knowles, 2016; Moore et al., 2014b); (c) intentional development of 21st century skills such as problem solving and critical thinking (NRC, 2012); and (d) social interaction, teamwork, and communication amongst students (Wieselmann, 2019; Moore et al., 2014b; Sanders, 2009). In spite of some common features in models for integrated STEM, a range of curricular approaches are being implemented in classrooms, and unfortunately, many curricular approaches do not explicitly address increasing STEM interest for *all* students.

Female students and students of color have been historically underrepresented in STEM majors and STEM careers (Corbett & Hill, 2010). Female, Black, and Hispanic

students are less likely to begin college as a STEM major and are less likely to graduate with a STEM degree (Landivar, 2013). Female students are earning undergraduate degrees at a lower rate in the fields of mathematics, engineering, and computer science (Fouad & Santana, 2017; Landivar, 2013, NSF, 2015). Female students earned only 20 percent of the bachelor's degrees in computer science, engineering, and physics in 2006 (Hill, Corbett, and Rose, 2010), and representation of women decreases even further at the graduate level and STEM-related professions (American Association of University Women Educational Foundation [AAUWEF], 2008; Beede et al., 2011; Hill et al., 2010; Hyde, Lindberg, Linn, Ellis, & Williams, 2008; NSF, 2017). In a recent study by Riegle-Crumb, King, & Irizarry (2019), Black and Hispanic STEM majors are 19 percent more likely to switch majors and pursue a non-STEM degree compared to their White peers. Thus, Blacks and Hispanics continue to be underrepresented in the United States STEM workforce. The United States STEM workforce in 2011 was six percent Black and seven percent Hispanic (Landivar, 2013).

While male and female K-12 students have equivalent achievement in STEM (National Center for Education Statistics [NCES], 2018), gaps in STEM interest become apparent by the end of middle school (Denson & Hill, 2010; Rogers, 2009). Many students find it difficult to relate to STEM and struggle to learn meaningful STEM when subjects are presented individually (Kelley & Knowles, 2016). Thus, there is a need for curricular frameworks that engage students in real-world, problem solving using content from across STEM and other disciplines (Moore et al, 2014; Roehrig, Moore, Wang., and Park, 2012b). Given the need to increase STEM access and interest for a broader

population of students, there is a critical need to also explore culturally relevant curricula that connects STEM to students' lived experiences ((Djonko-Moore, Leonard, Jolifield, Bailey, & Almughyirah, 2018; Roehrig, Campbell, Dalbotten, & Varma, 2012a).

Connecting STEM learning to students lived experiences empowers students, makes STEM learning more meaningful and relevant to their lives (Roehrig et al., 2012a) and enhances student engagement in science (Djonko-.Moore, et al., 2018).

Thus, the purpose of this study was to describe a framework for STEM integration that works to broaden STEM interest for *all* students, especially students from underrepresented groups, such as female students and students of color, and promotes inclusivity and STEM-literacy for all student populations. This framework uses students' lived experiences, incorporates cultural relevance, and promotes inclusiveness and community wealth-building, the strengthening of local communities by investing time and resources locally for the betterment of the community (Democracy Collective, 2014), through community engagement. The following research question guided this study: (a) *What are the features of a framework for STEM integration that works to promote integration of STEM content areas and foster STEM interest in a broad population of students?*

Literature Review

STEM Integration

A review of the literature shows that there is no single definition of STEM education, let alone STEM integration (Heil et al., 2013; Honey et al., 2014). In the ongoing pursuit to improve STEM education, several models of STEM integration have

been developed. For example, Moore and colleagues' (2014b) framework includes six tenets (see Table 3.1) for STEM integration which they define as a holistic approach for merging some or all four STEM subjects into one class, unit, or lesson that is based on connections between STEM subjects and real-world problems.

Table 3.1.

Framework for STEM Integration in the Classroom (Moore, et al., 2014b)

Tenet 1	Motivating & Engaging Context	Students need to have various personally meaningful contexts that provide them with access into the activity (Brophy, Klein, Portsmore, & Rogers, 2008; Carlson & Sullivan, 2004; Frykholm & Glasson, 2005)
Tenet 2	Engineering Design Challenges	Develops problem-solving, creativity, and higher-order thinking skills (Morrison, 2006).
Tenet 3	Learn from Failure/Redesign	The activity should allow learners to learn from failure and then have the opportunity to redesign (Moore, et al., 2014a).
Tenet 4	Mathematics and/or Science Content as Main Objectives	There must be mathematics and/or science content as main objectives of the activity(Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004; Harris & Felix, 2010; Mehalik, Doppelt, & Schunn, 2008). The activity should enhance the students' abilities in science and/or mathematics through the use of engineering design to develop technologies. It is even better if there is exposure to other non-STEM disciplines (e.g., reading or social studies) that are related to the overall activity.
Tenet 5	Student-Centered Pedagogies	Pedagogies for the instruction of the mathematics and science content must be student-centered pedagogies, such as inquiry & discovery (Smith, et al., 2005; Furner & Kumar, 2007; Stinson et al., 2009) that help students develop their scientific or mathematical knowledge in a manner that deepens conceptual understanding.
Tenet 6	Teamwork & Communication	Well-designed STEM integration curricula will emphasize teamwork (Carlson & Sullivan, 2004; Selingo, 2007; Smith et al., 2005) and communication (Dym, Agogino, Eris, Frey, & Liefer, 2005; National Governors Association, 2010; National Academy of Engineering[NAE] & National Research Council [NRC], 2009; Selingo, 2007).

Similar to Moore et al (2014b), the Committee on Integrated STEM Education

developed a descriptive framework for STEM integration that calls for student goals

related to “STEM literacy, 21st century competencies, STEM workforce readiness, interest and engagement and making connections between STEM disciplines” (Honey et al, 2014, p. 32). Kelly and Knowles (2016) call out STEM practices (engineering design, scientific inquiry, and mathematical thinking) as critical for students to engage in real world problems and see connections between the disciplines.

Common across all models is an argument that STEM integration is a way to increase and broaden student participation and interest in STEM by helping students make connections between STEM domains, other content, and their lived experiences (Honey et al, 2014) through contextualizing learning on authentic, real-world problems (Kelly & Knowles, 2016; Moore et al, 2014b; Roehrig, et al., 2012b). Learning is promoted through student-centered and problem-based approaches to teaching (Bransford et al., 2000; Wang et al., 2011). Researchers also agree that integrated STEM provides a robust learning environment for social interaction and teamwork that are crucial to STEM learning (Sanders, 2009; Wieselmann, 2019). Noticeably absent in these models is any explicit mention of curricular approaches specific to promoting learning for under-represented students such as females and students of color. These curricular approaches, including the incorporation of personal relevance and community strengths and engagement, are described below.

Personal Relevance

Culturally relevant pedagogy (CRP) focuses on academic success for all students (Ladson-Billings, 1990; Ladson-Billings, 1994). Teachers who practice CRP strive for educational equity by removing barriers to opportunities and success, particularly for

those in under-represented groups (Ladson-Billings, 1994;1995b). CRP is based on the assumption that when academic knowledge and skills are situated within the lived experiences and frames of reference of students, they are more personally meaningful, have higher interest appeal, and are learned more easily and thoroughly (Gay, 2000). In contrast to more common traditional teaching, students show higher academic success when teaching occurs through their own cultural and experiential lens (Gay, 2000; Ladson-Billings, 1994; 1995a).

Another argument in favor of CRP is that it uses a student's cultural knowledge to preserve his/her culture and overcome any negative effects of the predominant culture (Ladson-Billings, 1994; 1995a). Such negative effects occur when students from under-represented groups do not see their history, culture, or background represented in curricular materials in the classroom, nor do they see many teachers and other people with higher social capital who look like them. This discrepancy can negatively impact how students of color view themselves and their culture (Ladson-Billings, 1994; 1995a).

A third argument in favor of CRP is that it allows teachers to cultivate education that empowers and enables students to be critically conscious and work cooperatively for social justice (Cummins, 1986; Ladson-Billings, 1990). In order to foster educational equity, students need to gain the skills and knowledge to become active citizens who are able to criticize current cultural norms, values, and institutions that create and perpetuate injustices and inequalities in our society (Ladson-Billings, 1995a).

In today's society, social justice is concerned with the environment, gender, race and other forms of inequality (Pachamama Alliance, 2019). In teaching, this means to see

and act to combat inequity and oppression, and at the same time, advocate for freedom and justice for everyone. The focus is on how people, policies, practices, curricula, and institutions can be utilized to emancipate instead of persecute the people underserved by the decisions of the oppressors (Sensoy & DiAngelo, 2009). Thus, students can be empowered to make a difference in their lives and their community by promoting fairness and equity.

Community Wealth-Building

Community wealth-building is an economic development movement that strengthens local communities through the expansion of democratic ownership and control of businesses and employment and developing a community's assets in a way that keeps the wealth within the local community. The goal of community wealth is to help a community and its families take control of their own economic future (Democracy Collective, 2014). Partnerships between local schools and community members can be a powerful form of community wealth-building. Local businesses that are willing to invest their time and resources into helping students are contributing to the community's prosperity in the future. Students can work with community experts and learn how they can make a difference together.

Development of a Community-Based Conceptual Framework for STEM Integration

The goal of the framework is to guide educators in developing inclusive integrated STEM curricula that engages all students in order to create positive community change. The framework brings together the literature on STEM integration and cultural relevance to explicitly provide guidance for generating interest in STEM for under-represented students. The framework includes nine components, with some overlap among the components: (i) STEM integrated across disciplines; (ii) motivating and engaging, real-world context; (iii) project-based learning; (iv) community-based problem; (v) 21st century skills; (vi) cultural relevance; (vii) inclusiveness; (viii) community strengths and expertise and (ix) community change.

STEM Integrated Across Disciplines

STEM content is integrated within one or more core subjects (as opposed to STEM content that is integrated within a science unit and implemented by a single science teacher.) STEM can be integrated into other subjects such as social studies and ELA. The idea of integration across STEM and other disciplines aligns with the STEM integration framework put forth by Honey et al. (2014).

Motivating and Engaging, Real-World Context

In this framework, integrated STEM is contextualized by motivating and engaging, real-world context. This is in order to connect students to the activity in a personally meaningful way (Brophy et al., 2008; Carlson & Sullivan, 2004; Frykholm & Glasson, 2005; Moore et al, 2014b). In order for learning to be meaningful, students need

to be given the opportunity to connect their prior knowledge to newly acquired knowledge, and then apply their new knowledge to real-world contexts (Ausubel, 1968).

21st Century Skills-Collaboration, Critical Thinking, and Problem-Solving

In this framework, integrated STEM should be designed to help students to develop 21st century skills (NRC, 2012; Wang, et al., 2011). There is a need for teachers to implement student-centered instructional practices and have high expectations for *all* students. This is especially the case in urban schools with a high population of under-represented students where traditional and remedial instruction is most common. Instead, STEM teachers need to help facilitate students working together and challenge their students through problem-solving and critical thinking. We expand the notion of group work and problem-solving to include collaboration with community members in working to solve community-based problems in order to elevate other ways of knowing about STEM professionals and STEM learning that are well beyond the regular classroom and encourage students to engage with their community and lived experiences.

Project-Based Learning

Teaching today continues to follow traditional practices of teacher-centered instruction, giving priority to lecture, practice, and review (Marzano & Toth, 2014). These practices are particularly common in urban classrooms. However, instruction is more meaningful when students learn by doing (Hannover Research, 2011) and take part in their own education. Through project-based learning, students are posed with a real problem or driving question. Students are motivated by need to find a solution to the problem by applying their newly acquired knowledge. Inquiry is emphasized, allowing

students to construct their own meaningful understanding of what they are learning rather than memorizing decontextualized facts in traditional instruction (Edelson, 2001; Singer et al, 2000). Project-based learning encourages creativity, imagination, exploration, and invention, as it gives students the chance to investigate and inquire about their projects in their own way and take ownership of their work (Calabrese Barton et al, 2013; Calabrese Barton, Tan & Rivet, 2008; Chatman, Nielsen, Strauss, & Tanner, 2008; Denner & Werner, 2007; Eisenhart & Finke, 1998; Lyon & Jafri, 2010)

Community-Based Problem

Integrated education must be project and activity-based in which students apply knowledge to solve real life problems that have social meaning (Beane, 1995;1996). In the new framework put forth in this study, students are introduced to problems related to their community's health, environment and safety that directly affects their lives. Their consciousness is raised in terms of any inequalities related to the issues at hand in order to promote social justice and community change. Such problems include trying to reduce violence in one's community by creating a safe community space and finding ways to combat pollution from local businesses causing health and environmental problems in the community. In this framework, student groups design solutions to real-world community-based problems that are relevant to their lives. Through this work, students provide information to promote change in their communities. Students may even present their work to their community.

Personal Relevance

Our framework is aligned with relevance. Students create meaning from real-world issues that are a part of their daily lived-experiences within their own community (Ladson-Billings, 1995a; Stein, 1998). Because students are invested in the success of their learning as it directly impacts their lives, students are more inclined to be interested in what they are learning about. Teachers and community members are also involved in a relative context or solving a real problem that affects the entire community. Hence, students, teachers, and community partners, may find it easier to connect with one another, understand one another, and build relationships with one another.

Inclusiveness

This framework argues for access and success in STEM for *all* students, and it is not merely for the gifted, talented, and privileged few. In this way, STEM programming is more equitable and inclusive. This framework is grounded in the belief that STEM programming should be included during the school day in core classes (science, mathematics, social studies, and ELA) and inclusive for all students. This is to ensure that all students are given the opportunity to receive a high quality education and participate in STEM. With this inclusive approach, all students benefit from STEM integration.

Community Strength and Expertise

Our community-based framework advocates for creating partnerships between school and community. These community connections tie into *community wealth-building*-- developing assets in such a way that the wealth stays local (Pachamama Alliance, 2019). This includes investing in local businesses such as buying locally

produced goods and services. This also relates to the work Maggie MacDonnell, 2017 Global teacher of the year, in the Inuit village of Salluit, in the Canadian Arctic. MacDonnell built programs through school and community partnerships in order to “cultivate resilience, hope and build self-belief in her students” (Educational International, 2017, May 11). Community experts and leaders such as teachers and other professionals invest their time and share their expertise with students, “giving them the tools that they need in order to be masters of their own destiny” (Educational International, 2017, May 11). Students, teachers, and community members alike are all invested in solving local problems because they are all working to strengthen their shared community by creating positive change within the community.

Community Change

The framework also calls for making a positive change for the community. Students are made aware of the social injustices and inequity in the world and within their own communities. Together, along with the community, students build awareness and work to solve these problems. Figure 3.1 is a model of the Community-Based Framework for STEM Integration put forth in this study. In the following section, the framework is described in action through examples of integrated STEM units developed at an emerging, urban STEM middle school.

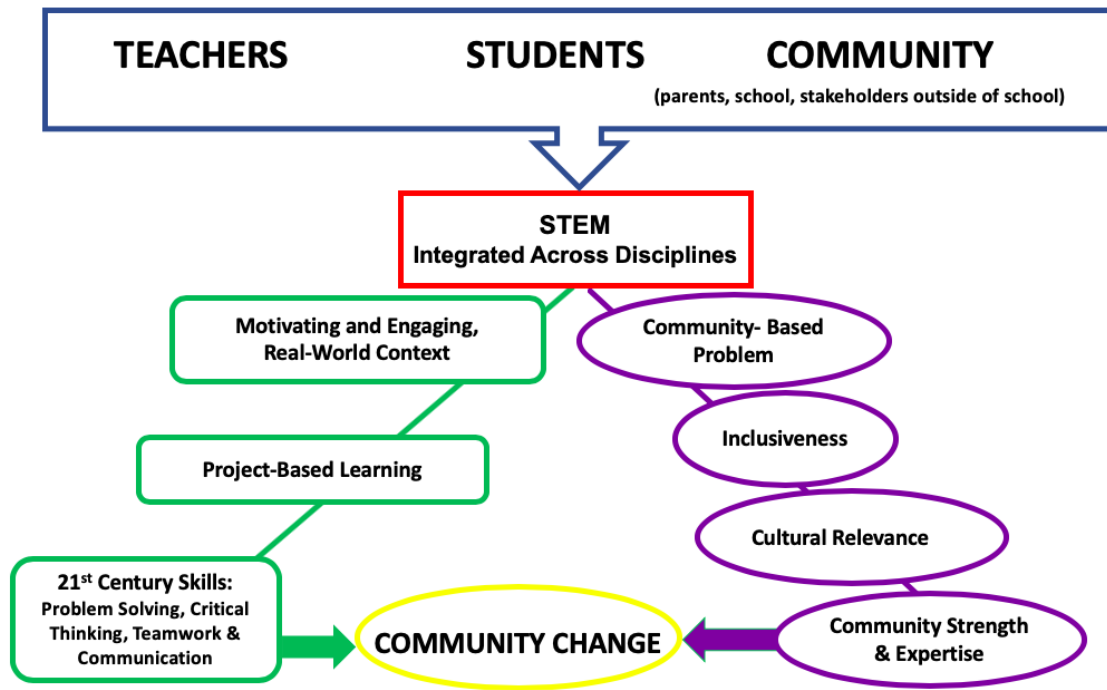


Figure 3.1. Community-Based Framework for STEM Integration

Context of Study

The setting for this study was Falconer Middle School, an emerging urban STEM school. Falconer was one of five secondary schools that was part of a larger study in which the overarching goal was to research the process of developing STEM programming within an urban, public school district located in the Midwestern United States. In each school, a STEM team was created and provided with professional development support, including a STEM fellow (graduate student in STEM education) who helped teams of teachers from the core and elective courses develop and implement STEM strategies and curricula.

Falconer's Neighborhood and Community

Falconer Middle School is located in a diverse, working-class neighborhood. Around the time of this study, the neighborhood had the highest rate of housing foreclosures in the city (Horsley, 2007). Approximately 50 percent of the students in the neighborhood attended local schools (Hawkins, 2007). Within the past 12 years, the city's Board of Education decided to close several middle and elementary schools, including Falconer. Due to efforts of the community residents, Falconer re-opened its doors in September 2015 as a community school with a STEM focus.

Demographics and Academic Proficiency

At the time of this study, a total of 397 sixth, seventh, and eighth graders made up the entire student body at Falconer Middle School (State Report Card, 2018). The student population of Falconer was 72.3 percent Black, 17.6 percent Hispanic, 1.8 percent White, 2.0 percent Asian, 3.0 percent American Indian/Alaska Native, 0.5 percent Native Hawaiian/Pacific Islander, and 2.8 percent two or more races. The percentage of the student population at Falconer Middle School who filed paperwork to qualify for free/reduced lunch was 87.9 percent. The percentage of Falconer students who were English learners was 10.8 percent, and the percentage of Falconer students who received special education services was 27.7 percent. At Falconer, 7.1 percent of its students were homeless (State Report Card, 2018). According to the 2018 State Comprehensive Assessment reports, 12.2 percent of Falconer students were proficient in math, 18.7 percent were proficient in reading, and 7.8 percent were proficient in science (State Report Card, 2018).

STEM Curriculum Development

The work toward becoming a STEM school primarily occurred in grade-level STEM teacher teams supported by the school STEM Coordinator and the university STEM Fellow. Grade level teams included teachers from all core disciplines as well as teachers of elective courses. The teams met regularly during the school year, and collaborated in developing, planning, and implementing the integrated STEM units. This interdisciplinary approach aimed for all students throughout each grade had the opportunity to experience the STEM units, as opposed to many other school approaches that structure programs in STEM only for students taking advanced coursework or outside the regular school day. Chapter two of this dissertation focused on the work of the STEM team toward becoming a STEM school. In this chapter, the focus is on the curriculum developed by the teacher teams aligned with the conceptual framework for promoting community engagement through integrated STEM.

Two integrated STEM units are featured in this study: 1) Liberty Playground, an eighth-grade unit from year one; and 2) MidWest Metal, a seventh-grade unit from year two. Liberty Playground was implemented during the school day towards the end of the school year in year one, and MidWest Metal was implemented at the end of the first quarter in year two. This interdisciplinary and inclusive approach ensured that all students throughout each grade had the opportunity to experience the STEM units. Brief descriptions of each of these units are provided in Table 3.1, and in the following section, they are described in detail through the lens of the conceptual framework.

Table 3.2

Integrated STEM Units

Unit	Description
Liberty Playground	Eighth-grade students partnered with community members to redesign of Liberty Playground, a local park near the school. Students created and conducted surveys for community outreach, researched local parks and local history, learned about how the Mississippi watershed is impacting the park redesign, created scaled models of the park redesign, wrote essays and created slide presentations which they presented to the school and the community. Students worked side by side with local designers and architects of the park.
MidWest Metal	Students researched the environmental effects of a local metal recycling plant that was located near Falconer. Students were asked to provide evidence to support their stance as to whether or not they agree with the ruling that is mandating MidWest Metal to relocate.

Examples of Using the Conceptual Framework through the Integrated STEM Units

Liberty Playground Unit

Liberty Playground was developed in collaboration with the STEM Fellow and the eighth-grade STEM teacher team, which included science, ELA, social studies and art. The Liberty Playground unit is an example of a collaboration in which students, teachers, and community partners worked together help to make a difference in their community through the redesign of a community park. The *real-world, community-based problem* involved a local park, Liberty Playground. The park was run down and the community was looking to find ways to reduce the crime, violence and pollution in the neighborhood. There was a need to create a safe place for people to get together and participate in daily physical activity in the neighborhood (Urban Research and Outreach-Engagement Center, 2016). Community members also recognized the potential of the park redesign to improve the treatment of stormwater in the area. Students were asked to work with community members “to create a new collective vision for the playground” (Mississippi Watershed Management Organization [MWMO], 2019) and redesign the park.

Throughout the unit, eighth-grade students, core eighth-grade teachers, the art teacher, and community partners worked in collaboration with one another. Students worked with community members in efforts to redesign and rebuild the playground in order to improve the local community. Teachers met with local architects, designers, and scientists in order to plan student involvement and collaboration. In each of their classes, students worked on different aspects of the park redesign.

In **science** class, students learned about the Mississippi watershed, stormwater management and the effects of littering in the park and the community on the local environment, including the watershed. Some students wrote essays about the impact of the watershed on the community. For example, one student explained how rainwater carries garbage that ends up as sewage runoff into the Mississippi River. The river provides food and shelter for animals and drinking water for the community. Thus, it is important to keep our water clean (MWMO, 2019).

In their **ELA** class, students wrote essays about their specific projects and involvement in the playground restoration. Students designed and conducted surveys in order to identify the needs of the community. Students created a visual display and graph of the results of a school-wide survey that asked for what the community hoped to add to the park. Students also wrote about their visions of the park and how the park could potentially decrease violence in the community. Below is an example of a students' essay on Liberty Playground:

Violence is a common thing in [our neighborhood]. It affects us all in some way. Some families lose members to shootings, stabbings and kidnappings. People are afraid to let their children outside by themselves because of this stuff. Things have been like this for quite some time, and we all hope it will stop. [Liberty] Park may have the potential to change things ... bring our community together. ... and bring the possibilities of a safer community.

In their **social studies** class, students researched the local history of the neighborhood and other parks nationwide. They surveyed the student body to find out

what students hoped to gain from the park redesign. Students created Google slides presentations of their research. Students also conducted interviews with students, teachers, the architect and the designer of the park. In one student interview, the interviewee suggested to “put a recreation center inside the school building that is by the park.” The interviewer agreed and pointed out in his essay:

There is not one recreation center in [the city] that you can get in for free...

Overall, I think that [Liberty] Park is going to be a park where everyone can get together and just forget about the violence and have fun.

In **art** class, students worked with a local architect, designer and artist of the park. Groups of students used both math and design principles to brainstorm, design, and build scaled three-dimensional models of their vision of the park. Students presented their models and other related work in their classes and during a school and community-wide STEM event.

During their in-class and STEM event presentations, students described what they learned from their experiences throughout the Liberty Park unit. Students explained the history of parks both nationally and locally. They described the potential impacts of the park redesign on the environment, health, and safety of the community. They also discussed their ideas regarding the redesign and what they learned from their experiences.

Liberty Playground Connections to the Community-Based Framework for STEM Integration

Personal relevance. Liberty Playground is an example of making an integrated STEM unit personally relevance to students’ lives. The playground is located in the

neighborhood where the students live and where Falconer is located. By working with local community members to make the playground a safe and welcoming place for their own community, the project is relevant and impactful to their own daily lives. Students worked together with other community members to make a *positive change* for their shared community.

Throughout this unit, students discussed the social injustices of their community, including high crime rates and violence. They reflected on how redesigning the park to be a welcoming and safe place for community members to gather could help reduce violence and crime in the neighborhood. By creating awareness of these issues and the need for community safety, students are able to begin to impact their community in a *positive* way and work together toward *social justice*.

Community strengths and expertise can also include local community members investing in the youth within the community. Using the example of the Liberty Playground unit, a local architect, designer, and artist volunteered to work with local middle school students from Falconer Middle School. They worked side by side the students and redesigned the playground. Community professionals invested their time and expertise into the youth of the community. Along with the students, community professionals took action and created a positive *community change* within the community through improving the park and through impacting student education and engagement within the community.

Inclusiveness. Liberty Playground is also an example of how this framework incorporated inclusiveness. The unit was implemented during the regular school day in

core classes of science, mathematics, social studies and ELA. All eighth-grade students were able to participate in the unit. For example, one morning, all eighth graders gathered in the cafeteria with the community experts and brainstormed ideas of the park redesign.

As depicted in the framework, students, teachers, and community members collaborated with one another. Within the framework, teachers did not hold the knowledge and power, and students were not silenced. Instead, together with their peers, teachers, and community members, students were part of a collaboration in which all members engaged in co-generative dialogue (Emdin, 2016) and worked together to co-construct knowledge. Teachers and community members were facilitators of learning. Students had a space to voice their ideas, as it is their questions from their own lived experiences that drove the curriculum. Students were invested in their own learning because *their* learning impacted *their* own community where they live.

MidWest Metal Unit

During year two of this study, Falconer teachers built upon the work from year one and explored the development and implementation of other integrated STEM units. The framework from year one was used to guide their work in year two. Each unit implementation included a Community Connections Day, which is explained in the following sections.

In this MidWest Metal unit (pseudonym), seventh-grade students were introduced to MidWest Metal, a local recycling plant that may be causing air pollution and lead poisoning in their community. The seventh-graders researched the environmental effects of MidWest Metal, located near Falconer. Students were asked to provide evidence to

support their stance as to whether or not they agreed with the legal ruling that was mandating MidWest Metal to relocate.

In this unit, students were specifically examining the potential effects of lead and air pollution from this metal recycling plant. Students were learning about these phenomena through the first Community Connections Day. The first Community Connections Day consisted of guest speakers and activities for the whole seventh grade. Guest speakers included the following community members: a nurse from the state's department of health, a representative from the state pollution control agency, and student presentations of lead soil testing in the community. The nurse presented on health issues such as asthma and lead poisoning. The state representative from the pollution control agency discussed the role of the agency, the effects and the prevalence of air and lead pollution to the local residents, and the settlement between MidWest Metal and the state pollution control agency.

Student presentations included results from soil testing and a personal connection to lead poisoning. MidWest Metal included student projects which included soil collection, testing, research, and presentations. Prior to the first Community Connections Day, students collected soil samples from the yards of their homes, the school, and the recycling plant.

The STEM fellow sent the soil samples to be tested for lead. A few of the students' houses had dangerous levels of lead in their yards, according to the collected sample results from the city. For example, one sample had an average reading of 872.82 parts per million (ppm) of lead (Minneapolis Health Department, 2017). If a reading is

between 100 and 5000 ppm, the city recommends that the soil should be covered to prevent children from being exposed to it (Minneapolis Health Department, 2017).

During the Community Connections Day presentations, a group of students put together a Google Slides presentation about the soil testing results. Also, another student, Kira, spoke to her entire seventh grade class about her baby brother and how he suffered from lead poisoning. In the afternoon, students then broke up into small groups and investigated the pros and cons of MidWest Metal relocating in terms of the health, environmental, and economic impact to the community.

The MidWest Metal unit demonstrated interdisciplinary connections across content areas. For **mathematics**, students learned about the measurement of parts per million (ppm) in terms of lead levels in blood. For **science**, students learned about air pollution, asthma, and lead poisoning. For **ELA**, students wrote claim, evidence, reasoning statements to justify their reasoning as to whether they agree or disagree with the mandate MidWest Metal to relocate to a more rural area within the state. For **social studies**, students read and discussed articles about the social, environmental, health and economic impact that the plant has had on society and how the relocation of MidWest Metal will affect the community.

MidWest Metal Connections to the Community-Based Framework for STEM Integration

Project-based learning. Following the Community Connections Day, students completed additional projects related to the MidWest Metal unit. A few months after Community Connections Day, a small group of students presented their research from

this unit at a science fair at a local university and won first place. In addition, during term four, Kira (pseudonym), the student speaker from Community Connections Day who spoke about her brother suffering from lead poisoning possibly due to the dangerous lead levels in her yard, conducted a follow-up study. She retested the soil from her yard for lead. This time, she took samples from several different locations on her property. She presented her work at the STEM showcase at the end of the school year at the STEAM Showcase.

21st century skills. Through this unit, students were able to work to develop 21st century skills. They collaborated in student groups read articles related to recycling, air pollution, and lead poisoning and put together poster and Google Slides presentations. In the afternoon of the Community Connections day, student groups presented their work to the entire seventh grade class. Following these presentations, students voted as to whether or not they agreed with the decision mandating MidWest Metal to relocate with evidence to justify their position. Students used *critical thinking skills* to justify their reasoning.

Relevance and inclusiveness. The MidWest Metal unit is relevant to the students at Falconer. MidWest Metal Recycling Plant is located about one-half of a mile from Falconer Middle School in the same neighborhood and the students at Falconer. Thus, MidWest Metal had a direct impact on their neighborhood and their health. At the time of this study, the zip code area where the MidWest Metal is located had the highest rates of hospitalization due to asthma in the state. It also has the highest rates of lead poisoning in children in the city (Yuen, 2018). Due to air quality violations, including elevated lead levels in the air, state regulations mandated the plant to relocate to a more

rural area within the state (Dunbar, 2017; Reilly, 2018). The MidWest Metal unit incorporates social justice, as it increases student and community awareness of health and environmental issues present in the neighborhood. The entire seventh grade was given the opportunity participate in the unit, promoting *inclusiveness*, leaving no students behind.

Community strengths and expertise. The MidWest Metal unit also ties into community strengths and expertise. Representatives of the State Department of Public Health and the State Pollution Control Agency came to Falconer to invest in the Falconer students and share their knowledge with students. Through this, and through student research facilitated by their teachers, students were able to increase awareness within their community regarding MidWest Metal, air pollution, and lead poisoning, which is affecting the entire community.

Discussion

The conceptual framework developed in this study is an example of how a school can meaningfully integrate STEM for all students and positively impact the community. There are several features of the framework that work to foster STEM interest in a broad population of students. The framework incorporated the main characteristics from other STEM integration frameworks : (i) interdisciplinary connections across content areas; (ii) real-world problem; and (iii) project-based learning; (iv) the opportunity to develop 21st century skills, including problem solving, critical thinking, teamwork & communication. However, the framework expanded on these tenets of high-quality integrated STEM to explicitly address relevance and community strengths and expertise to promote STEM interest and engagement for all students. These features include: (a) personal relevance

(Ladson-Billings, 1995a; (b) inclusiveness (Peters-Burton, 2018); (c) community strengths and expertise (Democracy Collective, 2014; Educational International, 2017, May 11); (d) a relevant, community-based problem (Kelly & Knowles, 2016; Moore et al, 2014b), and (e) community change.

Personal Relevance

The Community-Based Framework for STEM Integration allows students to connect with their own communities and lived experiences. It raises student awareness of and involvement in issues that affect their lives in order to help others. This way, it promotes equity, fairness and social justice.

Inclusiveness

The framework put forth in this study is an all-inclusive approach to STEM integration. Integrated STEM units are implemented during the regular school day so that all students can participate and engage in STEM-learning. In this way, all students have the opportunity to participate in STEM.

Community Strengths and Expertise

As a form of community strengths and expertise, Falconer built partnerships with community experts. For the Liberty Playground unit, community members volunteered their time and resources, working with students to redesign a community playground for the entire community to enjoy. On the Community Connections Day for the MidWest Metal unit, experts shared their knowledge about health and environmental issues with the students to raise awareness of these important issues within the community. This empowers students to make a difference in their lives and their community (Cummins,

1986; Ladson-Billings,1990) and, in turn, fosters their interest and motivates students to engage in STEM.

Motivating and Engaging, Real-World Context and Relevant, Community-Based Problem

Another feature of this framework is engaging students in a motivating and engaging, real-world context that addresses a relevant, community-based problem that directly relates to their own lives. The Liberty Playground unit introduced students to their community's need to redesign a local park. The MidWest Metal unit provided students with the opportunity to learn about health and environmental issues that are directly affecting people within their own community. In this way, Students are given the opportunity to make connections between STEM and their community. Thus, STEM learning is personally meaningful and *relevant* to students lived experiences. This promotes student engagement and interest and leads to higher academic success (Gay, 2000; Ladson-Billings, 1994; Ladson-Billings,1995a).

Community Change

Another novel feature of this framework is that the end goal is community change. Students were part of positive changes within the community, including redesigning a community park and increasing community awareness of lead poisoning and air pollution. When students are actively involved in an integrated STEM project in which they were a part of making positive changes within their own community, their STEM interest and engagement in collaboration and STEM learning is fostered.

Conclusion

This study presented a community-based framework for STEM integration. The framework is unique in that it shows how STEM integration can be used to solve a relevant problem and promote inclusivity and utilize local strengths and expertise in order to create a positive change within a community. Two curricular units are exemplified in this study in order to show STEM can be surfaced in urban communities in a positive and meaningful way. In order to provide STEM opportunities for a broader population of students, it is imperative to allow students to make personal connections to STEM within their own communities. Based on the results of this study, we suggest using the conceptual framework for STEM integration that was developed in this study as a guide for future curriculum development and research.

Chapter 4: Fostering STEM Interest in Female Students through STEM Integration at a Developing STEM Middle School

Introduction

Innovations in science and engineering have made the United States the world leader that it is today (National Academies of Sciences, Engineering, & Medicine, 2007). However, at present, the United States is losing its competitive position within the STEM fields the number of students who participate in STEM declines. Thus, preparing America's future scientists, technologists, engineers, and mathematicians is a growing concern (ACT, 2017; PCAST, 2010). This concern emanates from the increasing demand for STEM workers, with the number of STEM jobs growing much faster than non-STEM jobs over the last decade (24.4 percent versus four percent, respectively) (Noonan, 2017). Thus, it is imperative that the United States improves the current preparation of its young citizens in STEM (PCAST, 2010; National Academy of Sciences, 2010; Thomas & Williams, 2010).

However, a focus on workforce concerns must clearly address a critical concern that the population of students entering STEM degree programs and careers does not reflect the current demographics of the United States population. STEM fields have historically been, and continue to be, dominated by White men, particularly in engineering, computer sciences, and physics (NSF, 2015). While women make up 48 percent of the workforce in the United States, they only hold 24 percent of STEM jobs (Beede et al., 2011). The underrepresentation of women in STEM fields limits their participation in high growth, lucrative, STEM professions and leaves an untapped

opportunity to broaden the STEM workforce and ameliorate the predicted future employee shortages in STEM fields (PCAST, 2012).

Thus, a current emphasis in STEM education is to better understand gender equity in STEM. Middle school has been identified as a critical time for the development of career identities (Blackhurst & Auger, 2008; Gibbons & Borders, 2010; Jackson et al., 2011) and a time when interest in science and engineering decreases sharply, even when grades remain high (Christidou, 2011; Lindahl, 2007). Particularly for girls, STEM interest starts to decline as they enter middle school, which is problematic as girls' career aspirations are largely formed by the age of thirteen (Lindahl, 2007). While no difference was found by gender in STEM attitudes among fourth grade students, by the end of eighth grade, more male students were interested in pursuing a STEM career compared to female students (Riegle-Crumb et al., 2010). This gap continues to widen throughout high school; only 12 percent of female students during their senior year in high school are interested in pursuing a career in a STEM field compared to 40 percent of male students (Sadler, Sonnert, Hazari, & Tai, 2012).

In order to engage more female students in STEM, educators need to find ways to encourage students to identify with STEM, establishing a positive attitude toward STEM education, and understanding potential STEM career paths (Thomas & Williams, 2010). One possible way to promote the development of a STEM-related identity is through STEM integration (Honey et al., 2014) -- a student-centered, interdisciplinary approach for merging some or all of the STEM disciplines based on connections between STEM subjects and real-world problems (Honey et al., 2014; Moore et al., 2014b). Thus, the

purpose of this study is to explore STEM interest in girls after their participation in integrated STEM in order to find ways to motivate, engage and sustain STEM interest among this population of students. The following research question guided this study: *In what ways does a community-embedded STEM integration experience foster aspects of STEM interest in middle school girls at a developing STEM school?*

Literature Review

STEM Integration

Historically, from elementary through postsecondary, student learning within discrete subjects has been emphasized (National Education Association [NEA], 1894; Marzano & Toth, 2014). Specific to STEM, K-12 teaching has traditionally focused on the individual subjects of mathematics and science. However, this disciplinary approach is not helpful for most students, as students find it difficult to make connections to real-world applications and consequently, often become disinterested in science and mathematics (Kelley & Knowles, 2016). STEM integration is a new approach with the potential to provide an authentic approach to learning that can promote student interest in STEM through the seamless integration of more than one disciplinary subject. (Honey et al., 2014).

Efforts to promote STEM integration within K-12 education have culminated in the development of the *Framework for K-12 Science Education* (NRC, 2012) and the subsequent *Next Generation Science Standards* (NGSS Lead States, 2013). The *Framework* emphasizes the importance of both engineering and scientific practices with the overall goal for students to learn core content through engaging in scientific inquiry

and engineering design (NRC, 2012). However, while there is agreement that approaches to STEM integration merge science, technology, engineering, and mathematics, STEM has no common definition across stakeholders in K-12 STEM education (Bybee, 2010). Researchers agree that STEM integration provides a real-world context which encourages students to construct and apply knowledge of mathematics and science to authentic problems (Heil et al., 2013; Honey et al., 2014; Kelley & Knowles, 2016; Sanders, 2009; Wang et al., 2011). Other agreed upon characteristics include engaging students in critical thinking, which includes problem-solving, creating, and higher-order thinking skills (Morrison, 2006), as well as learning from failure through redesign opportunities (Lehrer, Schauble, and Lucas, 2008; Moore, Guzey, & Brown, 2014a; Moore et al., 2014b; Schank & Neaman, 2001), and the promotion of communication skills, collaboration and teamwork (Moore et al., 2014a; Moore, et al, 2014b; Wieselmann, 2019).

Framework for STEM Integration

Within this study, we draw on the STEM integration framework of Moore et al. (2014b). This framework has six tenets which are summarized in Table 4.1.

Table 4.1

Framework for STEM Integration in the Classroom (Moore, et al., 2014b)

Tenet 1	Motivating & Engaging Context	Students need to have various personally meaningful contexts that provide them with access into the activity (Brophy, Klein, Portsmore, & Rogers, 2008; Carlson & Sullivan, 2004; Frykholm & Glasson, 2005)
Tenet 2	Engineering Design Challenges	Develops problem-solving, creativity, and higher-order thinking skills (Morrison, 2006).
Tenet 3	Learn from Failure/Redesign	The activity should allow learners to learn from failure and then have the opportunity to redesign (Moore, et al., 2014a).
Tenet 4	Mathematics and/or Science Content as Main Objectives	There must be mathematics and/or science content as main objectives of the activity(Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004; Harris & Felix, 2010; Mehalik, Doppelt, & Schunn, 2008). The activity should enhance the students' abilities in science and/or mathematics through the use of engineering design to develop technologies. It is even better if there is exposure to other non-STEM disciplines (e.g., reading or social studies) that are related to the overall activity.
Tenet 5	Student-Centered Pedagogies	Pedagogies for the instruction of the mathematics and science content must be student-centered pedagogies, such as . inquiry & discovery (Smith, et al., 2005; Furner & Kumar, 2007; Stinson et al., 2009) that help students develop their scientific or mathematical knowledge in a matter that deepens conceptual understanding.
Tenet 6	Teamwork & Communication	Well-designed STEM integration curricula will emphasize teamwork (Carlson & Sullivan, 2004; Selingo, 2007; Smith et al., 2005) and communication (Dym, Agogino, Eris, Frey, & Liefer, 2005; National Governors Association, 2010; National Academy of Engineering[NAE] & National Research Council [NRC], 2009; Selingo, 2007).

Gender Equity Issues in STEM

Gender inequality in STEM exacerbates the shortage of the STEM workforce. Additionally, fewer female citizens entering the STEM workforce deprives the nation of benefitting from female expertise and diverse perspectives (PCAST, 2010). The National Assessment of Educational Progress (NAEP) and the Program for International Student Assessment (PISA) studies reveal that there are no major differences in ability between male and female students in science and mathematics (NCES, 2018). Yet, female students are earning undergraduate degrees at a lower rate in the fields of mathematics, engineering, and computer science (Fouad & Santana, 2017; Landivar, 2013; NSF, 2015). In 2017, females earned only 32 percent of STEM² degrees or certificates from postsecondary institutions in the United States (NCES, 2019). Female students earned only 20 percent of the bachelor's degrees in computer science, engineering, and physics in 2006 (Hill et al., 2010), and representation of women decreases even further at the graduate level and STEM-related professions (AAUWEF, 2008; Beede et al., 2011; Hill et al., 2010; Hyde et al., 2008; NSF, 2017).

Valian (2007) suggests that fewer female students seek careers in STEM because of lack of interest. Female students' decline in STEM interest is noticeable at an early age and by the end of middle school, the gender gap in STEM field interest in American students is already apparent (Reigle-Crumb et al., 2010). Interest in STEM is shaped by

² STEM fields include biological and biomedical sciences, computer and information sciences, engineering and engineering technologies, mathematics and statistics, and physical sciences and science technologies (NCES, 2019).

social and environmental factors: lack of female role models, self-efficacy, and work-family balance. These factors may contribute to a belief of potential success or failure in STEM fields (Beede et al., 2011; Correll, 2004; Eccles, 2006) which can influence a female student's interest and staying power in a STEM career.

Lack of female role models. Since there are fewer women in STEM, the stereotypes of STEM professionals reflect men. If young girls see women role models in STEM, they are more likely to see themselves in STEM. Hence, they are more inclined to identify with STEM, maintain interest in STEM, and choose to pursue a STEM major and career (Schellinger et al, 2018). The lack of female role models may also suggest to young women that gender bias or the more favorable treatment of men over women will be an issue (Milkman, Akinola, & Chugh, 2015; Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012; Reuben, Sapienza, & Zingales, 2014).

Self-efficacy. Another factor that may influence STEM interest in female students is their self-efficacy, i.e., the self-confidence and self-perceptions of their academic abilities as compared to male students. Pajares (2005) found that females report less confidence in learning STEM subjects as compared to males; these differences in self-confidence in learning STEM subjects begin in middle school and continue throughout their education, and careers. Even among female and male students with similar mathematics achievement, female students assess their abilities in mathematics lower than their male student counterparts (Dweck, 2006a). Female students hold themselves to a higher standard than male students in mathematics and believe that they must be exceptional in order to be successful in "male" dominant fields (Dweck, 2006a). Hence,

female students are less likely to believe that they will succeed in a STEM career. Even high-achieving female students in mathematics may exit from STEM majors, leaving fewer female students compared to male students pursuing careers in STEM (Correll, 2004; Hill et al., 2010).

Girl-Friendly Approaches to STEM

In an effort to engage girls in science, Newbill and Cennamo (2008) encouraged science educators to start instruction by facilitating discussions about the emotions that are associated with negative attitudes that exists towards science. They suggest (a) “activat[ing] existing attitudes toward science at the beginning of the instruction; (b) encourage[ing] learners to think about how they feel about science; (c) encourag[ing] learners to discuss, perhaps in same-sex groups, their feelings about science, and (d) includ[ing] language for discussing emotion in the instruction” (p. 59). Girl-friendly strategies have been shown to foster STEM interest in middle school students (Dare, Refferty, Scheidel, & Roehrig, 2017). These strategies include:(a) linking content to student’s own prior experiences or with their life situations; (b) encouraging students to discuss and reflect upon the social importance of science; (c) allowing content to be shown in application- oriented contexts; (d) providing first-hand experiences; and (e) showing how science can be used to help and benefit others and help humanity; and (f) including female role models who show a positive attitude toward science (Dare et al., 2017; Häussler, Hoffmann, Langeheine, Rost, & Sievers, 1998; Newbill & Cennamo, 2008).

Approaches to STEM integration align with girl-friendly strategies. For example, four tenets of the interdisciplinary STEM integration model put forth by Moore et al. (2014b) were found to be girl-friendly by Dare and colleagues (2017). The use of a motivating and engaging context (tenet one), helps students to link science content to prior experiences and encourages students to discuss and reflect upon the social importance of science, which also make them appealing to girls (Dare, et al, 2017; Häussler et al., 1998; Newbill & Cennamo, 2008). Engineering design challenges (tenet two) allow girls to see science in application-oriented contexts (Dare et al, 2017; Häussler et al, 1998; Newbill & Cennamo, 2008). Similarly, the use of student-centered pedagogies (tenet five) and teamwork and collaboration (tenet six), provides first-hand experiences, and encourages students to discuss and reflect upon the social importance of science, as well as including collaborative learning opportunities (Dare, et al, 2017; Häussler et al, 1998; Newbill & Cennamo, 2008).

Conceptual Framework

Given that this study aims to contribute a deeper understanding of girl-friendly strategies that promote aspects of STEM interest for middle school female students, the *SciGirls Seven -- Proven Strategies for Engaging Girls in STEM* (Schellinger et al., 2018) was used to frame the study. These strategies were developed to engage more girls in STEM, raise girls' STEM interest, and improve their attitudes towards STEM careers (Flagg, 2010). The *SciGirls Seven* encourages “collaborative, meaningful, creative, open-ended activities that promote a growth mindset and critical thinking; and emphasize the use of female STEM role models” (Schellinger et al., 2013, p.3) to overcome barriers that

hinder girls from participating in STEM. These barriers include (a) overrepresentation of male students in STEM; (b) stereotypes that STEM is for boys; (c) few female role models in STEM careers; (d) girls uninformed about STEM fields; and (e) many girls lacking self-confidence when it comes to STEM (Malcom-Piqueux & Malcom, 2013). The SciGirls Seven Strategies are detailed in Table 4.2.

Table 4.2.

SciGirls Seven - Proven strategies for engaging girls in STEM (Billington, et al., 2013)

Strategy 1	Embrace collaboration. Girls benefit from collaboration, especially when they can participate and communicate fairly. Girls thrive when they work together to make science, technology and engineering an intentionally social experience.
Strategy 2	Are personally relevant. -Girls are motivated by projects they find personally relevant and meaningful. Girls become motivated when they feel they can make a difference. If girls see STEM as relevant to their own lives, their attraction to these subjects is likely to increase.
Strategy 3	Offer hands-on, open-ended participation. Girls enjoy hands-on, open-ended projects and investigations. Educators and role models can encourage and promote exploration, imagination, and invention by encouraging girls to ask questions and find their own paths for investigation.
Strategy 4	Accommodate preferred learning styles. Girls are motivated when they can approach projects in their own way, applying their creativity, unique talents, and preferred learning styles. Girls should take ownership of their own investigations, collecting data, solving problems and communicating their findings and results.
Strategy 5	Provide specific, positive feedback. Girls' confidence and performance improves in response to specific, positive feedback on things they can control—such as effort, strategies, and behaviors. Self-confidence can make or break girls' interest in STEM. Adults can support girls' efforts by encouraging their problem-solving strategies; allowing them to struggle and/or fail; emphasizing that their skills can be improved through practice.
Strategy 6	Allow for critical thinking. Girls gain confidence and trust in their own reasoning when encouraged to think critically. Educators should cultivate an environment that encourages creative thinking, questioning, trial and error and authentic, personal discoveries.

Strategy 7 Involve role models and mentors. Girls benefit from relationships with role models and mentors. Seeing women who have succeeded in STEM helps inspire and motivate girls. By hosting field trips and visiting programs, role models tangibly demonstrate how girls can succeed.

Context of Study

This study took place at Falconer Middle School during the 2017-2018 school year. Falconer was one of five schools that was part of a larger study, in which the overarching goal was to support and research the process of developing STEM programming within an urban, public school district located in the Midwestern United States. In each school, a STEM teacher team was created and provided with professional development support, including a STEM fellow (a graduate student in STEM education) who helped teams of teachers develop and implement STEM strategies and curricula.

Falconer's Neighborhood and Community

Falconer is a self-defined, emerging urban STEM school located in a diverse, working-class neighborhood. Around the time of this study, the neighborhood had the highest rate of housing foreclosures in the city (Horsley, 2007) and approximately 50 percent of the students in the neighborhood attended local schools (Hawkins, 2007). Within the past 12 years, the city's Board of Education decided to close several middle and elementary schools, including Falconer. Due to the efforts of the community residents, Falconer re-opened its doors in as a community school with a STEM focus.

At the time of this study, a total of 397 sixth, seventh, and eighth graders made up the entire student population at Falconer Middle School (State Report Card, 2018). The

student population of Falconer was 72.3 percent Black, 17.6 percent Hispanic, 1.8 percent White, 2.0 percent Asian, 3.0 percent American Indian/Alaska Native, 0.5 percent Native Hawaiian/Pacific Islander, and 2.8 percent two or more races. The percentage of the student population at Falconer Middle School who filed paperwork to qualify for free/reduced lunch was 87.9 percent. The percentage of Falconer students who were English learners was 10.8 percent, and the percentage of Falconer students who received special education services was 27.7 percent. At Falconer, 7.1 percent of its students were homeless (State Report Card, 2018). According to the 2018 State Comprehensive Assessments reports, 12.2 percent of Falconer students were proficient in math, 18.7 percent were proficient in reading, and 7.8 percent were proficient in science (State Report Card, 2018).

The first author of this paper served as the STEM fellow at Falconer. In addition to her role as a researcher, the STEM Fellow spent 10 – 20 hours each week at Falconer meeting and planning with the STEM coordinator (Ms. Betty) and the STEM team and co-teaching with STEM teachers. This allowed her to build relationships with the participants in this study, including the target students and the STEM coordinator (second author). This rapport with the participants may have helped them to share their thoughts and feelings openly with the STEM fellow. It is also important to acknowledge the potential bias that this may have created. It is possible that students might avoid sharing any negative thoughts or experiences.

Participants

The entire seventh grade class participated in two STEM units, MidWest Metal in the Fall of 2017 and Civil War Soldier in the Spring of 2018, described in the next section. Following the two units, fourteen students (nine girls and five boys) volunteered to work on a follow-up project as an elective/independent study within the school day. Seven target students were chosen from these fourteen students based on the following criteria: (a) they are girls; (b) they completed their project and presentation at the end of year STEM showcase; and (c) they voluntarily participated in a focus group within a week after their presentations. Table 4.3 provides demographic information and career goals for each of the seven target students.

Table 4.3

Target Students

Pseudonym	Race/Ethnicity	Career Goal(s)
Sara	Hispanic	photographer; business
Camila	Hispanic	architect; immigration lawyer
Dep	Asian/Hmong/Vietnamese	photographer; artist; musician
Kira	Hispanic	middle school biology teacher
Aaliyah	African-American	chemical engineer
Danita	Hispanic	biomedical or electrical engineer; medical or forensics field
Aahna	Asian/West Indian	prosthetics engineer

Integrated STEM units

The two units developed by the STEM team were (a) MidWest Metal and (b) Civil War Soldier, each involving a full day where the entire seventh grade class participated in a “Community Connections Day” bringing together students, teachers and community members for a full-day STEM learning event.

MidWest Metal unit. MidWest Metal Recycling Plant (pseudonym) is located about one-half of a mile from Falconer Middle School in a large, urban Midwestern city. The zip code area where the MidWest Metal is located has the highest rates of hospitalization due to asthma in the state. It also has the highest rates of lead poisoning in children in the city (Yuen, 2018). Due to air quality violations, including elevated lead levels in the air, state regulations mandated the plant to relocate to a more rural area within the state (Dunbar, 2017; Reilly, 2018). As part of this unit, students were specifically examining the potential effects of lead and air pollution from this recycling plant. Students collected soil samples from the yards of their homes, the school, and the recycling plant. The STEM fellow sent the soil samples to be tested for lead.

The Community Connections Day consisted of guest speakers and activities for the whole seventh grade. Guest speakers included: a nurse from the state’s department of health and a representative from the state pollution control agency. The nurse presented on health issues such as asthma and lead poisoning. The state representative from the pollution control agency discussed the role of the pollution control agency, the effects and the prevalence of air pollution and lead poisoning to the local residents, and the settlement between MidWest Metal and the state pollution control agency. Also, a group

of students volunteered to present their soil testing results. Kira, one of the seventh-grade target girls of this study, spoke to her class about her baby brother suffering from lead poisoning.

In the afternoon, students then broke up into small groups. Students explored both science and social studies content through their investigation of the pros and cons of MidWest Metal relocating in terms of the health, environmental, and economic impact to the community. Student groups read science-related articles about recycling, air pollution, and lead poisoning and created presentations. Each group presented their work to the entire seventh grade class. Following these presentations, students voted as to whether or not they agreed with the decision mandating MidWest Metal to relocate with written evidence to justify their position.

One month after the MidWest Metal Community Connections Day, target students Kira, Dep and Aaliyah presented their research about MidWest Metal at a science fair at a nearby university and won first place. The girls also presented this research at the end of the school year at the STEM showcase.

Civil War Soldier unit. Throughout this unit, students were asked to learn about the Civil War and the life of soldiers in the war. They were challenged to think of ways to improve the lives of Civil War soldiers. Students began learning about background knowledge related to the Civil War prior to the second Community Connections Day. Students studied the Civil War in social studies class. In English Language Arts (ELA) class, seventh graders read a book about a Civil War hero called *Soldier's Heart*

(Paulsen, 2000). Students also went on a field trip to the state history center to learn about their state's involvement in the Civil War.

During the second Community Connections Day, student groups rotated through interactive presentations, each within a separate classroom. These groups included (a) technicians from a prosthetics clinic, (b) a local author, (c) map surveyors, (d) a special presentation on battles of the Civil War, and (e) a brainstorming session in which students were asked to use the engineering design process and begin to brainstorm ideas as to how they would design a product that would improve the life of a soldier during or after the Civil War.

STEM Follow-Up Projects

During the last quarter of the school year, all students were given the opportunity to complete an additional follow-up project related to the integrated STEM units. These follow-up projects were completed during the school day and facilitated by the STEM Fellow, STEM coordinator, and a local engineer who volunteered his time. Eleven students, including six of the target girls, selected to follow through with their designs from the Civil War Soldier Unit and participate in a follow-up group project. These projects were presented at the STEM showcase at the end of the school year. Two of the target girls, Dep and Aaliyah, were involved in two showcase projects. Dep, Aaliyah, and Kira presented their work from MidWest Metal at the STEM showcase. Dep and Aaliyah presented two different follow-up projects at the STEM showcase from the Civil War Soldier Unit, each with different groups. Kira, conducted her own follow-up study to

MidWest Metal and retested the soil from her yard for lead. Table 4.4 includes the STEM Showcase projects given by the seven target girls in this study.

Table 4.4

STEM Showcase Projects

Name of Project	Description of Project	Target Students
Civil War Soldier's Jacket	-designed Civil War Soldier's Jacket appropriate for various weather conditions -tested different materials in hot and cold and created prototype	Dep, Camilla, & Sara
Prosthetics	-designed and built a leg prosthetic	Aahna, Aaliyah, & Danita
MidWest Metal*	-tested soil from various locations in community -researched potential health risks of local metal recycling plant and pros and cons of its relocation.	Kira, Dep, & Aaliyah
Lead Soil Testing	-follow-up study from Midwest Metal*; -student tested soil from various locations around her house and found to have dangerously high lead levels	Kira

*MidWest Metal is a pseudonym for the name of the recycling plant and the name of the students' project.

Methods

The research design for this study was a single embedded case study contextualized within the integrated STEM experiences with multiple units of analysis (Yin, 2014). The units of analysis were the seven female target students who completed

an additional project based on one of the two STEM units. The case was the developing STEM interest of these female students and was bounded by the participation in the two integrated STEM units and follow-up projects.

Data Collection

The five data sources for the study are described in Table 4.5. Data sources were collected by observation of the target students (including the STEM showcase), reflections from the target students about their work (written and focus group), reflections of the STEM Fellow, and two interviews with the STEM coordinator. The STEM fellow completed weekly reflections that summarized the work of the students throughout the STEM units and follow-up projects.

Table 4.5

Data Sources

Type of data	Source of data	Time of collection
Student written reflection	End of each unit	7 target student
Focus groups	End of school year after showcase	7 target students
STEM showcase presentations	End of school year	7 target students
STEM fellow written reflections	Weekly during the school year	STEM fellow
Interviews with STEM coordinator	End of school year & six months after end of school year	STEM coordinator

Focus groups took place a few days after the STEM showcase. The STEM fellow and STEM coordinator facilitated and audio-recorded each focus group. During the focus groups, students were asked to reflect on their experiences during the two integrated STEM units and their other STEM experiences outside of school during elementary school and their first year (sixth grade) at Falconer. Students were also asked to elaborate on their current STEM interests and future plans related to college and careers.

The STEM fellow interviewed the STEM coordinator at the end of the school year, and another follow-up interview took place six months later. During these interviews, the STEM coordinator was asked to reflect on her experiences working with the target students in this study and how these experiences may have fostered their STEM interests.

Data Analysis

The audio recordings of focus groups, observations of the STEM units and presentations served as the primary data sources. In the initial coding cycle, transcripts were inductively coded individually by the STEM fellow and another graduate student serving as a STEM fellow at a different school. The two researchers consolidated the codes into three main themes (Miles, Huberman, & Saldaña, 2014): (a) Connections to students' lives and to helping others; (b) Presenting their work; (c) Interdisciplinary Projects and Collaborative Workspace. The first author then recoded the data deductively using the SciGirls Seven Strategies (Billington et al., 2013) and the original codes from the initial coding. The original three themes were revised and expanded into five emerging themes. Each theme was aligned with supporting literature, including its

alignment with the SciGirls Seven Strategies (Billington et al., 2013) and to the Framework for STEM Integration put forth by Moore et al. (2014b) .

Findings

Five main themes emerged from this research. Each theme emerged as an important aspect of the STEM project experienced by the girls that fostered STEM interest.

Theme 1: Community and Personal Connections

Connections to helping others within their community. Students were able to make connections between what they learned from participating in the STEM units and helping people within their community. Reflections from the MidWest Metal unit included students emphasizing the importance of knowing how to prevent the dangers of lead (lead poisoning) and air pollution (asthma) and the importance of recycling in their community. For example, Aaliyah stated:

We found out that the people that live in [the community] around [MidWest Metal] would also be affected by [lead], because it can spread. If it's underground it's going to stay there for ... thousands of years ... Lead in the ground can affect the air, the plants and animals that live around it...when lead gets into blood vessels, it...hurts [young children] more because since they're still developing...and the lead can still cause a lot of problems like...how the blood flows...it can be fatal.

Students also made connections to what they learned from the Civil War Soldier unit and helping others within their community. For example, regarding the prosthetics project, Danita expressed the need to make prosthetics more affordable to others:

I think it's important because we ... would know what resources they use and how they could have done it better. And maybe if we figured that out a little bit more, it probably would be more cheaper [*sic*] for some people who can't afford actual prosthetics.

Similarly, Aaliyah noted:

I like the way that we were ... making a project to help someone, and it would benefit others. Instead of just one person, it could spread, and other people could use that same prosthetic idea to make something for other people and take our idea like and ... innovate it... to make [it] a little better for other people that need prosthetics.

With regards to the Civil War Jacket project, Dep explained how clothing was important historically and still is today, for people within her own Hmong community who made their own clothes. She related this aspect to the hand-made uniforms sewn for Civil War soldiers and the importance of an all-weather jacket, perhaps even for soldiers today. She described the importance of her project in helping others:

How it would benefit others in that clothing is a huge part of a person's life

[Clothing is] what it gives you ... Does it keep you warm? ... Gives you cooling?

[*sic*]...Especially since it's the Civil War ... You're in war [for] two or three years straight without no change of clothing [*sic*].

Personal connections. Students were also able to make personal connections to what they learned from participating in the STEM units. Upon reflection of the MidWest

Metal unit, Danita wrote about her personal connection to the dangers of air pollution in the community because she suffered from asthma. Kira spoke to the seventh graders at her school about how her little brother suffered from lead poisoning. Kira and other students collected soil samples from their own yards in the community and had the samples tested for lead. Kira did a follow-up study and collected several samples in different parts of her yard and tested the soil for lead by using a home testing kit. During her follow-up Lead Testing presentation, Kira explained, “Recently my brother had lead in him...it was...really high for him.”

Aahna was able to make a personal connection to her follow-up prosthetics project from the Civil War Soldier Unit and her own life. Aahna stated: “One of my cousins Half of her arm came off while she was born And, I guess she didn’t get a prosthetic to help her. So, she just lives with it like that and she got used to it.”

Theme 1 aligns with SciGirls Seven Strategy 2: Girls are motivated by projects they find personally relevant and meaningful. Making connections to real-world problems, through the use of motivating and engaging contexts (tenet one), is also one of the main goals of quality STEM integration. When the students in this study were able to connect what they learned to their own lives and to help others within their own community, they showed interested in STEM learning. Through their engagement in the STEM projects, the girls saw that their actions truly mattered, and they began to connect STEM with making a difference in improving their own lives and their own community.

Theme 2: Self-Confidence

Students were given the opportunity to present their work and show their accomplishments to a broader audience, including their peers and other members of their school community. Four out of the seven target students said that their favorite part of the first unit, MidWest Metal, was presenting to the seventh grade class. Aahna stated:

“My favorite part was when me and my friends presented. I enjoyed presenting to my peers. I enjoy it because I was able to stand on stage without getting shy.”

Aaliyah also demonstrated self-confidence when she expressed that she enjoyed presenting her work. When asked what her favorite part of her Civil War Soldier project was, Aaliyah replied, “Getting to build the prosthetic...and then presenting it afterwards.”

During the focus group, Kira, Dep and Aaliyah discussed how they enjoyed presenting their lead poisoning project at the local university ecology fair and how they won first place. This success inspired Kira to complete a follow-up study on lead poisoning in her own backyard and present her findings at the STEM showcase.

Kira and the other girls also demonstrated self-confidence through their display of strong leadership within her school community. Ms. Betty worked closely with each of the girls for two years at Falconer Middle School as their teacher and mentor in various STEM related programs and projects. When asked how the girls had changed throughout these two years, she described their leadership in the school and the classroom community. Ms. Betty stated,

When [Kira] was in a large class with lots of behaviors and other kinds of stuff

going on, [she] didn't talk and she didn't want to be called out. [But then, Kira and] the [other] girls were starting to...see themselves differently...they became a lot stronger in their leadership in the school. [For example, Kira]...to go out on stage...and talk about lead poisoning from a personal standpoint...I thought was amazing. Because she was not a person that wanted any attention since sixth grade.

Theme 2 aligns with SciGirls Seven Strategy 4: Girls should take ownership of their own investigations, collecting data, solving problems and communicating their findings and results (Billington et al, 2013) and SciGirls Strategy 6: Girls gain confidence and trust in their own reasoning when encouraged to think critically (Chatman, Nielsen, Strauss & Tanner, 2008; Eisenhart & Finkel, 1998; Kim, Wei, Xu, Ko, & Ilieva., 2007). Theme 2 also aligns with Tenets 2 and 6 from the Framework for STEM Integration put forth by Moore et al. (2014b) as the girls worked in collaborative teams on a personally relevant engineering design challenge. This theme also parallels research that shows presentation of research at science fairs fosters students' STEM interest in pursuing STEM degrees and careers (Hedenstrom & Koomen, 2019). The opportunity to communicate their results through presentations at the STEM showcase and the university ecology fair helped students to improve their self-confidence, which may foster STEM interest in our target students.

Theme 3. Supportive and Collaborative Community

Students were given the space and time to work together in a supportive environment. The students created a sense of community amongst themselves. During the

MidWest Metal unit, students enjoyed working together in groups. When asked to describe a success from the MidWest Metal unit, Camilla wrote, “Working together is what made me feel successful.” Danita wrote, “A success was that my team and I went to present our information [about] soil lead because it is important to let [our community] know what’s really happening.” The students saw the importance of working together in order to inform and help the whole community from the dangers of lead.

During the last quarter of the school year, target students particularly enjoyed working together when completing their follow-up projects. Groups working on different projects oftentimes shared the same workspace. Whether they were working on the same project or a different one, students willingly helped and supported each other. Ms. Betty commented:

I think they worked together more in the projects than in the classroom. And it seems like when one of them got an idea ... the others tried to support them and let the other person run with the idea...They would reach out to each other and try to problem solve ... When Danita was trying out her peg leg, they all were supportive, and they had some comments on how to improve it. And it was all positive feedback to each other like, ‘ that’s cool.’ ‘Why are you doing that?’ or ‘how do you do this, then?’ I do remember that... I just like kick[ed] it back and listen[ed] to the buzz... Because I think I said, “listen to the buzz because that’s how a real classroom should be.”

Each small group worked with a mentor throughout their project. They created a small community together in which the girls were able to have conversations with one

another and with a mentor and role model who they trusted, versus someone who evaluates and tests them, such as a teacher in a traditional educational setting. Ms. Betty stated, “I think maybe just having each other...[feeling] supported ‘cause they've found each other too? I think that with that, they were able to talk more to the teacher. ”

Theme 3 aligns with SciGirls Seven Strategy 7: Girls benefit from relationships with role models and mentors. Theme 3 also aligns with SciGirls Seven Strategy 1: Girls benefit from collaboration, especially when they can participate and communicate fairly and Tenet 6 from the Framework for STEM Integration with emphasizes teamwork. With the help of a mentor, each group of girls worked together as a team, supporting one another throughout their project.

Theme 4: Student Agency and Choice

Target students were asked to share their thoughts about their experiences after each unit and following the STEM showcase. Responses revealed that they enjoyed participating in the hands-on, open-ended, interdisciplinary projects. The target students had expressed interest in pursuing a follow-up project of their choice.

After the second community connections day from Civil War Soldier Unit, students reflected on their experiences from the unit. Students were asked, ‘If you could improve the life of a Civil War Soldier, how would you do so? What would you do?’ Dep replied, “I would kinda get better food and clothing... For clothing, I could see what is comfortable and a material that is light at the same time.” Dep, Camilla, and Sara chose to design and create a soldier’s all-weather jacket for their STEM showcase project. After doing some research, they chose the type of materials to test and designed experiments to

test the materials in different temperatures. They also learned how to use a sewing machine and learned how to knit with wool yarn in order to create the jacket.

When asked to reflect on their favorite part of the second Community Connections Day after the Civil War Soldier Unit, Aaliyah said, “My favorite part was learning about prosthetics because it seems cool to design.” Danita and Ahna also noted that their favorite part about Community Catalyst Day was “prosthetics.” Thus, the three girls chose to build a leg prosthetic together for their STEM showcase project. Through hard work and collaboration, they designed, tested, and built four iterations until they created a prosthetic that worked.

Students were challenged to think critically and had the freedom to be creative and make their own decisions, applying their talents and strengths to their projects. At first, they were unsure of what they were doing, but as Ms. Betty said,

Once they understood, then they started rolling, and they were coming to me and telling me, ‘Well this is what we did and this is what we need to do...this is how you can support me... I need a pass so we can come together to get this done.’

Ms. Betty became less involved as the girls began to advocate for themselves and take ownership of their progress and their learning. This self-advocacy exemplifies the girls’ sense of agency and ownership of their research.

Theme 4 aligns with SciGirls Seven Strategy 3: Girls enjoy hands-on, open-ended projects and investigations and SciGirls Seven Strategy 4: Girls are motivated when they can approach projects in their own way, applying their creativity, unique talents, and preferred learning styles. Similarly, Tenet 5 from the Framework for STEM Integration

calls for the use of student-centered pedagogies that help students develop their own interests and knowledge.

Theme 5. Perseverance, Persistence, and Learning from Failure

Target students persevered together and completed their projects. They were persistent and never gave up, learning from their failures. For example, Aahna, Aaliyah, and Danita were able to create a working preliminary prototype of a prosthetic after several iterations, with much trial and error. Danita stated, “Not everything is going to be perfect the first try. You need to keep trying to figure out.” Aaliyah said, “More difficult type of work is going to be involved into [building a prosthetic]...and you're going to need to keep trying over and over again until something sticks or something works.”

Aahna explained her group’s extensive thought process in designing a prosthetic leg:

Our solution was to try to make [the prosthetic] more durable, ... not as heavy as ... ones in the Civil War. We try to keep the prosthetic... from slipping off... we tried something thinner and softer.. styrofoam...we learned that cutting the wood was very hard depending on the kinds of wood ... Leather (for the socket) is not easy to cut...there's different things in the leg than in an arm and a hand. So, we try the gear [but] it was...hard to ... attach it to the leg... we tried a pulley ... no good...we tried wheels but they have nothing to make them run through ... We chose the hinge. If you put in the back, we weren't able to put your foot there.... We tried to see which wood was lightest or more durable from three different

kinds. We just stuck with the ones we have that are light ...[you] learn from your mistakes.

Another example of learning from failure came from Camilla. Her group decided to design an all-weather Civil War soldier jacket. When asked what she liked and disliked about the project, Camilla stated,

I liked that we were learning new things that we were experimenting a lot...from your mistakes you learn. And so, that's actually motivated me a lot 'cause I [make] mistakes like a lot. And so through my mistakes I think I learned a lot. And while we were designing the Civil War jacket, there was like a lot of situations happening in the world, and some people like find [a] way to solve them. So, that's what we like about it. [What I did not like was]...that we didn't have enough time. I wanted more time, to do more prototyping experiments.”

Theme 5 aligns with SciGirls Seven Strategy 5: Girls' confidence and performance improves in response to specific, positive feedback on things they can control—such as effort, strategies, and behaviors. Self-confidence can make or break girls' interest in STEM. Adults can support girls' efforts by encouraging their problem-solving strategies; allowing them to struggle and/or fail; emphasizing that their skills can be improved through practice (Billington et al, 2013). Likewise, SciGirls Seven Strategy 6 states that girls gain confidence and trust in their own reasoning when encouraged to think critically and Tenet 3 of the STEM framework calls for critical thinking, as well as learning from failure through redesign opportunities (Moore, et al., 2014b). The girls designed and redesigned multiple iterations of the prosthetic leg. Their mentor and Ms.

Betty supported the girls and encouraged them to think critically and problem solve together. They let the girls struggle and fail and continue to try and not give up. The girls demonstrated grit as they learned from their mistakes and persevered until they created a prototype that worked. They embraced the realization that is okay to struggle and continue to try and try again, as this is all part of the iterative process of learning. Thus, the girls have demonstrated a true growth mindset (Dweck, 2006b).

Discussion

This study revealed connections between strategies within integrated STEM experiences and the development of middle school girls' interest in STEM. Emerging from this research are ways in which a community-embedded STEM integration experience fostered aspects of STEM interest in middle school girls at a developing STEM school. After participating in the STEM units, student reflections and experiences revealed that STEM interest is fostered when the STEM activities (i) give students the opportunity to make personal connections and connections to helping others within one's community, (ii) give students the chance to work in a supportive and collaborative community, (iii) build self-confidence in students; (iv) allow students to take ownership of their own learning; (v) encourage student to persevere and learn from their mistakes. These findings align with both SciGirls Seven Strategies (Billington et al., 2013) and the six tenets of the Framework for STEM Integration put forth by Moore et al. (2014b). Table 4.6 provides a summary of the five themes from this study aligned with the SciGirls Seven Strategies and Tenets from the Framework.

Table 4.6

Findings- Five Themes and the SciGirls Seven Strategies Related to each Theme

Theme	SciGirls Seven Strategy (SGS)	Tenet from Framework for STEM Integration
Theme 1: Connections to Helping Others within Their Community & Personal Connections	SGS 2 - Girls are motivated by projects they find personally relevant & meaningful	Tenet 1: Motivating & Engaging Context
Theme 2: Self-Confidence & Self-Efficacy	SGS 4 - Girls are motivated when they can approach projects in their own way, applying their creativity, unique talents, & preferred learning styles	Tenet 2: Engineering Design Challenges- problem-solving, creativity, and higher-order thinking
	SGS 6 - Girls gain confidence and trust in their own reasoning when encouraged to think critically	Tenet 6: Teamwork and Communication
Theme 3: Supportive & Collaborative Community	SGS 1 - Girls benefit from collaboration, especially when they can participate and communicate fairly	Tenet 6: Teamwork and Communication
	SGS 7 - Girls benefit from relationships with role models & mentors	
Theme 4: Student Choice & Ownership of One's Own Learning	SGS 3 - Girls enjoy hands-on, open-ended projects and investigations	Tenet 5: Student-Centered Pedagogies
	SGS 4 - Girls are motivated when they can approach projects in their own way, applying their creativity, unique talents, and preferred learning styles	Tenet 2: Engineering Design Challenges- problem-solving, creativity, &

		higher-order thinking
Theme 5: Perseverance, Persistence, & Learning from Failure	<p><i>SGS 5</i> - Girls' confidence & performance improves in response to specific, positive feedback on things they can control—such as effort, strategies, & behaviors</p> <p><i>SGS 6</i> - Girls gain confidence & trust in their own reasoning when encouraged to think critically</p>	Tenet 3: Learn from Failure/Redesign

This study contributes to the existing literature of girl-friendly strategies that engage girls in STEM. However, what is unique about this study is how a community-embedded STEM integration experience fosters aspects of STEM interest in middle school girls. None of the existing girl-friendly literature addressed how involving one's community in STEM integration fosters STEM interest in students. Making a concerted effort to involve community members in STEM integration through a designated Community Connections Day for each unit and making local connections to helping others within the community may have fostered STEM interest in a unique and meaningful way.

The six Tenets of the Framework was put forth in order for educators to assess and develop high-quality integrated STEM curricula. However, the framework is broad and does not specifically address gender equity. Thus, in order to increase the number of girls and women in STEM, the authors of this study recommend explicitly including girl-friendly strategies such as the SciGirls Seven Strategies and findings from this study to the Framework for STEM Integration put forth by Moore et al. (2014b). By merging the

findings from this study and SciGirls Seven Strategies and the Tenets of the Framework, educators will have a more comprehensive guide to help to foster STEM interest for a broader audience of students. Five specific recommendations are discussed below.

First, Tenet 1 of the STEM Integration Framework should more specifically describe what girls would find to *be a motivating and engaging context*. Our findings concur with previous research (Liston, Peterson & Ragan, 2008; Lyon & Jafri, 2010; Mosatche, Matloff-Nieves, Kekelis, & Lawner, 2013; Patrick, Mantzicopoulos, & Samarapungavan, 2009; Thompson & Windschitl, 2005) that STEM experiences should be personally and socially relevant and connected to students' lived experiences to foster girls' interests in STEM. Global and local community connections, such as the environment and health, provide examples for girls that help people to live better lives. This expands upon an aspect of STEM integration that connects STEM learning to relevant, real-world problems (Honey et al., 2014; Moore et al., 2014b). Girls are particularly drawn to real-world contexts in which they are given the opportunity to help others and the environment, whether local or global. Thus, improving the state of the world and its people at a global level is also particularly important to female students (Diekman, Brown, Johnston, & Clark, 2010). STEM learning that is framed in a way that connects students to such real-world, relevant problems can also foster STEM interest, particularly, in female students, in a similar way.

Second, *engineering design challenges* (Tenet two) are specifically motivating to girls and help girls build self-confidence in STEM by encouraging them to think critically. For example, in this study, Dep, Camilla, and Sara had the chance to apply

their creativity and unique talents when designing their Civil War Jacket. Danita, Aaliyah, and Aahna had a chance to problem solve and use higher-order thinking when creating several iterations of their leg prosthetic. All seven of the girls in this study had the opportunity to work as a team and communicate with one another. They were encouraged to think critically, which allowed them to gain self-confidence and trust in their own thinking.

Third, girls specifically benefit from *learning from failure* through opportunities to redesign. As stated in SciGirls Seven Strategy 5, girls' confidence and performance improves when given meaningful feedback. For example, in this study, the girls were given such feedback from their mentor when designing their prosthetic leg. They were able to use this feedback to redesign their prosthetic several times. They showed perseverance, persistence, and a growth mindset as they created several iterations until they created a working prosthetic.

Fourth, findings from this study suggest that the reasoning behind Tenet 5, *student-centered pedagogies*, that specifically engages girls in STEM should be included and expanded upon. Engage girls in scientific and engineering practices should include opportunities for girls to make choices as to what and how they engage in STEM and take ownership of their own learning. Students in this study were able to choose their STEM projects. As stated in SciGirls Seven Strategy 4, "Girls are motivated when they can approach projects in their own way, applying their creativity, unique talents and preferred learning styles" (Billington, et al., 2013).

Fifth, findings from this study show that working in a supportive and collaborative community helps to foster STEM interest in girls. This supportive community can include students, teachers, mentors, role-models and community members all working together on a project or challenge to help others within the community. This finding is aligned with that the extant literature that states “girls benefit from collaboration, especially when they can participate and communicate fairly” (SG7 1) (Billington, et al., 2013, p. 7), and “girls benefit from relationships with role models and mentors” (SG7 1) (Billington, et al., 2013, p. 8).

Future Research

This study focused on gender as an equity issue within STEM, however other equity issues exist and need to be explored. More research is needed in order to better understand what specific aspects of community-embedded STEM integration appeals to female students of color in particular. This will work to broaden and diversifying the population of students who enter STEM fields.

Chapter 5: Conclusion- Overarching Themes and Future Direction

This dissertation was composed of three interconnected studies. The studies all took place at Falconer Middle School, an urban, community school that was working to develop a STEM focus. The dissertation began with a case study, giving a broad overview of Falconer and its development as an emerging STEM school. The second study described a Community-Based Conceptual Framework for STEM Integration and provided two detailed examples of multi-disciplinary STEM units implemented at Falconer using the framework. The third study focused on how community-based STEM integration at Falconer fostered STEM interest in its female students. In this final chapter, three over-arching themes across all three papers of this dissertation are presented.

Overarching Themes

Theme 1: STEM-For-All. The first over-arching theme is the need for an inclusive approach to STEM integration that works to engage all students in STEM and promote STEM literacy for all. Currently, female students and students of color have been and continue to be under-represented in STEM majors and careers (Corbett & Hill, 2010; NSF, 2015). With a shortage of STEM workers and the need to remain competitive as an economic and political world leader in scientific and technological innovations, there is a need for the United States to broaden and diversify the population of students that participate in STEM (PCAST, 2010). This can be accomplished through the creation of STEM middle schools that serve under-represented students and community-based, STEM integration.

The first study describes the most important components of STEM programming development at an emerging STEM middle school. These include: (i) a STEM-focused curriculum for all, (ii) a well-prepared STEM teachers and professionalized teaching staff, and (iii) flexible and autonomous administration with freedom from the school district to develop its STEM programming. A Community-Based Framework for STEM Integration was developed in the second study. This framework expanded upon foundational elements of STEM integration in order to create an approach that would engage a broader audience, including under-represented students. In the third study, community-embedded STEM integration fostered STEM interest in female students of color, a population of students who are under-represented in STEM fields.

Theme 2: Community. The second overarching theme is community. Findings from this study showed that through community-embedded integrated STEM curricula, students were able to make connections between what they learned from participating in the STEM units and helping people within their community. In reference to the integrated STEM units, students emphasized the importance of a clean, safe and healthy neighborhood. Students spoke about the importance of raising awareness of how to prevent the dangers of lead (lead poisoning) and air pollution (asthma) and the importance of recycling in their community. When STEM connects students their community and lived experiences, learning is meaningful and engaging. Students develop an awareness of issues that affect their community including pollution in the air, soil, and watershed and designing a community playground. Students gain STEM knowledge in order to better understand these community issues and try to solve them. Thus, students'

community engagement can lead to increased engagement in STEM. Students work with teachers and community members to make a difference in shared surroundings and strengthen their community. In this way, students are invested in what they are learning and doing.

Theme 3: Social Justice. The third over-arching theme is social justice. Overall, this dissertation was written in order to raise awareness of social justice-related issues in STEM and promote gender and racial equity in STEM education. STEM education has historically benefitted the dominant culture and has not worked to advance under-represented students in STEM (Corbett & Hill, 2010; NSF, 2015). By incorporating relevance, community strengths and expertise and by raising social awareness of inequities, STEM integration can promote social justice and positive change. This is exemplified in the Liberty Playground Unit. Through this unit, students raised awareness of the high crime and violence in their neighborhood. They worked together with community members to redesign a local park in response to the need for a safe place for community members to gather and participate in outdoor recreation. Teachers and community experts worked alongside middle school students in order to build community wealth by investing their time and resources into educating the youth of the community. This is an investment in the future. Students, teachers and community members alike must be made aware of injustices within their community and their daily lives so that they can be a part of making a difference for a more equitable and just world.

The neighborhood where Falconer and its students live is also home to a metal recycling plant that has been linked to air pollution and lead in the soil causing high rates

of asthma and lead poisoning in community members. The community also suffers from a polluted watershed, high crime and violence. Citizens of the community deserve a clean and safe neighborhood that includes gathering and recreational space. Also, all students have a right to a quality STEM education. If people's health and safety are at risk and students are not getting the education they deserve, they must aware of these injustices in order to help improve their situation. Connecting students' to STEM-related, relevant, community issues that affect their lives can lead to increase student engagement in STEM learning and helps students to identify with STEM. Students begin to learn how they are able to make a difference in their own communities by applying their newly acquired STEM knowledge.

Future Direction

Moving forward, I hope to continue to research ways to foster STEM interest in under-represented groups. More research is needed on how to develop STEM programming in order to create more inclusive structures that promote STEM integration that benefits *all* students. This includes developing STEM schools and integrated STEM curricula in underserved populations with a STEM-for-all approach. We must set criteria for quality STEM programming and schools in all states to ensure that students who wish to participate are able to receive a quality STEM education.

As educators, we must continue to find ways to incorporate relevance and promote social justice in our curricula. We must take the time to connect STEM learning to the school's community. In this way, students are invested in what they are learning and doing because it involves creating a positive change within their own community.

Teachers and community members are also invested in students' learning as they work with students to build community wealth to benefit all community members. Fostering STEM interest may also lead to stronger STEM identities and academic success in STEM. Perhaps, this can be explored in future studies.

There is much more work to be done in order to achieve racial and gender equity in STEM. Overall, schools like Falconer are slowly moving in the right direction. Developing community-based STEM integration in urban middle schools will help to foster STEM interest and engagement in under-represented students, particularly in female students and students of color. Falconer students illuminated Mahatma Gandhi famous words: "You must be the change you want to see in the world."

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APPENDIX A: Interview Protocols

Interview Protocol for Principals in STEM Schools- September 2016

1. Please tell me a little about the school you currently work in.
 - a. What do people need to know to understand your school's history and reputation?
 - b. What about your school's evolution and challenges, etc?
2. Could you describe your personal and/or professional mission for this school?
 - a. Are there particular problems you wish to overcome?
 - b. Do you have certain targets you're trying to reach?
 - c. Are there desirable shifts in the environment that you're trying to encourage?
3. In your mind what does it mean for _____ to be a STEM school?
 - a. In what ways might a STEM focused school look different than traditional schooling?
 - b. How does STEM look in practice?
 - c. How close are you to your ideal STEM program?
 - d. What are barriers to implementing a STEM focus?
 - e. What are some successes you've had in implementing a STEM focus at your school?
4. Why did you transition/or are you trying to transition to have a STEM focus in your school?
 - a. Who was involved in this decision? (CC 5)
 - b. How were you able to convince key stakeholders that this was a good direction for the school? (CC 5)
 - c. What are benefits to the community and students in becoming a STEM focus school?
 - d. Who is driving these changes on a day-to-day basis? (CC 9)
5. What steps were necessary/or are you considering to transition to having a STEM focused school?
 - a. I know you're in the process of becoming a STEM school, what transitional steps have you taken so far?
 - b. Were there any additional funding sources required to make this transition? (CC 5)
 - c. How were those funds allocated? Where did they come from?
 - d. What do you look for in a STEM teacher and are you able to find these characteristics? (CC 7)
 - e. How bought in are teachers with this transition to a STEM focused school?
 - f. What steps have you taken to get teachers on board with this transition? (CC 9)

- g. What changes do you hope to see teachers making in their practice to have a STEM focus? (CC 7)
 - h. Have you utilized any external or internal training around STEM for the personnel in your building? (CC 7)
- 6. What types of technology are available at your school? (CC 3)
 - a. In what ways do you hope teachers are using technology in their classrooms?
- 7. What district or state issues influence your work here?
- 8. What kind of student do you hope your school will be producing?
- 9. What is your rationale for selecting students for STEM classes/programming? (CC 8 and 10)
 - a. Do you consider math, reading and/or science proficiency in selecting students for your STEM classes/programs?
 - b. Are all students in your school receiving STEM classes/programming?
 - c. How are various math and reading proficiency levels supported for students in your STEM classes/programs?
- 10. What are additional considerations would you recommend for another principal looking at transitioning to a STEM focus?
 - a. What do they need to know before they start?
 - b. What resources have you found most helpful?
- 11. My role with this grant is to be spending time working with your teachers, how do you see me being most helpful in this role?
- 12. When we're getting together in November, what goals would you have for our common time together with Dr. Peters-Burton?

Interview Protocol for Teachers/Teacher Leaders in STEM schools

1. Please tell me a little about the school you currently work in.
 - a. What do people need to know to understand your school's history and reputation?
 - b. What about your school's evolution and challenges, etc?
2. What is your previous experience with STEM fields/content? (CC 7)
 - a. What does STEM mean to you? How does STEM look in practice?
 - b. In what ways might a STEM focused school look different than traditional schooling?
 - c. In what ways do you think STEM is important?
 - d. What are the barriers for engaging your students in STEM?
 - e. What successes have you had in implementing STEM with your students?
3. How would you describe your leadership roles in your school? (CC 9)
 - a. How has that changed over time?
4. Why did you choose to be part of a STEM leadership team in your school? (CC 7)
 - a. Who was involved in this decision? (CC 5)
 - b. How were the teachers selected for this cohort? (CC 9)
 - c. What is your participation in building a STEM focus in your school?
 - d. What are benefits to the community and students in becoming a STEM focus school?
5. What steps have you witnessed in your school's transition to having a STEM focus?
 - a. I know your school in the process of becoming a STEM school, what transitional steps have you observed or been a part of so far? (CC 1)
 - b. How have you seen other teachers respond to this transition?
 - c. What changes do you hope to see teachers making in their practice to have a STEM focus? (CC 2)
 - d. In what ways has your school supported you in this transition?
 - e. Were there any additional funding sources required to supplement this transition? (CC 5)
 - (i.) How were those funds allocated? Where did they come from?
6. What are your greatest concerns in teaching STEM? (CC 7)
 - a. Are you equally comfortable with all the subject areas in STEM?
 - b. How will you address these concerns in your teaching?
7. What types of technology are available at your school? (CC 3)
 - a. In what ways do you hope teachers are using technology in their classrooms?

8. What policy or district issues affect your work here?
9. What kind of student do you hope your school is producing?
10. What is your rationale for selecting students for STEM classes/programming?
(CC 8 and 10)
 - a. Do you consider math, reading and/or science proficiency in selecting students for your STEM classes/programs?
 - (i.) Are all students in your school receiving STEM classes/programming?
 - b. How are various math and reading proficiency levels supported for students in your STEM classes/programs?
11. What are additional considerations you would recommend for another teacher looking at transitioning to a STEM focus in their class?

Interview Protocol – Mid Year- March 2017

INDIVIDUAL MEANING OF STEM

1. What does STEM mean to you at this point?
 - a. What does it mean to be a STEM school?
 - b. How is STEM different from interdisciplinary work?
 - c. Has your definition of STEM changed based on your work in this STEM teacher team?
 - d. In what ways have you implemented STEM in your classroom, if at all?
 - e. How do you feel STEM aligns (or doesn't) with your own approach to teaching?
 - f. What are some things you're currently working on to improve your practice?
 - g. How does this relate to STEM, if at all?

STEM INFLUENCING STUDENTS

2. In what ways are STEM experiences valuable for students?
 - a. How do you think your students would define STEM?
 - b. What changes have you seen in your students as a result of STEM programming?
 - c. Can you describe a student who you feel would most benefit from STEM experiences?
 - d. Can you describe a student who you feel would struggle the most in STEM experiences?
 - e. How would you respond to these struggles?
 - f. What modifications have you made in your STEM curriculum that incorporates cultural relevance in order to improve student attitudes towards STEM?

TEAM WORK WITH STEM

3. Describe the STEM team at your school.
 - a. Why do you think you were selected to be part of this STEM team?
 - b. Why do you think the teachers on the team were invited to be part of this STEM

team?

- c. What assets do the different teachers on this team bring to the group?
- d. In what ways have you learned from your colleagues on this team?
- e. In what ways has this team worked well together?
- f. What are some ways you see that the team could improve their productivity?
- g. How are STEM team members implementing STEM in their classrooms?
- h. What are some challenges the STEM team has faced in implementing STEM?
 - (i) How was this handled?
 - (ii) Who was involved?
 - (iii) Did you make any changes in response to these challenges?
 - (iv) Do you feel that these challenges have been overcome? And if not, what need so happen to successfully implement STEM in your school moving forward?
- i. Have there been times through this process of working with the STEM team that have been uncomfortable or frustrating for you?
 - (i) How would you describe these moments of dissention or frustration?
 - (ii) How did you respond?

SCHOOL WORK WITH STEM

4. Has the work of the STEM team been successful in influencing STEM integration in your school so far?
 - a. If so, please give examples of how you see this playing out.
 - b. Are there any changes in practice that you hope to see your colleagues make?
 - c. How do you see your work on this team influencing the work of other teachers in your school?
 - d. Do you see your school becoming a STEM school?
 - (i) Why or why not and in what ways?

LEADERSHIP

5. What does the word “leader” mean to you?
 - a. What do you think are the top 3 characteristics of an effective leader?
 - b. Who would you classify as a leader in your school?
 - c. What makes them a leader?
 - d. Are there people other than the administrative team that you would consider leaders and if so, what makes them leaders?

Only ask for Admin or Team Leaders:

- e. How would you describe your leadership on this team?

Only ask for teachers on the team that are not Team Leaders:

- f. How would you describe the leadership of your STEM team leader on this team?
- g. In what ways do you see yourself exhibiting leadership in your school?