ABSTRACT

WILLIAMS, DANNIE T. A Formative Evaluation of a STEM Academy at a Rural High School. (Under the direction of Dr. Lance Fusarelli).

STEM programs in rural areas often struggle to attract and retain qualified human capital as well as engage and retain students. These challenges yield continuous calls for improvement and accountability. Previous study findings point to evaluations which are most often commissioned to satisfy accountability requirements with little thought to the value that incorporating evaluation into program design from creation throughout implementation might have on the aforementioned challenges and improving program quality. Including formative program evaluations which are “utilization-focused” throughout the program life cycle encourages adaptation to refine program development (Frechtling, 2010). The purpose of this qualitative study was to use formative evaluation methods to investigate the perceptions of administrators and educators on the best methods for supporting the development and sustainability of a fledgling STEM academy at a rural high school in the Piedmont region of North Carolina. This study builds on existing research in the fields of STEM education, program evaluation, and professional development for STEM educators.

Findings were examined via content analysis methods and interpreted via constructivist theory, theory of third space, and theory of change. Findings demonstrated that the program in question suffered from a number of threats to its continued development and sustainability such as a crisis in leadership, a lack of well-articulated goals and outcomes, and a lack of grounding in the empirical research prior to launch. On this basis, it is recommended that districts with similar contexts use the theory of change model to specify goals, identify pertinent research, and formalize processes and protocols so that programs are less vulnerable to unplanned changes in leadership.
A Formative Evaluation of a STEM Academy at a Rural High School

by
Dannie T. Williams

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APPROVED BY:

Dr. Lance D. Fusarelli
Committee Co-Chair

Dr. Joanne Caye

Dr. Gregory E. Hicks
Committee Co-Chair

Dr. Henry L. Johnson
ACKNOWLEDGEMENTS

The completion of this research would not have been possible without the hand of my Eternal Father who allowed me to continue this journey despite the odds that were against my physical and medical health.

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To the Superintendent of the LEA, who approved and supported me to do my research and to the Principal who was a gracious host who assisted me in connecting with her staff members.
Last, but certainly not least, to the Glory of God! His providential love and care made it all possible from start to finish. For God’s kindness and healing hand…He brought me this far by faith!

Philippians 4:13 NIV “I can do all things through Christ who gives me strength”.
BIOGRAPHY

Rev. Dannie T. Williams was born in Franklin County, NC and is the 16th of 18 children born to the late Jessie and Rose Ella Perry-Williams, who were sharecroppers. Dannie and his siblings were raised in a disciplined household, where they learned the value of work, responsibility and intellectual development.

He joined Perry’s Chapel Church in Louisburg, NC at an early age where he professed his faith in Jesus Christ. During his junior year in high school in 1975 at the tender age of 17, he answered the call into the Gospel Ministry and proclaimed his initial sermon and received his License as a Minister.

After high school in 1976, he attended and completed the Federation of Holy Trinity Churches Minister’s Bible Conference in Richmond, Va. In 1982, he was ordained and installed as the founding Pastor of the Holy Trinity Church in Franklin County, NC where he served until 1994.

In 1991, Williams attended the Life Underwriters Training Council in Bethesda, MD, where he earned a Graduate Status in Marketing. In 1993, he began to matriculate at Shaw University in Raleigh, NC. Throughout his matriculation at Shaw, Williams maintained honors status, and was inducted into the Alpha Chi National Honor Society. He served as president of the Student Government Association and was also a member of the Pinnacle Club of the University.

In 1994, Williams became an Associate Pastor of the Rocky Branch United Church of Christ (UCC), in Kenly, NC. On May 5, 1996, he answered the call to serve as the Senior Pastor of the Melfield UCC in Haw River, NC, where he continues to serve. He is the current President of the Board of Directors of the Southern Conference, United Church of Christ.
In 1998, he graduated from Shaw University with a BA degree in Criminal Justice and minors in Sociology and Public Administration. In 2005, he earned his Master of Theology from Christian Bible College in Rocky Mount, NC. In 2006, he graduated from North Carolina State University in Raleigh, NC with a MSA degree in Public School Supervision and Administration.

Williams served as Vice President of the Eastern North Carolina Association of Churches of the Southern Conference United Church of Christ, from 2000-2001. In 2001 he became the Minister for Church Life and Education for the Southern Conference, UCC.

As a veteran of public education, he has served in numerous capacities in the field. From 1991-1995, he was a teacher’s assistant, bus driver and a reading tutor for Franklinton Elementary in Franklinton, NC. At Parker Middle School in Rocky Mount, NC, he was a Middle School Social Studies Teacher and department chair from 1998 to 2001. Williams taught at the W.L Greene Alternative School in Nashville, as a middle and high school teacher in the areas of Science, Math, Social Studies, English and Character Education from 2003 to 2005.

He has served three terms as the At-Large School Board Member of Franklin County Schools and served an administrator at numerous sites including Assistant Principal in the Rocky Mount Public Schools principal in the Edgecombe County Schools System, and Principal with the Lenoir County Public Schools in Kinston, NC. He served as the Executive Director for Human Resources and Auxiliary Services for Hertford County Public Schools and currently serves as the Chief of Human Resources with the Franklin County Public Schools in Louisburg, NC.
# TABLE OF CONTENTS

LIST OF TABLES .................................................................................................................. viii
LIST OF FIGURES ................................................................................................................ ix

Chapter 1: Introduction ................................................................................................. 1
  Statement of the Problem ......................................................................................... 7
  Purpose of the Study ............................................................................................... 8
  Background of the STEM Academy ........................................................................ 10
  Research Questions .................................................................................................. 16
  Definition of Key Terms .......................................................................................... 17
  Summary .................................................................................................................... 19

Chapter 2: Literature Review ....................................................................................... 20
  Documentation .......................................................................................................... 21
  Conceptual Framework ............................................................................................. 23
  Hybridity and Third Space ....................................................................................... 34
  Active Learning Spaces ............................................................................................ 41
  Schools-Within-a-School Models ............................................................................. 47
  STEM Education and Issues of Equity and Inclusion .............................................. 50
  Teaching and Learning in Rural Environments ....................................................... 52
  Professional Development for Active Learning ...................................................... 54
  Effective Practices for Evaluating STEM Programs ................................................. 55
  Summary .................................................................................................................... 64

Chapter 3: Research Method ...................................................................................... 65
  Defining the Sample .................................................................................................. 66
  Research Method and Design .................................................................................. 69
  Materials and Instrumentation ................................................................................ 73
  Assumptions ............................................................................................................ 78
  Limitations .............................................................................................................. 79
  Delimitations .......................................................................................................... 81
  Ethical Assurances ................................................................................................... 82
  Summary .................................................................................................................... 83

Chapter 4: Findings .................................................................................................... 85
  Results ...................................................................................................................... 103
Theme I: Lack of Clarity & Cohesion ................................................................. 112
Theme II: Crisis of Leadership ........................................................................ 113
Theme III: Lack of Sufficient Training and Professional Development .......... 115
Chapter 5: Discussion, Implications, Recommendations, and Conclusions .......... 118
   Evaluation of the Findings ........................................................................ 121
   Recommendations for Practice ................................................................. 127
   Recommendations for Future Research ..................................................... 129
References ..................................................................................................... 133
APPENDICES ................................................................................................. 148
   Appendix A: Letter of Site Permission ....................................................... 149
   Appendix B: IRB Approval ........................................................................ 150
   Appendix C: Interview Questions for STEM Educators & Administrators ...... 151
   Appendix D: A Priori Coding from Extant Literature .................................. 154
   Appendix E: Thematic Codes and Excerpt Frequency ............................... 156
   Appendix F: Cost Projection for the High School “C” STEM Academy Program... 157
LIST OF TABLES

Table 2.1. Two Views of Technology ................................................................. 29
Table 2.2. Comparison of Science and Engineering Practices ............................. 31
Table 2.3. A Selection of Science and Technology Skills and Practices ................... 32
Table 2.4. Mathematical Standards for Mathematical Practice ............................. 33
Table 2.5. Positive and Negative Effects of Problem-based Learning ................... 41
Table 2.6. Information Collection Procedures ..................................................... 62

Table 3.1. Document Review Categories ........................................................... 75
Table 3.2. Adapted Steps for Critical Discourse Analysis. Based on Fairclough’s Model (1992) ................................................................. 77

Table 4.1. Document Review Categories ............................................................. 94
Table 4.2. Demographics of Educator Respondents ............................................. 95
Table 4.3. Demographics of Veteran Educator Respondents ............................... 96
Table 4.4. Demographics of Novice Educator Respondents ................................ 97
Table 4.5. Demographics of Educator Respondents with Formal Training in STEM Field... 98
Table 4.6. Demographics of Administrator Respondents .................................... 99
Table 4.7. Indirect Student Indicators for SY 2018-2019 ..................................... 99
Table 4.8. STEM Academy Teacher Attrition by School Year .............................. 100
Table 4.9. Major Events and Key Changes during the Life Cycle of the STEM Implementation .................................................................................. 102
Table 4.10. Demographics of Respondents Entering at Year 2 of the Program Implementation ............................................................................. 103
Table 4.11. Demographics of Respondents Entering at Year 3 of the Program Implementation ............................................................................. 103
Table 4.12. STEM Program Perception Survey Data, Addressing RQ1 ..................... 104
Table 4.13. STEM Program Perception Survey Data, Addressing RQ2 ..................... 106
Table 4.14. STEM Program Perception Survey Data, Addressing RQ3 ..................... 110
LIST OF FIGURES

Figure 1.1. Cost Projection for the High School “C” STEM Academy Program .................. 12
Figure 2.1. Graphic of STEM learning framework ......................................................... 27
Figure 2.2. NC State Scale-UP Classroom ................................................................. 44
Figure 2.3. Active Learning Classroom 1 ................................................................. 45
Figure 2.4. Active Learning Classroom 2 ................................................................. 46
Figure 2.5. Active Learning Classroom 2 ................................................................. 46
Figure 2.6. Active Learning Classroom 3 ................................................................. 47
Figure 2.7. The CIPP Formative Evaluation Framework ............................................. 57
Chapter 1: Introduction

The U. S. Department of Labor most recently published estimates projecting that occupations in the STEM (Science, Technology, Engineering, and Mathematics) fields are growing at a rate of 17% in the United States (Glennie, Mason, Dalton & Edmunds, 2019; Noonan, 2017). Additionally, STEM degree holders tend to command higher incomes, even when they engage in non-STEM related careers (Noonan, 2017). Science, Technology, Engineering and Mathematics professionals are gravely important to the continued growth and sustainability of the American economy (Bates et al., 2019). Therefore, preparing future professionals in these fields must also be a high priority in American schools (Carnevale, Smith & Melton, 2011). The goal is to prepare students not only for work, but to develop them as critical thinkers who extend their knowledge through application and innovation (Barak, 2012). As students matriculate through secondary programs and institutions of higher learning, they should become science literate, and this knowledge base can improve their own lives and the lives of others as they become professionals, patients, caregivers, and consumers (Blackmore & Kamp, 2008).

Innovation leads to new information, new products, new processes, and new systems that sustain and grow the economy (Carnevale, et al., 2011). However, the ability to innovate in these fields depends on the expertise of the professionals who enter the workforce with a solid knowledge-base in the STEM disciplines. With the continued growth of this sector outpacing the professional opportunities in other fields, it is clear that many of the lucrative careers of the present and future require more than just a basic understanding of math and science (Noonan, 2017). For this reason, the work done in K-12 educational settings to prepare students for advanced study and careers in the area of STEM are of critical importance.
Beyond the importance of STEM careers and their impact upon the U.S., STEM is important because the disciplines the term encompasses pervade every part of our daily lives (Blackmore & Kamp, 2008). Science impacts essential areas such as food production and pharmaceuticals. Good engineering ensures that the designs of cars, roads, and bridges are safe. Meteorological technology helps us to prepare for local and global weather events. By exposing students to STEM education and giving them opportunities to explore STEM-related concepts during the course of the regular school day, it is hoped that students they will develop a passion in one of these areas and hopefully pursue a careers in a STEM field (Irvin, Byun, Smiley & Hutchins, 2017).

In addition to passion and professional aspirations, STEM education is also relative to issues of equity and inclusion (Gutiérrez & Lee, 2009; Reigeluth, 2018). Science and technology innovation has created both benefits and challenges. As innovation has increased the quality of people’s lives and contributed to globalization, it has also created a “knowledge-based economy” that privileges some and marginalizes others (Arcidiacono, Aucejo & Hotz, 2016; Russell, Escobar, Russell, Robertson, & Thomas, 2018). Those without access to quality STEM education can quickly become at a disadvantage in societies that privilege these disciplines more and more. Women, communities of color, language minorities, and the poor have seen the disparities that already created gaps in their opportunities and achievement, widen as a result of the increased emphasis on fields where they have been traditionally underrepresented (Segarra, et al., 2019). However, quality STEM education helps to bridge the economic, ethnic, and gender gaps often found in the science and technology fields. Research has demonstrated a correlation between early exposure to STEM and both girls and minorities propensity to continue in these disciplines in terms of advanced learning and careers (Kuenzi,
Science and mathematics performance indicators are particularly low for minority students who represent a growing demographic in the U.S. One such group, students from Latinx communities, has increasingly become a larger percentage of the American population. Their involvement and performance (or lack thereof) in STEM education will reverberate throughout society (Kuenzi, 2008). It is clear that our entire society can benefit from educating the current and future workforce in the STEM fields and that this education must begin early, be ongoing, and be inclusive of marginalized communities.

To the aforementioned end, States and Local Education Agencies (LEAs) in the United States have been struggling to redesign high schools so that all students can receive a STEM education that prepares them for college, career, and lives of contribution and service. Since 1995, Trends in International Mathematics and Science Study (TIMSS) has generated reports which track performance trends in mathematics and science of students in various countries. In 2007, in the United States’ eighth grade science scores were lower than those in nine countries located in Asia and Europe (Desilver, 2017). On the eighth-grade tests, seven out of 37 countries had statistically higher average math scores than the U.S., and seven had higher science scores (Desilver, 2017). America faces increased challenges to its worldwide standing as a leader in STEM fields.

To address these challenges, former President Barak Obama made improving STEM education a priority early in his presidency (U.S. Department of Education, 2016). He asserted that every American student deserves access to high quality STEM education so that they might be prepared for the jobs and careers available both now and in the future. The Obama Administration spent over seven years developing STEM education collaborations between businesses and government. They also developed policies that focused on maximizing the
federal budget to increase student access and participation in active, rigorous STEM learning experiences. In addition, the administration sought to inspire and recognize young inventors, discoverers, and makers as an attempt to encourage them along their STEM pathways. It is estimated that American companies will need over 1.5 million employees with STEM knowledge and skills in the future (Business Roundtable, 2017). However, skilled workers in these areas are necessary for many of the jobs available currently as well (Carnevale, Smith, & Melton, 2011; Rothwell, 2013). A strong STEM education ensures that the students will have the skills needed to access jobs both now and in the future.

The development of sustainable STEM education is not just a national priority, but one that is of growing importance locally in North Carolina. STEM careers are on the rise in North Carolina and the need for well-trained professionals is tremendous (Glennie, Mason, Dalton, & Edmunds, 2019). Recognizing the need, members of the North Carolina State Board of Education wrote the following in 2014: “Beyond focusing on Science, Technology, Engineering, and Mathematics, STEM education provides the opportunity to teach students what to do when they do not know what to do, how to process and act in new and uncomfortable situations, and how to understand, interact, and lead in the jobs, communities, and world in which they live” (North Carolina State Board of Education, 2014, p. 7). STEM education is not only an area of study, but it is also a way of teaching and learning that is collaborative, project based, and focused on solving real world problems. The state board’s comments suggest a desire for educational change that is about more than just academic content. Issues such as collaboration and real world applicability are broader than just academic programs and require alternative teaching strategies and alternative learning environments.
The need for alternative learning environments has increased in recent years and paralleled the movements toward and for more school choice, smaller educational units, and greater emphasis on STEM education. Many students need an alternative to large traditional high schools. Alternative learning environments enable educators to match instructional strategies to the interests, social-emotional needs, and learning styles of students. Research indicates that for adolescent learners, an active learning environment adds to greater motivation and increased attachment to learning (Breunlin, Mann, Kelly, Dunne, & Lieber, 2005). This not only requires new learning environments, but also updated instructional approaches and a teaching workforce that is prepared to administer such (Hudley & Mallinson, 2017).

One form of alternative learning environment is the school-within-a-school (SWAS) model, which was developed at the secondary level to transform large, comprehensive high schools into more specialized, manageable and humane units (Daniels, Tse, Stables, & Cox, 2017; George & Lounsbury, 2000; Reigeluth, 2018). One notable response to the demands for improved educational environments in which to encourage STEM education is to create a STEM focused SWAS. A SWAS is an administrative unit created within a larger school that is a separate and distinctive entity (George & Lounsbury, 2000). This distinction is created by providing the SWAS with its own teachers, courses, space, and environment (McGaw, Piper, Banks, and Evans, 1994).

For many adolescents, positive connections to adults, peers, school, and learning are associated with the reduction of absences, disciplinary reports, and improved student achievement (Breulin et al., 2005). SWAS, and in particular those associated with the STEM programs, have been found to have supplied these type of positive connections between students and their schools, but these findings have been primarily documented in urban and metropolitan
settings (Ihrig, Mahatmya & Assouline, 2018). For centuries North Carolina was largely rural, with an agrarian economy based on tobacco farming, and although the state has evolved from its agricultural roots toward post-agrarian aspirations, there are still many parts of the state that are very rural and desperately poor (Johnson, 2003; Summers, 2019).

Poor, rural, communities are particularly vulnerable to issues such as unemployment, homelessness, and lack of educational attainment (Irvin, Byun, Smiley, & Hutchins, 2017). Curbing these negative outcomes requires a multi-pronged approach that is inclusive of partnerships with local education entities. Changing these outcomes also requires highly skilled teachers but this human resource is difficult to come by in rural settings (National Education Association, 2015). North Carolina politicians and policy makers have come to the realization that teacher retention has a great impact on student outcomes and program viability, particularly in rural settings where teachers are more difficult to recruit and more likely to leave (National Education Association, 2015; North Carolina General Assembly, 2018).

As SWAS’s have become more viable alternatives, it has become necessary to evaluate their implementation practices and the impact these programs are having on the students they serve. Determining the specific differences these programs make for students in these rural settings also means looking at the effects of these programs on the teachers and administrators who run them (Ihrig et al., 2018; Jayaratne, 2016). Learning how these programs can be improved to add more value to students, educators, and the communities they serve is an issue that preoccupies internal and external stakeholders (Jayaratne, 2016; Wilkerson & Haden, 2014). Including formative program evaluations which are “utilization-focused” throughout the program life cycle encourages adaptation to refine program development and may have implications for student and teacher retention (Frechtling, 2010). STEM program developers
and funders can benefit from evaluation as it is critical practice which reveals key information such as what data to collect, which data collection methods are appropriate, and how to effectively communicate these findings.

**Statement of the Problem**

North Carolina’s unemployment rate hit a record high in 2012, when it rose to 9.2% (National Conference of State Legislatures, 2012). The closure of mills and factories in rural North Carolina had a devastating effect on both unemployment rates and poverty levels as the state’s economy was still largely based on agriculture, lumber, and textiles. The loss of these industries necessitated better education and job training to fill occupations that require a much more sophisticated, technology driven, set of skills and knowledge (Glennie et al., 2019; Stewart, 2012). The problem this study addressed is that improving the development and sustainability of STEM programs in rural areas via STEM schools-within-a-school academies is often negatively impacted by a lack of appropriate formative program evaluation.

Providing the modern skills and knowledge necessary for an increasingly science and technology driven work-force and society is largely the responsibility of teachers. The research is rich with studies concluding that the teacher is the single largest school-based factor affecting student academic growth (Goldhaber, 2007; Rivkin, Hanushek, & Kain, 2005; Rockoff, 2004). Yet, studies also reveal that retaining quality teachers in rural teaching environments is a great challenge which has serious implications for student outcomes and program quality (National Education Association, 2015; North Carolina General Assembly, 2018).

STEM programs in rural areas often struggle to attract and retain qualified human capital as well as engage and retain students. These challenges impact program quality and yield continuous calls for improvement and accountability. Previous study findings point to the fact
that program evaluations, which are most often commissioned to satisfy accountability requirements, give little thought to the value that incorporating evaluation into program design from creation throughout implementation might have on the aforementioned challenges (Jayaratne, 2016; Shavelson, 2018; Wilkerson & Haden, 2014). Including formative program evaluations which are “utilization-focused” throughout the program life cycle encourages adaptation to refine program development and may have implications for student and teacher retention (Frechtling, 2010).

**Purpose of the Study**

The purpose of this qualitative study was to use perceptual data and formative evaluation methods as a means to investigate strategies for supporting the development and sustainability of a fledgling STEM academy at a rural high school in the Piedmont region of North Carolina. Formative program evaluation, sometimes referred to “utilization focused” evaluation, assesses the worth of a program while program activities are still forming (Wilkerson & Haden, 2014). It includes a range of formal and informal assessment procedures that take place during the course of program implementation and support the development and improvement of the program throughout its life cycle (Jayaratne, 2016; Shavelson, 2018). The data used to inform the study was culled from open-ended surveys, focus groups, and a large archival data set which was used to investigate the perceptions of administrators and educators on the best methods for supporting the development and sustainability of the program. The records included represent the perceptions and work product of teachers and administrators from a small, rural, public high school in the piedmont of North Carolina.

An evaluation of the STEM Academy has relevance for STEM research and applications, as well as for rural education research. There was a need to evaluate STEM
education programming at the high school to determine the benefits of the program and implementation as well as to address the dearth of research addressing the challenges of STEM education in rural settings. Further, there was also a need to determine the adaptations and changes necessary to contribute to the continued development and sustainability of the program under study with the ultimate goal of ensuring that the investment of resources was indeed contributing to student achievement.

This research was undertaken to elicit and examine the perspectives of secondary STEM teachers and administrators by examining anonymized respondent records after respondents had taken part in focus groups and survey sessions around their work in the STEM academy. In addition to the response records, the investigator reviewed many documents produced by the teachers, school leaders, and district administrators during the course of the three-year implementation. During the course of the study, the data set was mined via stratified sampling techniques to determine teacher inclusion with nine total teachers or 20% of the educators being selected for the study. The smaller number of administrators allowed for a census of their group and all three of the school leaders’ surveys and focus group responses were included. The archival data included 947 pages of artifacts that were either used for program planning or generated during the course of the previous 3 years of implementation. The primary and secondary data analysis was oriented from the lenses of STEM education, program evaluation, and professional development for STEM educators and will provide the STEM education community and interested stakeholders with an updated and specific understanding of how secondary STEM programs in rural settings might be improved to ensure growth and sustainability.
Background of the STEM Academy

In 2017, the school board in a small, rural school district in the piedmont of North Carolina approved exploration activities for the creation of a school-within-a-school STEM academy model. Per document SBP013, a PowerPoint presentation to an open session of the school board, the stated purposes of this program were to aid in the redistribution of students across the county’s three high schools, and improve equity in terms of human and fiscal resources across the county. During the exploratory stage of the implementation, it was revealed that twice as many students attended the county’s two outlying high schools, causing a significant strain on their physical infrastructures as well as stretching thin the capacity of leadership and instructional staff. High school A and B both had student populations of at or more than 1000 students, but High School C, the proposed STEM site had only 517 students at the time of the exploration study. In addition to causing student population imbalances in terms of numbers, the current configuration was causing racial and socio-economic imbalances with the majority of the county’s poor, minority, and special needs students attending high school C. Rather than forcing the students and teachers to move via re-districting or forced busing, the exploratory team developed the idea for this alternative school-within-a-school, in hopes that the setting, climate, structure, size, and program offerings would lure students and staff to high school C based on an interest in the program.

A secondary purpose of the program was to develop a skilled workforce for the changing business and industry of the area. Until the 1990s, this rural area’s chief industries were agriculture, lumber, and textiles (Stewart, 2012). Due to global outsourcing of textile and manufacturing to other countries, the city’s economy has decreased drastically. The shortage of skilled workers for emerging STEM careers in the county and local surrounding areas created a
challenge and opportunity that the STEM implementation could address. The academy was designed to promote innovation and creativity through contextual, project-based learning, and student-centered instruction for students in the ninth through twelfth grades. STEM education has been looked to offer relevant problem-solving opportunities while drawing on creative and collaborative skills to increase interest and engagement in these fields.

The exploratory committee consisting of leaders from the local business community, community college, work force development bureau, school district personnel, teachers, and parents met to discuss what they envisioned for the STEM Academy. The team envisioned high-quality, culturally relevant STEM learning experiences for every student. Using the STEM 2026 framework as a launching pad, the team endeavored to design programming that would support students to develop an interest in and passion for STEM concepts and careers (Bates et al., 2019). The team also sought to cultivate a sense of community and belonging for interested students that would hopefully put them on a path toward lifelong learning pathways in the STEM fields through both formal and informal educational programming in the school. The STEM 2026 model includes six interconnected components:

- Engaged and networked communities of practice
- Accessible learning activities that invite intentional play and risk
- Educational experiences that include interdisciplinary approaches to solving “grand challenges”
- Flexible and inclusive learning spaces supported by innovative technologies
- Innovative and accessible measures of learning
- Societal and cultural images and environments that promote diversity and opportunity in STEM
Based on the aforementioned components as well as the two goals of equitable distribution of human and fiscal resources as well as improved workforce development, the team developed a tentative implementation plan depicted via a logic model in figure 1.1 below.

**Figure 1.1**

*Cost Projection for the High School “C” STEM Academy Program*

<table>
<thead>
<tr>
<th>Needs</th>
<th>Explanation</th>
<th>Cost-Year One (25 new students)</th>
<th>Cost-Year Two (50 new students)</th>
<th>Cost-Year Three (50 new students)</th>
<th>Cost-Year Four (50 new students)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology for 1:1</td>
<td>Students receive devices for use at school/home</td>
<td>$4500.00</td>
<td>$9000.00</td>
<td>$9000.00</td>
<td>$9000.00</td>
</tr>
<tr>
<td>Furniture for Classrooms</td>
<td>Vertebrate desks and chairs for collaboration</td>
<td><em>$20,247.80 (estimate)</em></td>
<td><em>$20,247.80 (estimate)</em></td>
<td><em>$20,247.80 (estimate)</em></td>
<td>--</td>
</tr>
<tr>
<td>Furniture for Media Center</td>
<td>Reconfigure media center as collaborative space for student work</td>
<td>$13,869.00</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>STEM Coordinator</td>
<td>Utilizing Existing Position; Additional 2 Months Employment</td>
<td>Approx. $9000.00</td>
<td>Approx. $9000.00</td>
<td>Approx. $9000.00</td>
<td>Approx. $9000.00</td>
</tr>
<tr>
<td>Summer Professional Development</td>
<td>Includes training, materials, travel, and stipends</td>
<td>$4500.00</td>
<td>$4500.00</td>
<td>$4500.00</td>
<td>$4500.00</td>
</tr>
<tr>
<td>Supplies and materials</td>
<td>Supplies and materials for mini-challenges, grand challenges, projects</td>
<td>$5000.00</td>
<td>$5000.00</td>
<td>$5000.00</td>
<td>$5000.00</td>
</tr>
<tr>
<td>Summer STEM Academy Boot Camp for Students</td>
<td>Stipends for teachers, materials</td>
<td>$2500.00</td>
<td>$4000.00</td>
<td>$4000.00</td>
<td>$4000.00</td>
</tr>
<tr>
<td>SREB Professional Development</td>
<td>PBL PD for all staff, job-embedded coaching, leadership coaching, TLMS STEM PD</td>
<td><strong>$17,270.00 (approx.) Governor’s Innovation Grant Funded (no cost to district)</strong></td>
<td><strong>$17,270.00 (approx.) Governor’s Innovation Grant Funded (no cost to district)</strong></td>
<td><strong>$11,440.00 (District funded)</strong></td>
<td>--</td>
</tr>
</tbody>
</table>

*If programmatic funding cuts are to be incurred, the furniture for classrooms would be adjusted

**This is an estimate based upon current AMSTA planning budget*
The academy opened in the Fall of 2017 with approximately 25 ninth-grade students and an additional 40 students in the Fall of 2018. In year 1, the academy consisted of 20 males and 5 females from the feeder middle school. One student enrolled from the local charter school. Of the 25 students chosen, fifty percent of the students were first generation potential college students, with 15% in the free and reduced lunch category and 25% minority students. The aforementioned demographic figures did not accurately reflect the demographics of the school or the county. In the previous year, fifty-eight percent of the students in the comprehensive high school were potential first-generation college students, 57% of the students were eligible for free and reduced lunch, and 47% percent were racial or ethnic minorities (U.S. Census, 2011). In Year 2, the enrollment increased by forty-two additional students, with twenty-two being males and twenty being female students. 55% of the second year cohort were eligible for free or reduced lunch.

The curricular path of this academy was like that of the traditional high school, as it followed a curriculum designed to increase STEM-related core content through integrating the subject matter with technology-infused projects or problem-based learning in the content classes. During the first year, students utilized additional time to explore and study different STEM-related careers before choosing to pursue a definite career pathway. Classroom lessons were based on contextual and Project Based Learning (PBL), student-centered instruction, and team driven collaboration supported by technology. The daily schedule was rigid, and the only changes were driven by re-grouping based on standardized assessment scores. The teachers were expected to incorporate team-teaching, Socratic seminars, and PBL workshops called mini and grand challenges. The original STEM Academy staff consisted of eight content teachers and a coordinator, but this configuration changed many times throughout the course of the three-
year implementation, as can be seen in Tables 4.7 and 4.8. Initially, the academy utilized the administrative and student support services of the comprehensive high school with the expectation of complete independence by year 3. Additional faculty members were expected to be added each year. In the first year, staff members received common planning in the afternoons in one centralized workspace. The Academy was designed to encourage innovation via the following combined STEM/CTE career pathways:

- Agriculture, food and natural resources
- Architecture and construction
- Business management and administration
- Finance
- Health sciences
- Hospitality & tourism
- Human services
- Information Technology
- Manufacturing
- Law, Public Safety, and Corrections
- Transportation

Students in the academy were expected to graduate college and career ready. Students could achieve credits toward a two-year associate’s degree or college transfer credit via the program’s partnership with the local community college and local private junior college. This was aligned with the Academy’s stated mission and vision which was to graduate students ready for college, career and life.
This study was focused mainly on sophomore and junior students at the high school as the study took place mid-way through the third cohorts first year. The STEM Academy has an inclusive enrollment process. There were no stated academic admission criteria, however, faculty and administration did interview potential students and review academic, discipline, and attendance records before extending invitations for admission. There were no formal records kept by the district to track the acceptance rate of potential applicants. In order to be admitted into the Academy, the student and guardian completed and application and each application was entered into a database which assigned a numerical identifier based on the time it was received. There were only 25 seats available year 1, 2, and 3, per the implementation documentation, however, adjustments were made in terms of seat availability each year, based on demand. Once all applications were received and screened, if there were more applicants than seats available, students were waitlisted in order of submission. Any student who applied after the initial application period was added to the end of the waitlist.

Based on the stated implementation plan, during the students’ freshman and sophomore years, experiences with advanced technologies to “discover their career interests through field trips, guest speakers, virtual mentoring, job shadowing, contextualized curriculum and real-world projects” (Project 2026, 2016, p. 1) will be provided. During the junior year, students will concentrate on completing a specific career certification related to their career area. Students will continue to take responsibility and initiative for their own learning through internships, work-based projects, and use of digital curriculum resources to better develop their entrepreneurial skills (Steering Committee, 2016).

Through its creation, this academy made a bold attempt to reinvent traditional, comprehensive high school education. The instructional design was based on students’ career
interests, utilizing technology integration blended with a rigorous core curriculum integrated with community and work experiences. Students were projected to have the opportunity to earn up to twenty-one college credits during their high school career. The committee further stated that each student would have three available choices upon graduation. At graduation, each student can: 1) apply to any college or university, 2) enter entry level jobs with the certificate, or 3) choose to complete the credential at the partner community colleges or apply their earned hours toward a 4-year degree at one of the partner universities. It is through one of these opportunities that the students will be prepared to compete globally as skilled, productive employees (Steering Committee, 2016).

**Research Questions**

This study addressed the following three research questions:

RQ1. What distinguishing features of the creation and subsequent implementation of the STEM Academy were perceived as salient for program development and sustainability by respondents?

RQ2. How did perceptions of the STEM program vary among respondents who entered at different points in the implementation?

RQ3. How did perceptions of the STEM program vary among different subsets of respondents?

To answer these questions, these areas will be evaluated: how the Academy was created, the fidelity in which the program is implemented, STEM student engagement/adaptation with curriculum and program activities, and the culture of the Academy. The evaluation will be approached from a pragmatic philosophical perspective, which focuses on the nature of experience, and holds that one’s actions, experiences, and beliefs result from experience in school, and are influenced by the social context (Morgan, 2014). This approach was considered
appropriate for the context of the STEM Academy because of its focus on experience, action, and social context. This formative evaluation study aids in expanding the research on STEM education in rural schools by examining the impact of this model on its students.

**Definition of Key Terms**

The following terms are defined to help the reader understand the use of each term with the context of this study.

**Active Learning.** Active Learning is an educational approach that puts the students at the center of the learning process and transfers the responsibility of the learning from the teacher to the student (Doppelt, 2003, p. 256).

**Formative Program Evaluation.** A formative program evaluation is defined as a range of formal and informal assessments procedures that take place in process, or during the course of a program to help determine and improve program outcomes (Smith & Branstetter, 2016).

**Problem-based or Project-Based Learning.** Problem-based or Project-based learning is a student-centered approach where students learn about a subject by working in groups to solve a real-world problem or answering a complex question. Students work on an engaging project over an extended period of time (Sababha, Alqudah, Abualbasal & AlQaralleh, 2016).

**School-Within-a-School or SWAS.** One form of alternative learning environment is the school-within-a-school (SWAS) model, which was developed at the secondary level to transform large, comprehensive high schools into more specialized, manageable and humane units (Daniels, Tse, Stables, & Cox, 2017; George & Lounsbury, 2000; Reigeluth, 2018).

**STEM.** STEM is an acronym for science, technology, engineering, and mathematics (Glennie, Mason, Dalton, & Edmunds (2019)).
**STEM Education.** STEM education is an academic attempt to inspire students to take an interest in STEM subjects in elementary, middle or high school. Focusing on STEM at an early age benefits student in future careers, and in turn will benefit the greater economy (Glennie et al., 2019).

**Technologies.** Technologies are described as solutions designed by humans to fulfill a need; for example, a pen, water filtration, wheelchairs and tunnels, computers, etc. The process that creates what is needed to solve human problems is the engineering. Engineering designs curriculum uses in math and science subjects to teach about technology and engineering (Brenner, 2009).

**STEM Academy.** A STEM academy is a school for science, technology, engineering, and mathematics. STEM academy features an integrated core curriculum of math, science, and engineering class, that intends to prepare students for educational and workforce opportunities in STEM careers (Careless, 2011).

**21st Century Skills.** 21st Century Skills are a cluster of skills and competencies based on the definition from Biomedical, Industry, and Engineering researchers. In this application, it is the ability to reason and solve problems using STEM knowledge. These skills also include developing “critical thinking skills, collaboration skills, communication skills, creativity and innovation skills, self-direction skills, local connections (applying what they have learned to local/community issues) and using technology as a tool for learning” (Ravitz, Hixson, English, & Mergendoller, 2012, p. 3).

**Student Engagement.** Student engagement represents both the time and energy students invest in educationally purposeful activities and the effort institutions/instructors devote to using effective educational practices. This includes five benchmarks: “level of academic challenge,
enriching educational experiences, active and collaborative learning, supportive campus/school environment and student-faculty interaction” (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008, p. 542).

Summary

In this chapter, the investigator justified the need to explore the perceptions of Secondary STEM educators and administrators about strategies to support the development and sustainability of STEM programs in rural contexts. This exploration was undertaken via qualitative formative evaluation using survey instruments, focus groups, interviews, and document analysis. Chapter 1 includes the purpose, theoretical framework, research questions, and background of STEM education in general as well as specific relevant information about the site under consideration for this study. Potential benefits of the study have been described via the significance of the study. Finally, terms and definitions which are important to understanding the study have been delineated with the appropriate citations. The following chapter will review the literature related to the themes of the study. A review of the relevant research literature is presented in Chapter 2. Chapter 3 outlines the research methodology including the context of the study, research questions, and data collection tools and procedures and a justification for the selection of such. The findings of the formative evaluation will be described in Chapter 4. Chapter 5 will provide a summary of the major findings, a discussion of those findings, implications for practice, and recommendations for further research.
Chapter 2: Literature Review

The purpose of this qualitative study was to use perceptual data from educators and administrators, artifact review, and formative evaluation methods as a means to investigate strategies for supporting the development and sustainability of a STEM academy at a rural high school in the Piedmont region of North Carolina. Developing multiple methods of assessing program effectiveness is important as it offers the researcher several dimensions and perspectives from which to judge practices, programs and outcomes (Burniske & Meibaum, 2012). Educator and administrative survey instruments and interviews can provide valuable insight into the teaching and learning environment of a classroom, thus survey instruments can be a valuable component when designing comprehensive program evaluation systems (Bates et al., 2019). Formative program evaluation, sometimes referred to “utilization focused” evaluation, assesses the worth of a program while program activities are ongoing (Wilkerson & Haden, 2014). In the case of the program under study for this investigation, the implementation was nascent so a program evaluation method had to be selected that matched the program’s phase of development. STEM programs that are newly beginning will have different evaluation needs than those of long-standing programs (Wilkerson & Haden, 2014). While program materials are still being developed, programmers can use formative evaluation methods such as focus groups and interviews to receive real-time feedback from implementers and targeted users (Burniske & Meibaum, 2012). This can allow for developers to make changes before practices and policies have become codified or entrenched.

The purpose of this chapter was to review the theoretical and empirical literature relevant to the current investigation. This chapter begins with a review of the school-within-a-school model as an evidence-based improvement model and a review of the characteristics
associated with successful leadership in rural schools. The second section reviews the STEM-based learning model, which is rooted in constructivism and is aligned with the stages of development theory and the Third Space Theory as the cultural framework necessary to successfully implement a STEM program. This review will help orient readers to the complexity of the 21st Century classroom environment and the necessity for active learning spaces. Next, the investigator sought to succinctly review the recent literature referencing the important professional development practices with regards to training teachers in the STEM fields. Finally, this chapter concludes with a review of the literature on formative evaluation as a research method.

Documentation

The approach for conducting the literature review was determined by the aforementioned principle themes of 21st century learning, alternative learning environments, the school-within-a-school phenomenon, constructivism, schooling in rural environments, and third space theory. Examining these themes supported the investigator’s ability to formulate and answer the study’s research questions and to discover areas where the investigation might add to or extend the knowledge base for colleagues and stakeholders. In order to frame the research questions, the literature review is organized both thematically and chronologically, including a treatment of both historical and contemporary research regarding the development of STEM education programs. To locate materials for this study, research was conducted in Academic Search Complete, ERIC, EBSCOhost, ProQuest, SpringerLink, Education Research Complete, Scopus, JSTOR, PsycINFO, Science Direct, and Google Scholar. Keywords used were: science, technology, engineering, mathematics, professional development, STEM, case study, secondary, secondary data analysis, archival data analysis, formative evaluation, program
evaluation, implementation science, rural education, barriers, facilitators, implementation, 21st century learning, college and career readiness, program development, effective pedagogical practices in STEM, career technology education, vocational education, vocational training, CTE, theory of change, logic models, third space theory, active learning spaces, alternative learning settings, vocational schools, educational equity, stratification sampling, homogeneous purposive sampling, implementation, perceptual data, survey tools, educational measurement, educational assessment, qualitative program evaluation, qualitative inquiry, school engagement, hybrid spaces, STEM-rich, equity-oriented, traditional high schools, comprehensive high schools, graduation rates, self-efficacy, cognitive learning theory, cognition, engineering design, higher education, university, matriculation rates, schools-within-a-school, learning space design, project based learning, problem based learning, performance evaluation diversity, rural education, human resources retention, human capital retention, teacher recruitment, teacher retention, teacher attrition, student attrition, at-risk students, critical literacy theory, database repositories, databases warehousing, ad hoc queries, SQL, socket layer protection, and encryption.

It was necessary to provide methodological justification for the review of the relevant literature (Boote & Beile, 2005). Doing so allows other scholars and practitioners to evaluate the findings of the current study in relationship to the existing literature (Boote & Beile, 2005). This will also support readers in their understanding of the process the investigator undertook to select, analyze, and synthesize texts during the review of literature relevant to the researcher’s specific topic of study.

To begin the literature review process, the researcher began by reading the articles and texts discovered through the initial key word search. Once the review of the selected literature
was complete, additional key words were discovered and added to the search agents and a second set of articles and texts was retrieved. The bank of key words became the basis of the a priori code tree used to identify key documents in the school district’s database warehouse. A priori codes are those which are generated prior to the study based on key terms from the related literature and the conceptual framework (Vaismoradi et al., 2016). These codes and key words supported the researcher in developing ad hoc queries for the database. An ad hoc query is a non-standard inquiry created to obtain information as the need arises (Nguyen, Nguyen, & Nguyen, 2017). Next, the investigator began the process of citation tracing, concept saturation, and finally concept mapping.

The citation tracing process was used to find the key references across the literature relevant to the topic under study. Citation tracing involves tracing which authors cite which works and identifying the relationships across these citations (Siguenza-Guzman et al., 2015). This process gives the researcher a concrete method for identifying gaps in the literature and it gives insight into how other authors are examining the relevant concepts. The citation tracing led the investigator to concept saturation, which is the point at which one begins to see repetition in citations, authors, and concepts (Siguenza-Guzman et al., 2015).

**Conceptual Framework**

**Constructivist Theory.** In education there is no one theoretical framework that accounts for how children or adults learn. Rather, there are several theories, some of which are competing, about how humans learn. The constructivist theory of learning is one of the few that is rigorous enough to demonstrate continuity and provide concrete practices for use across the teaching and learning process (Slavin, 2019). The theory of constructivism varies according to one's perspective and position. In education, constructivism has a variety of philosophical
perspectives. Piaget (1967) described personal constructivism as the idea that each person constructs their own ways of understanding the world around them. Social constructivism as postulated by Vygotsky (1978) builds on the ideas of personal constructivism and adds that learning is a social process that occurs on two levels. The first level is actual development where the learner can solve problems independently but the second level involves the potential for development, known as the “zone of proximal development” (ZPD). In the ZPD learners are able to understand at a high level under the guidance of a more knowledgeable teacher or peer (Vygosky, 1978). Von Glasersfeld (1995) advocated radical constructivism pushing the notion that one can only know things that they have experienced.

The tenets of constructivism birthed the inquiry-based learning movement (Laksana, 2017). Despite all the research on constructivism, so-called 21st century learning processes still too often rely on the “factory” model that encourages students to “sit in straight rows, listen to lectures, … fill out worksheets, [and] read from texts under the watchful eye of the teacher” (Peterson & Hittie, 2003, p. 155). John Dewey’s take on constructivism “argued that education must be experience-based, centering on ideals such as open-mindedness and discipline in aim-based activity” (Glassman & Whaley, 2000, p. 2). Dewey believed these aim-based activities could be done using long-term projects, or project-based learning that grew out of a child’s interest. He also saw learning as a continuously fluid process such that when one aim was achieved it set the groundwork for the next aim (Dewey, 2011).

Guven and Duman (2007) describe project-based learning as “one of the most effective learning strategies for constructing knowledge and thinking creatively … [and provides] supports and reinforces many of the principles emphasized in brain-based learning” (p. 77). In
project-based learning, students are given a project where they gather knowledge through focusing on questions and deep investigation of topics that are applicable to their daily lives.

The aforementioned research serves as a foundation for best practices in teaching STEM subjects in the classroom. Research around best practices for teaching STEM disciplines are student centered and based on experiential studies that scaffold from confirmatory, structured, and guided to open inquiry and exploration of the real world (Harland, 2011). STEM education which is well-aligned to careers and higher education has the potential to positively impact and transform lives.

Unfortunately, the educational system needs significant improvement in STEM education (STEM School, 2013; U.S. Department of Education, 2015). Former President Barack Obama stated that, "Leadership tomorrow depends on how we educate our students today—especially in science, technology, engineering and math" (U.S. Department of Education, 2015, p. 1). STEM pervades every aspect of social life, such as economics, accounting, health care, education, religion, computer engineering, mechanical engineering, electrical engineering, audio-visual engineering and should be given serious attention in order to better prepare for the future.

The United States is falling behind internationally; ranking 25th in mathematics and 17th in science among industrialized nations and this may be partly due to a lack of proper application of instructional strategies (U.S. Department of Education, 2015). Only 16% of American high school seniors are proficient in mathematics and interested in a STEM career (U.S. Department of Education, 2015). Even among those who go on to pursue a college major in the STEM fields, only about half choose to work in a related career (U.S. Department of
Education, 2015). The problem may be attributed to the fact that schools have previously offered STEM courses but without the use of instruction with hands-on exercises.

The urgency to improve academic achievement in STEM is evident in the literature (American Association for the Advancement of Science 1989, 1993; Accreditation Board for Engineering and Technology, 2004; International Test and Evaluation Association 2007; National Council of Teachers of Mathematics, 2000; National Research Council, 2012). These organizations develop and review studies about the best practices related to brain-based learning (Jensen, 2005; National Research Council, 2000). President Obama helped initiate this research by establishing Vision 2026 which stipulates a STEM education for all students beginning in preschool and continuing through high school and beyond. STEM 2026 builds on over a decade of research on ensuring all students graduate ready for college entry, career, and life.

Despite high level government research and additions to the literature from professional organizations, teachers have not been the beneficiaries of all this knowledge and still report difficulties conceptualizing STEM education (Nadelson et al., 2012). Research suggests that teachers must know their content and how to teach it (Nadelson et al., 2012; Shulman, 2015). Therefore, for high school teachers, an integrated STEM education model with accompanying professional development must be installed to meet the lofty Vision 2026 goals. Figure 2.1 demonstrates the conceptual framework for a STEM-based educational model (National Academy of Sciences, 2009; National Research Center, 2009). STEM educators must understand the relationship between the domains: scientific literacy, technology literacy, mathematical thinking, and the engineering design process and how essential they are to a positive community of practice.
In the graphic, the first pulley, the engineering design process, provides the students with a systematic approach to problem-solving (National Academy of Sciences, 2009; National Research Center, 2009). The engineering design process is also a means to integrate subject matter. Students are able to use the engineering design process to reflect on their own experiences and construct their own STEM knowledge. For effective learning to occur, Brown, Collins and Druiguid (1989) state that:

Engineering and technology provide a context in which students can test their own developing scientific knowledge and apply it to practical problems; doing so enhances their understanding of science—and, for many, their interest in science—as they recognize the interplay among science, engineering, and technology. We are convinced that the engagement in the practices of engineering design is as much a part of learning science as engagement in the practices of science. (p. 12)

**Figure 2.1**

*Graphic of STEM Learning Framework*

In engineering practices, both scientific inquiry and engineering design are connected through behaviors and scientific reasoning (Kelley & Knowles, 2016). Learning by doing is essential. Scientific inquiry prepares students to think and act like real scientists, ask questions, hypothesize, and conduct investigations using standard scientific practices. However, an inquiry-based approach involves a high level of knowledge and engagement on the part of the teachers and students (Kasza & Kelly, 2017). Rural teachers often lack experience conducting authentic scientific experiments and have difficulty in creating inquiry experiences in the classroom (Dewees, 1999). Many teachers tend to neglect the “minds-on” portion within a “hands-on” experiment which should be embedded within any true constructivist approach to science (National Research Council, 1989).

Technological literacy, the third pulley, is innate in educational technology. The term technology is so broad (Barak, 2012) that it may be best to view technology from two perspectives: an engineering and a humanities perspective. These views align with the Standards for Technological Literacy: Content for the Study of Technology defines what K-12 students need to become technologically literate citizens. Table 2.1 lists the critical components to defining both the engineering and humanistic prospective.
Table 2. 1

Two Views of Technology

<table>
<thead>
<tr>
<th>Engineering perspective of technology</th>
<th>Humanities perspective of technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology consists of:</td>
<td>Technology can be viewed as:</td>
</tr>
<tr>
<td>• A distinct body of knowledge</td>
<td>• More than a sum of tools, instruments, artifacts, processes, and systems</td>
</tr>
<tr>
<td>• An activity or a way of doing</td>
<td>• Influences the structure of the cultural/social order regardless of its user intentions</td>
</tr>
<tr>
<td>• Design, engineering, production, and research procedures</td>
<td>• Serving human values and influence value formation</td>
</tr>
<tr>
<td>• Physical tools, instruments, and artifacts</td>
<td>• Autonomous social and economic forces that often override traditional and competing values</td>
</tr>
<tr>
<td>• Organized integrated systems and organizations that are used to create, produce, and use technology</td>
<td>• Capable of unanticipated positive as well as destructive social and economic consequences</td>
</tr>
</tbody>
</table>


It is expected that both the engineering and technology components of STEM are taught simultaneously (Barak, 2012). STEM educators should help students use technology as a tool to integrate subjects and serve as a vehicle of change.

This leads to the final pulley, mathematical thinking. Students want and need to know how they will use math in their daily lives. An integrated STEM approach contextualizes math. Tillman et al. (2014) conducted a study that found that students’ scores increased significantly when students used prototypes and 3D printing technology in their math classes. It is unfortunate that not all high school subjects can by taught in this way, but students can learn
how to analyze and evaluate solutions, through manipulation of models, allowing students more opportunities to make connections (Burghant & Hacker, 2004).

This leads to the final component which is a community of practice the environment in where all this learning takes place. Lave and Wagner (1991) describe a community of practice as a place where assisting the learner to move from a novice understanding of knowledge, skills, and practices toward mastery as they participate in a social practice of a community.

In a community of practice, novices and experienced practitioners can learn from observing asking questions, and actually participating alongside others with more or different experience. Learning is facilitated when novices and experienced practitioners organize their work in ways that allow participants the opportunity to see discuss, and engage in shared practices (Levine & Marcus, 2010, p. 390).

The Next Generation Science Framework (NGS) describes the common practices for scientists and engineers in terms of learning outcomes for students (National Research Council, 2012). These learning outcomes are important as they describe what it is necessary for students to know and be able to do. Table 2.3 compares common practices in the fields of science and engineering and describes the similarities, differences, and areas of overlap.
### Table 2. 2

*Comparison of Science and Engineering Practices*

<table>
<thead>
<tr>
<th>Scientific Practices</th>
<th>Engineering Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begins with a question about a phenomenon.</td>
<td>Begins with a problem, need, or desire that leads to an engineered solution.</td>
</tr>
<tr>
<td>Using models to develop explanations about natural phenomena.</td>
<td>Using models and simulations to analyze existing solutions.</td>
</tr>
<tr>
<td>Scientific investigation in field or lab using a systematic approach.</td>
<td>Engineering investigation to obtain data necessary for identifying criteria and constraints and to test design ideas.</td>
</tr>
<tr>
<td>Analyzing and interpreting data from scientific investigations using a range of tools for analysis (tabulation, graphical interpretation, visualization, and statistical analysis) locating patterns.</td>
<td>Analyzing and interpreting data collected from tests of designs and investigations to locate optimal design solutions.</td>
</tr>
<tr>
<td>Mathematical and computational thinking are fundamental tools for representing variables and their relationships. These ways of thinking allow for making predictions, testing theory, and locating patterns or correlations.</td>
<td>Mathematical and computational thinking are integral to design by allowing engineers to run tests and mathematical models to assess the performance of a design solution before prototyping.</td>
</tr>
<tr>
<td>Constructing scientific theory to provide explanations is a goal for scientists and grounding the explanation of a phenomenon with available evidence.</td>
<td>Constructing designing solutions using a systematic approach to solving engineering problems based upon scientific knowledge and models of the material world. Designed solutions are optimized by balancing constraints and criteria off existing conditions.</td>
</tr>
<tr>
<td>Arguments with evidence is key to scientific practices by providing a line of reasoning for explaining a natural phenomenon. Scientists defend explanations, formulate evidence based on data, and examine ideas with experts and peers understandings.</td>
<td>Arguments with evidence is key to engineering for locating the best possible solutions to a problem. The location of the best solution is based on a systematic approach to comparing alternatives, formulating evidence from tests, and revising design solutions.</td>
</tr>
</tbody>
</table>

Adapted from Next Generation Science Standards. Retrieved from https://www.nextgenscience.org/
Table 2.3 details key practices that build the knowledge, skills, and dispositions found common practices in science and technology while investigating and solving problems (Kolodner et. al, 2003).

Table 2.3

A Selection of Science and Technology Skills and Practices

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding a problem and what might need to be investigated</td>
<td>Identifying criteria, constraints, problem specifications</td>
</tr>
<tr>
<td>Generating questions that can be investigated</td>
<td>“Messing about” with and understanding materials</td>
</tr>
<tr>
<td>Investigation with a purpose-experimentation, modeling, learning from cases, managing variables, accurate observation and measuring, seeing patterns,…</td>
<td>Investigation for the purpose of application-designing and running models, reading and learning from case studies,…</td>
</tr>
<tr>
<td>Informed decision making, reporting on justifying conclusions</td>
<td>Informed decision making, reporting on and justifying design decisions</td>
</tr>
<tr>
<td>Iteration toward understanding</td>
<td>Iteration toward a good enough solution</td>
</tr>
<tr>
<td>Explaining scientifically</td>
<td>Explaining failures and refining solutions</td>
</tr>
<tr>
<td>Investigation planning</td>
<td>Prioritizing criteria, trading them off against each other, and optimizing</td>
</tr>
<tr>
<td>Communication of ideas, results, interpretations, implications, justifications, explanations, principles</td>
<td>Communication of ideas, design decisions, justifications, explanations, design rules of thumb</td>
</tr>
<tr>
<td>Teamwork, collaboration across teams, giving credit</td>
<td>Teamwork, collaboration across teams, give credit</td>
</tr>
</tbody>
</table>

Table 2.4 provides the math standards for math practice located in the Common Core standards for mathematics identifying the necessary habits needed when solving mathematical problems.

**Table 2.4**

*Mathematical Standards for Mathematical Practice*

<table>
<thead>
<tr>
<th>Make sense of the problem and persevere in solving it. Mathematically proficient students explain the meaning of a problem and looks for solution entry points.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reason abstractly and quantitatively. Mathematically proficient students are able to decontextualize—create abstractions of a situation and represent it as symbols and manipulate.</td>
</tr>
<tr>
<td>Construct viable arguments and critique the reasoning of others.</td>
</tr>
<tr>
<td>Model with Mathematics.</td>
</tr>
<tr>
<td>Use appropriate tools strategically.</td>
</tr>
<tr>
<td>Attend to precision.</td>
</tr>
<tr>
<td>Look for and make use of structure.</td>
</tr>
<tr>
<td>Look for and express regularity in repeated reasoning.</td>
</tr>
</tbody>
</table>

*Adapted from Common Core State Standards for Mathematics, pp. 6–8*

These practices, the nature of these disciplines, as well as the context of science, technology, math, and engineering provide the learner with authentic examples that could help to illustrate the interdisciplinary nature of the STEM connections. An integrated STEM approach should support the ideal of STEM content being taught alongside engineering practices as they are equally important in terms of students’ ability to learn in the disciplines and see the similarities between their work and the work of scientists, technologists.
engineers, and mathematicians in the field (Kelley & Knowles, 2016). The hope is that identifying these similarities might lead students to make informed decisions about possible STEM careers. This is important as companies both foreign and domestic report acute shortages of qualified candidates in STEM fields (Glennie, Mason, Dalton & Edmunds, 2019; Noonan, 2017). In the event that students have the academic knowledge, they sometimes still lack the non-technical skills such as teamwork, innovative thinking, and communication which are necessary for success and which can be transmitted through the work of communities of practice. This missing set of skills is referred to in the literature as “third space” because it includes soft skills that extend beyond content and technical expertise (Flook et al., 2008; Napoli et al., 2005; Wall, 2005). This type of learning is best accomplished via hybrid spaces. Hybrid spaces are described in the literature as those spaces, whether physical or social, where learning takes place (Calabres, Barton & Tan, 2017).

The theory of change framework. Theory of Change (ToC) is both a theoretical model and a specific type of methodology for planning, participation, and evaluation of organizational programs and in formative evaluation is often depicted via a logic model (see figure 2.7) (Wilkerson & Haden, 2014). ToC also harmonizes with critical theories such as the Theory of Third Space and have been used to ensure equitable distribution of power. Theory of Change (ToC) is both a practitioner’s model and a specific type of methodology for planning, participation, and evaluation of organizational programs and his been traditionally used to promote social change (Weiss, 1997).

Hybridity and Third Space

The theory of third space. The concept of hybridity as expressed via the theory of third space will also serve as part of the conceptual framework underpinning the study (Hulme et al.,
Hybridity is a helpful way to conceptualize how students learn and organize their knowledge. The theory of third space is a product of postcolonial philosophy. The Third Space is taken from the work of the influential cultural and post-colonial theorist Homi Bhabha and it refers to the intersection between cultural practices and physical space “which gives rise to something different, something new and unrecognizable, a new area of negotiation of meaning and representation” (Bhabham, 1990, p.211). The Theory of Third space helps to explain the transformative nature of complex learning environments (Engestrom, 1999). Postcolonial refers to the period of cessation from colonial rule in Africa, Asia, and Latin America.

Postcolonialism encompasses the ways of thinking and modes of behavior in the newly independent states (Wolf, 2010). This period was characterized by intercontinental calls for nation building. This placed the newly independent states in a unique place, a third space. Living in what were previously colonized states, the peoples of Africa, Asia, and Latin America were many generations from the first space of their traditional native culture and closely situated to tension filled and angst ridden second space of Euro-centric culture (Woolf, 2019). These newly independent populations created a third space of existence that was influenced but not dominated by the first and second spaces. Third space theory is the creation by formally colonized people of an identity space that resists imposed racist, classist, and other oppressive forces in their lives (Bhabha, 1994).

According to Wolf (2010), meaning is produced beyond cultural boundaries and chiefly located in the third space. This third space, an in-between or negotiated space, falls between referential systems and antagonism. The postcolonial third spaces were typically amidst adversarial first and second spaces. The third space is the space between two binaries or poles that may often pull in opposite directions (Wolf, 2010). Bhabha suggests a more dramatic
birthing of the third space as a product of the complete collapse of the previously defining narratives of modernity based on patriarchy, class, and colonialism (Radcliffe, 2011).

Over time, the theory of third space has been applied in various disciplines and within less contentious contexts (Woolf, 2019). Increasingly, the theory of third space began to speak to the politics of change. This is demonstrated in the diverse ways researchers apply this theory. Third space was used in the analysis of national maps produced by indigenous organizations in Ecuador. Third space also speaks to something well beyond the traditional or historical colonized-colonizers binary (Radcliffe, 2011).

Third Space has been used as a way of describing both culture in the post-colonial world (Bhabha, 1994; Young, 1995) and desirable classroom environments (e.g., Calabrese Barton & Tan, 2017; Gutiérrez, Baquedano-López, Alvarez, & Chiu, 1999; Mojé, 2001; Mojé, et al., 2004). Versions of Third Space and hybridity have appeared in a variety of academic fields including politics, postcolonial theory, geography, second language learning, general education, and science education. This broad application of the various applications of Third Space warrants its use in this study.

In research and learning, hybrid spaces have many definitions. Gutiérrez, López, Tejada, and Baquedano-López (1999) discussed hybrid or third spaces as spaces where students are confronted with competing ways to “transform conflict and difference into rich zones of collaboration and learning” (p. 286). Calabrese Barton and Tan (2017) describe these spaces as support systems that bridge traditionally marginalized communities and privileged spaces to make all voices heard. Moje, Ciechanowski, Kramer, Ellis, Carrillo, and Collazo (2004) define hybrid spaces as those where traditional boundaries of official or academic ways of thinking and
doing can be expanded, as conflicting knowledge and discourses of different spaces are brought together.

This is important as we begin to understand how students learn outside of traditional learning spaces (Gutiérrez, 2008). It allows us to consider how learning translates across the settings in the everyday lives of students (Gutiérrez & Lee, 2009) by broadening the definition of learning beyond mastering a concept but also how learning is adapted to fit the needs of a learner.

Gutiérrez (2008) and Rahm (2008) found that it is in hybrid space where students who are traditionally disengaged in science and math can find meaningful learning opportunities in hybrid spaces. These students’ voices can be expanded in these settings by participating in “to new forms of learning, a reframing of the role of education and of the self as a historical actor, and the development of an important set of tools that facilitates social and cognitive activity” (Gutiérrez, 2008, p. 159).

Hybrid spaces are also about STEM, science that emerges from doing, social interaction and negotiation, that is mediated by technology, engineering, and math as tools in practice (Rahm, 2010). These hybrid spaces can be deemed as “opportunity” spaces that draw on the students’ prior experiences and knowledge to develop an interest to “genuine science literacy” (Ram, 2008, p. 120). Hybrid spaces can give learners authentic authority in learning settings (Calabrese Barton, Tan, & Rivet, 2008). It provides a holistic education and address educating the whole child by addressing the cognitive, social, and emotional needs’ and positioning the student regardless of their academic background as competent (Gutierrez & Lee, 2009), making for productive and meaningful learning environment.
Individual and virtual communities or digital spaces can also be hybrid spaces. Many examples of how students’ actions with technology can also influence the physical space because it is social, facilitating dialogue and opportunities to socialize while constructing knowledge (Smørdal, Slotta, Moher, Novellis, Gnoli, Lopez Silva, Lui, Jornet, Jahreie, & Krange, 2012). Calabrese Barton and Tan (2010) research suggests that having opportunities to engage in real-world, real-time science problems alongside practicing scientists, when accompanied with further opportunities to educate others about this work, situates youth in the position as community science and engineering experts.

A theory of third space lens is used in discussing the STEM Academy as a school-within-a-school. This seemed to be an appropriate lens as the STEM Academy is a third space contrived via the existence of the first space of the traditional classroom and the second space of project-based learning. The STEM Academy is an intense support system designed to meet the needs of seventy-five ninth and tenth grade students. The STEM Academy provides small groups in academics, computer skills, and EOG preparation (1st space), technology (2nd space), and operates autonomously with a cohort of students, budget, and resources (3rd space). The STEM Academy exhibits what Bhabha calls an “innovative site of collaboration” (Bhabha, 1994, p. 2). The STEM Academy as a whole is an innovative third space that invites greater student engagement.

New approaches and a renewed focus on STEM teaching—especially at the high school level—stress collaboration, innovation, and interdisciplinary learning. New approaches to STEM education must go hand in hand with new approaches to STEM spaces.

Shifting from classrooms to learning spaces requires a conceptual shift and the teacher to shift their focus from teaching to learning. To maximize the outcomes of a STEM based
learning model, active learning instructional models must be used in the classroom. These are any type of combination that holds the learner responsible for their own learning (Bonwell & Elson, 1991; Hammer & Hiordano, 2012; Prince, 2004). This type of learning in the nineties by promoting various student-centered approaches but Bonwell and Eison (1991) proposed that traditional lectures, where faculty stand at the front of the room and students listen and take notes, is passive. Wankat (2002) cites numerous studies that suggest that students’ attention spans during lectures is roughly fifteen minutes. Hartley and Davies (1978) found that the number of students paying attention begins to drop dramatically with a resulting loss in retention of lecture material. Students must do more reading, writing, and being engaged in the learning process (Bonwell & Eison, 1991). Students involved in active learning activities are described by Bonwell (2010) as:

- Students doing than more than passive listening during class
- Students are engaged in activities (e.g., reading, writing, thinking, talking and listening)
- There is less emphasis placed on information transmission and greater emphasis placed on developing student skills/knowledge
- There is greater emphasis placed on the exploration of attitudes and values
- Student motivation is increased
- Students can receive immediate feedback from their instructor
- Students are involved in higher order thinking (analysis, synthesis, and evaluation)

Collaborative, cooperative, problem, and team-based learning are all examples of active learning models. One could argue that they are one and the same based on the definition of active learning.
Collaborative learning, however, is basically when a student participates in a group with two or more students to learn something (Dillenbourg, 1999) but are individually assessed (Prince, 2004). Cooperative learning follows the same definition as collaborative learning but depends on equal participation on the part of the learner (Prince, 2004). In a review of ninety years of research, Johnson, Johnson, and Smith (1998) found that the individual work with students improved across the board when students worked in groups when they were monitored by the teacher.

Problem-based learning is an instructional strategy where the teacher presents a problem in class and uses it as a motivation for learning. It is usually combined with collaborative and cooperative learning activities. It is grounded in Dewey’s “learning by doing” ideology (Dewey, 2011; Akinoglu & Tandogan, 2007). Woods, Felder, Rugarcia, and Stice (2000) study describes different variations of Problem-based Learning (PBL).

Once a problem has been posed, different instructional methods may be used to facilitate the subsequent learning process: lecturing, instructor facilitated discussion, guided decision making, or cooperative learning. As part of the problem-solving process, student groups can be assigned to complete any of the learning tasks listed above, either in or out of class. In the latter case, three approaches may be adopted to help the groups stay on track and to monitor their progress: (1) give the groups written feedback after each task; (2) assign a tutor or teaching assistant to each group, or (3) create fully autonomous, self-assessed “tutorless” groups. (Woods, Felder, Rugarcia, & Stice, 2000 pp. 118-119)

Team-based learning combines all of these practices. Micahelson (2008) suggests that there are four essential elements for effective team-based learning:
Effectively formed and managed groups

Individual and group accountability for the quality of the work of the team

Frequent and timely feedback from the instructor

Students are using higher order thinking skills (analysis, synthesis, and

Table 2.5

**Positive and Negative Effects of Problem-based Learning**

<table>
<thead>
<tr>
<th>Characteristics of Problem-based Learning</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative</td>
<td>0.54</td>
</tr>
<tr>
<td>Instruction in problem-solving</td>
<td>0.54</td>
</tr>
<tr>
<td>Group</td>
<td>0.31</td>
</tr>
<tr>
<td>Individualized</td>
<td>0.23</td>
</tr>
<tr>
<td>Using problems</td>
<td>0.20</td>
</tr>
<tr>
<td>Inquiry based</td>
<td>0.16</td>
</tr>
<tr>
<td>Inductive</td>
<td>0.06</td>
</tr>
<tr>
<td>With non-expert tutors</td>
<td>-0.74</td>
</tr>
<tr>
<td>Self-paced</td>
<td>-0.07</td>
</tr>
<tr>
<td>Self-directed</td>
<td>-0.005</td>
</tr>
</tbody>
</table>


The research suggests that active learning methods yields more meaningful learning outcomes than traditional methods (McKeachie et al., 1986). There is greater satisfaction with active learning courses over traditional ones (McCarthy & Anderson, 2000). There is a connection between learning outcomes and the building and use of active learning spaces. It is mediated by the tangible things that affect classroom tangibles (e.g. quality of air, light, spatial density) and intangibles (school and classroom culture, sense of belonging and self-efficacy).

**Active Learning Spaces**

According to Brown and Long (2006), “Our growing understanding of how people learn affects the configuration of learning spaces and the technologies supporting them” (p. 9). Many
educators are “rethinking the use, design, and location of such learning spaces” (Brown & Long, 2006, p. 1). In the *Future of the Learning Space*, Long and Ehrman (2005) provide four ideas which can help shape our understanding of how active learning classrooms should be designed:

1. Learning by doing matters.
2. Context matters.
3. Interaction matters.
4. Location of learning matters

There is a growing amount of evidence that active learning spaces affect those students who are disengaged, absent, or feel excluded. Since family violence, poor health care, discrimination, or bullying are some of the causes of disengagement, active learning spaces become a place these students can go to forget about their problems and sometimes stop the behavior altogether (Bandura, 1997; Blackmore & Kamp, 2008). Schools that are poorly designed and poorly maintained often have the lowest educational achievement levels, can also have a detrimental impact on teacher and student morale and engagement, and negatively impact student outcomes (Filardo, 2008). The design of the learning spaces in a school can convey an institution’s philosophy about teaching and learning.

There are three assumptions that underpin the design principles of an active learning space:

1. Learning spaces must address the educational needs of 21st century learners (Chism, 2006; Fisher, 2002; Temple, 2007).
2. School buildings and classroom layouts should reflect culturally specific understandings and philosophies of education as well as to resource distribution (Bateman, 2009); for
example, the Reggio Emilia notion of the “environment as the third teacher or the 3rd space philosophy” (New, 2007; Rinaldi, 2006).

3. A good design leads to improved teaching practices which in turn affects student behaviors and student learning outcomes (Department of Education and Training Victoria, 2009; Flutter, 2006; Oblinger, 2006; Sanoff, 1995).

What does an active learning classroom look like today? Research suggests that student outcomes increase when learning in active, exploratory, and occurs in social settings (Bennett, 2007a; Boys, 2011; Chism, 2006; Cox, 2011; Oblinger, 2005). Campus classrooms, lecture halls, tutorial rooms, and other formal places of learning have changed little for centuries (Jamieson, 2003).

While there are no one size fits all design for classrooms, there are some features that are common. According to Leiboff (2010), the most common features of an active learning classroom include moveable or round tables and chairs with wheels or stackable chairs to provide additional floor space. There may be a desk or a podium in the center of the room to encourage the instructor to move around and facilitate group learning activities.

An online search for today’s active learning classrooms yields a lot of variety in how colleges are designed. The research is scarce for high school designs. Figure 1-1 shows an active learning classroom found at North Carolina State University that shows common features that include projection screens and white board space.
In high schools, three types of classrooms are suggested in the literature by Steelcase (2018) all of which are flexible in their design.

**Active learning classroom 1.** This flexible classroom allows both students and instructors to have control over their learning experience. It combines mobile, height-adjustable seats, and tables to encourage a blend of casual and more formalized arrangements. The benefits of this type of classroom include blended seating and tables, personal whiteboard to encourages creativity, and a large whiteboard for supporting collaboration. It also has half tables and buoy seating.
Active Learning Classroom 1

Presentation Set-up: Everyone has a clear view of the presenter.

Group Set-up: Students to collaborate and share in a variety of configurations that suit their learning styles.

Discussion Set-up: Students can modify the set up to encourage face-to-face connection and mutual sharing.

Adapted from Steel Chase
https://www.steelcase.com/content/uploads/2015/03/Post-Occupancy-Whitepaper_FINAL.pdf

Active learning classroom 2. This classroom invites engagement with clear zones to support multiple activities that take place simultaneously. Students can collaborate, listen to the teacher, read independently or do hands on activities all in the same class setting. The benefits for this type of classroom is the ergonomically designed chairs that allow students to regroup easily while staying comfortable and engaged. There is a breakout area for mentoring, individual work, or for collaboration.
This classroom follows the Makerspace model and encourages exploration and problem solving. It is considered a mobile setting where students can think, create, and share with one another. The benefits from this type of classroom environment is that the casualness of it
encourages team collaboration and student engagement in a variety of ways. The mobile furniture allows for quick grouping with minimal interruption.

**Figure 2. 6**

*Active Learning Classroom 3*

**Think Setup**- Desks are configured into small groups and are given ample space to brainstorm, plan and reflect.

**Make Setup**- Students can move and adjust tables to help them create. Supplies are readily available in the mobile storage units.

**Share Setup**- Students are seated in seats that either Swivel seating or adjust in height.

Adapted from Steel Chase
https://www.steelcase.com/content/uploads/2015/03/Post-Occupancy-Whitepaper_FINAL.pdf

**Schools-Within-a-School Models**

The need for more active learning spaces is a new concept, but the call for alternative learning environments is not. An “active learning space” is a term coined in the last 20 years or so (Brown & Long, 2006). The call for alternative learning spaces has seen an increase and the
concept began appearing regularly in the literature starting in the late 1960s (Burke, 1987). However, writing in 2010, Thomas asserted that the first alternative schools were really specialized vocational schools called academies and they began with the Stuyvesant High School which opened in 1904 as a manual training school for boys. These schools too were created to provide skilled laborers for the work force. Despite recent efforts at discrimination and exclusion, these schools were not conceptualized for the gifted and talented few, but as a means for providing poor and often troubled inner city youth with employment opportunities (Thomas, 2010).

In recent years the renewed calls for alternative learning environments has paralleled the movements toward and for more school choice, smaller educational units, and greater emphasis on STEM education. Many students, not just poor or troubled ones, need an alternative to large traditional high schools. Alternative learning environments enable educators to align instructional strategies to the diversity of interests, social-emotional needs, and learning needs of students. There is also support in the literature for the notion that for adolescent learners, an active learning environment adds to greater motivation and increased academic engagement (Breunlin, Mann, Kelly, Dunne, & Lieber, 2005).

One form of alternative learning environment is the school-within-a-school (SWAS) model, which was initially developed to transform large, comprehensive high schools into more specialized, wieldy, and humanistic learning enviroments (Daniels, Tse, Stables, & Cox, 2017; George & Lounsbury, 2000; Reigeluth, 2018). One such model STEM focused SWAS. A SWAS is an administrative unit created within a larger school that is a separate and distinctive entity (George & Lounsbury, 2000). This distinction is created by providing the SWAS with its own teachers, courses, space, and environment (McGaw, Piper, Banks, and Evans, 1994). The
National Association of Elementary School Principals officially recognizes a SWAS as "a separate entity, running its own budget and planning its own programs (Miller, 2005). However, school safety and building operation remain the responsibility of the principal of the larger, comprehensive school, and things like the use of shared space must be negotiated" (Miller, 2005).

SWAS, and in particular those associated with the STEM programs, have been found to have supplied these type of positive connections between students and their schools. For many adolescents, positive connections to adults, peers, school, and learning are associated with the reduction of absences, disciplinary reports, and improved student achievement (Breulin et al., 2005). Many educators and parents are drawn to the idea of trimming down the size of schools as much research as well as documentation of successful model programs has confirmed the academic, social, and financial benefits of smaller schools. Proponents of SWAS seek to leverage the advantages of both large and small schools by placing students into small learning communities while retaining access to the resources of the larger comprehensive school.

McComb (2000) and Jacobson (2001) have written that the standardized assessment scores of students in smaller schools are consistently higher than those of their peers attending larger comprehensive high schools. On reason for this phenomenon may be that smaller schools are more labile and administrators and teacher leaders are better able to reform curriculum and instructional strategies in a more timely fashion when schools are at a smaller scale (McComb, 2000). Additionally, smaller class sizes as well as an increased emphasis on teaming and interdisciplinary instructional strategies allow for more frequently and higher quality interactions between students and pupils (Kasza & Slater, 2017). This translates beyond standardized test scores, which are cognitive measures, to non-cognitive measures such as
attendance and graduation. Per McComb (2000), the average national dropout rate for high schools larger than 1,000 students is about 6.40%, but schools with less than 200 students boast half that dropout rate with student attrition calculated at 3.5%. Gewertz has written that these schools also have higher attendance rates, another important non-cognitive measure of student success (2001).

**STEM Education and Issues of Equity and Inclusion**

Equity should be prioritized in all educational improvement efforts. The most basic area of discrimination is the idea that only certain subsets of students should have access to STEM education such as boys, Asians, or the academically gifted (Thomas, 2010). All students can and should learn complex science because they world in which they now live as well as the world of the future require it (Glennie, Mason, Dalton & Edmunds, 2019; Noonan, 2017). Achieving this equity is an issue of social justice which requires critical theories such as the Theory of Third Space and Theory of Change.

Students from marginalized communities often face "opportunity gaps" in their educational experience with regards to STEM learning (Arcidiacono et al., 2016; Russell et al., 2018). These opportunity gaps may exist because of lack of resources or even qualified teachers (National Research Council, 1989). The NRC Framework and NGSS vision is that all students will have access to high quality science learning opportunities and will be able to succeed in science (NRC, 2013).

"Equity in science education requires that all students are provided with equitable opportunities to learn science and become engaged in science and engineering practices; with access to quality space, equipment, and teachers to support and motivate that learning and engagement; and adequate time spent on science. In addition, the issue of
connecting to students' interests and experiences is particularly important for broadening participation in science.”— NRC Framework, p. 28, 2013

In addition to the “opportunities gap”, an "achievement gap" between students of different socio-economic backgrounds also persists in science related fields (Arcidiacono et al., 2016; Russell et al., 2018). The literature supports the notion that this gap results and persists from a lack of equity in terms of opportunities to learn science for children from non-dominant communities (NRC, 2013). The NRC Framework says that "all science learning can be understood as a cultural accomplishment" and that a cultural perspective can increase engagement and meaning for students (NRC, 2013).

As innovation has increased the quality of people’s lives and contributed to globalization, it has also created a “knowledge-based economy” that privileges some and marginalizes others (Arcidiacono, Aucejo & Hotz, 2016; Russell, Escobar, Russell, Robertson, & Thomas, 2018). Those without access to quality STEM education can quickly become even further disadvantaged in societies that privilege these disciplines more and more. Women, communities of color, language minorities, and the poor have seen the disparities that already created gaps in their opportunities and achievement, widen as a result of the increased emphasis on fields where they have been traditionally underrepresented (Segarra, et al., 2019). However, quality STEM education helps to bridge the economic, ethnic, and gender gaps often found in the science and technology fields. Research has demonstrated a correlation between early exposure to STEM and both girls and minorities propensity to continue in these disciplines in terms of advanced learning and careers (Kuenzi, 2008). A diversity of perspectives leads to more ideas and more possible solutions to improve the world that we all share irrespective of our inherent differences.
Teaching and Learning in Rural Environments

Rural communities are particularly vulnerable to issues such as unemployment, homelessness, and lack of educational attainment (Irvin, Byun, Smiley, & Hutchins, 2017). Decreasing these negative outcomes requires a myriad of stakeholders willing to develop partnerships with local education entities. Improving these outcomes also requires highly skilled teachers, but skilled teachers are more difficult to recruit to rural settings (Hanushek, 2016; National Education Association, 2015). North Carolina politicians and policy makers have come to the realization that teacher retention has a great impact on student outcomes and program viability, particularly in rural settings where teachers are more difficult to recruit and more likely to leave (National Education Association, 2015; North Carolina General Assembly, 2018).

Rural schools are very different from urban and suburban schools and policy makers are finally beginning to understand that policies and practices that work in those other environments may not work in rural contexts (Hanushek, 2016; National Education Association, 2015). To support rural schools and rural communities, a different, more nuanced conversation must be had about how to attract resources (fiscal, physical, and human) to these areas. There are challenges when working in rural environments, but there are also strengths that may be typically overlooked such as smaller class sizes, parental involvement, and a strong sense of community support (Harmon, Henderson & Royster, 2003).

Writing in 2015, Allen shared an anecdote in the treatise Why Rural Schools Matter. “There’s a saying: When you’ve seen one rural school, you’ve seen one rural school,” yet policymakers often apply a one-size-fits-all approach failing to account for things like the impact of travel across vast distances for field experiences, the distance between some schools...
and the nearest research focused institutions of higher learning, and lack of internet infrastructure to support instructional technology. This may be lost on politicians and policy makers, but it is not lost on potential teachers and as a result, they often take their talents elsewhere (NEA, 2015).

**The effects of teacher shortages in rural environments.** While the problem of teacher shortages is affecting school districts around the nation, rural communities face a unique set of challenges which causes the teacher shortage crisis to be felt more deeply in these areas. Some of these challenges include lower salaries, teacher fears of isolation, limited affordable housing, and a lack of recreational activities to produce work-life balance (Arnold, 2004). According to a study by the United States Department of Education (2004), national research shows that urban areas have lower teacher turnover rates than rural areas and that teachers “prefer to work in schools with large concentrations of relatively high-income, low-minority, high-achieving students with lower discipline issues and more parent support.” Administrators in rural areas struggle to recruit and retain teachers for a substantial period, and many are often lured away by the higher salaries offered in urban areas.

Not only are teachers leaving rural areas, but the pipeline for educators is diminishing as well, with the number of students pursuing a degree in education having decreased over the last 10 years and many schools of education closing their doors due to lack of funding and low enrollment (Partelow & Baumgardner, 2016). This has led many districts to hire teachers without the proper licensure or even industry related experience (Partelow & Baumgardner, 2016). A decrease in the overall number of teachers has a disproportionate effect on rural areas compared to urban areas.
Professional Development for Active Learning

Most teachers teach how they were taught. Niemi (2002) argues that most teachers are still lecturing and telling students what to do, which means that students are not effectively using their cognitive skills. Active learning effectiveness is connected to teacher education (Niemi, 2002). Michael (2007) describes the barriers teachers identified in using active learning instructional strategies. The most common concern noted in his interviews was that too much time goes into the preparation of active learning lessons. They are also concerned with having less control over the classroom and they may not be able to cover all the material in a class session.

Knight and Wood (2005) compared students’ performance in a lecture based and an inquiry based biology course and found that the students who were taught with (a) in-class activities in place of some lecture time, (b) collaborative work in student groups, (c) increased in-class formative assessment, and (d) group discussion were observed to make significantly higher learning gains and have better conceptual understanding of the material. Chickering and Gamson (1987) assert:

Learning is not a spectator sport. Students do not learn much just by sitting in class listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to experiences, apply it to their daily lives. They must make what they learn part of themselves. (p. 4)

Lessons learned in research on constructivism and in collaborative and cooperative learning all echo the same sentiments—that active learn transforms student (Brooks & Brooks, 1999; Dillenbourg, 1999; Land et al., 2012; Prince, 2004). More research is needed on how to
STEM-based learning can transform the education of students who attend rural schools where funds and motivation are lacking.

**Effective Practices for Evaluating STEM Programs**

School evaluation is an important process that includes administrative, pedagogical and managerial improvements. Evaluations constitutes an on-going cycle for program planning, implementation and improvement (Patton, 2011). Formative and summative evaluations are the two ways to monitor the teaching and learning processes (Ebel and Frisbie, 1991; Patton 2015). Because schools are complex and dynamic and quality has become a key word in education, program evaluation is extremely important.

Effective evaluation practices stipulate that one selects the appropriate data and data collection methods to align to the program’s duration and intended outcomes. However, more often than not the evaluation budgets for STEM programs are minimal. To ensure that a formative evaluation provides tools and practices that an organization can continue to use after the conclusion of the study, it was important that the investigator align the data collection practices with the intended outcomes of the program, maximize the evaluation offerings, and minimize the time and expense necessary to analyze the data and report on findings. In general, the more rigorous the evaluation study, the more justified evaluators are in making causal claims regarding program effectiveness. In order to do this appropriately, rigor typically involves costly and complicated randomized control trials or quasi-experimental designs (Rossi et al., 2003). However, this level of rigor is more appropriate for more well-established STEM programs of longer duration which have already been in the regular practice of using evidence-based evaluation techniques for planning and continuous improvement. In the context of a
newly launched program, the data collection techniques need to provide as much rigor as possible while keeping in mind the limited time, resources, and previous evaluation activities.

The Context, Input, Process and Product Process (CIPP) set of approaches to formative evaluation was created and described by Daniel Stufflebeam in 1971, as an improvement on the dominant experimental design model of its time (Stufflebeam & Shinkfield 2007). Stufflebeam intended CIPP Model evaluations to focus on program improvement instead of proving something about the program. The CIPP model has been thoroughly documented as being usefulness across a variety of educational and non-educational evaluation settings (Sax, 1980; Stufflebeam & Shinkfield, 2007; Asadi, Raza, Akbari, and Ghafor, 2016).

What makes this model different from other models is that it focuses on the context for the evaluation of teaching learning and development process. The most important thing about this model is that it provides a holistic view of every element by evaluating context, input, process and output from every angle. With the help of this model, evaluation can be done systematically, fulfilling the general needs of evaluation. (Stufflebeam & Shinkfield, 2007). Figure 2.7 shows the four dimensions used for quality evaluation at school level. These dimensions/evaluations focus on the aspects of educational goals and objectives, mission and vision, including the different dimensions of context, input, process and product. The framework of implementation of CIPP model for quality evaluation. Additionally, there are also series of questions that guide the four elements of the CIPP process evaluation. Figure 2.7 is a type of logic model. A logic model is a visual depiction of the shared relationships among the resources, activities, outputs, outcomes, and impact for your program, also known as a Theory of Change. The logic model depicts the relationship between a program’s inputs, activities or processes and its intended effects, outcomes, or products (Reider, Knestis, &
Malyn-Smith, 2016). Once programs are underway, formative evaluation which include clear, coherent logic models create a continuous feedback loop that guides programmers’ decisions about changes and adaptations. This feedback loop forces programmers and practitioners to examine their enacted practices in light of their stated beliefs about program outcomes (Hollingworth, 2018).

Figure 2. 7

The CIPP Formative Evaluation Framework

Context evaluation. Looking at context as a part of the evaluation process helps to assess the needs and opportunities within the defined environment (Stufflebeam & Shinkfield, 2007). The objectives of context evaluation are to define, identify and address the needs of the target audience. This includes examining and describing the context of the school being evaluated. It includes an examination of the mission and vision as well as the goals and objectives of school (Khuwaja, 2001; Stufflebeam, 2002). The different types of methods for the evaluation of context include surveys, document reviews, data analysis and interviews (Stufflebeam, 2003). Some questions that context deals with are the following:

1. Are the mission and vision of the school suitable or not?
2. Do the goals and objectives generate from the mission and vision?
3. Are the courses taught relevant to the goals and objectives?
4. Is the school fulfilling non-academic needs?

**Input evaluation.** The purpose of input evaluation is to provide information for determining the resources used to meet the goals of the program (Khuwaja, 2001). The resources include time resources, human resources, physical resources, infrastructure, curriculum and content for evaluating the quality of education at school. Some questions that come under the context of input are:

1. What are the different skills that students will gain?
2. Is there any balance between the types of instruction delivered?
3. What type of resources should the school use for effective teaching and learning?
4. Are there active learning spaces for the students? What types of experiences are provided in the science laboratories and library? Are they well maintained?
5. How are teachers using their teaching skills for effective teaching learning?
6. Do the teachers have appropriate knowledge, skills and attitude for teaching?

**Process evaluation.** Process evaluation focuses on the running of the program and teaching learning processes. Implementation is a phase in which the inputs are used in effective manner to achieve the desired aims, objectives, goals of the product. The evaluator assesses the processes to understand how the school is working and which processes are responsible for maintaining the quality of education. In this phase, implementation decisions are made (Patil & Kalekar, 2014). Processes of the school include systematic approaches, teaching learning activities, parent teacher meetings, annual functions, co-curricular and extracurricular activities; it also includes student’s end of course and final examinations are analyzed (Print,1993). Process evaluations descriptions are guided by the questions like the following:

1. Has computer technology been used in many school practices?
2. Are teachers and students of the school actively participating in different activities?
3. Is there effective two-way communication between administration, teachers and other staff?

4. Can formative evaluation of teaching learning process be done?

5. Which types of activities are conducted in the school?

**Product evaluation.** Product evaluation focuses on the outcomes of the school. The focus of the product is not on the student’s achievement of grades but the knowledge, skills and dispositions they develop that will allow them to function in society. The purpose is to prepare students for college, career and life so that they can stand on their own after graduation (Scriven, 1994). The questions that guide school evaluation are:

1. What are the students’ achievements of in co-curricular and extracurricular activities?
2. What are the different summative and formative assessment strategies used by the teachers to assess learning?
3. How will students practically implement what they have learned?
4. How are the different activities of the students recorded?
5. How could quality of teachers and school reputation be improved?

The CIPP model deals with products or outcomes at different points during the beginning, implementation and designing of the educational program. Outcomes are then mapped with objectives, weaknesses are noted, and expected changes are made for the betterment of the quality of education (Sancer, Baturay & Fadde, 2013).

**Designing the evaluation study.** There are no best methods for conducting formative evaluation study, only those most appropriate to whatever the context requires. Stufflebeam (2003) advises that evaluators to use whatever methods necessary and useful to reach defensible judgment which could include both qualitative and quantitative methods. The evaluator should
also be careful to take into consideration the context or situation to be evaluated, the appropriate methods for data collection, how information is to be organized and analyzed; and reporting findings appropriately are all critical to any successful evaluation. So, when collecting data, an evaluator should be collecting, correcting, and initial analyzing and synthesizing information that ranges from background contexts to matters such as costs and types of activities.

The first step is to establish rapport and trust with the client and stakeholders. When evaluating the context, the evaluator should focus on laying a sound foundation for the potential study. According to Stufflebeam and Shinkfield (2007), careful preliminary investigation is pivotal. The goal is to stay focused on key questions, such as identifying key audiences, clarifying pertinent values and criteria, as well as determining information requirements about the project.

When organizing and analyzing information, all information collected should be systematically and accurately recorded, and securely kept. Analysis of information should be focused on answering the basic evaluation questions (Stufflebeam and Shinkfield 2007). Although evaluator and school administrator may collaborate to determine the basis of the study, it is the responsibility of the evaluator to synthesize and analyze the data to produce appropriate reports for the client. Evaluators need to analyze and synthesize information in order to provide clients with sound, meaningful and creditable information.

Results obtained from the analysis are then used for preparing and presenting oral and printed evaluation reports. Reporting activities may occur throughout and after completion of an evaluation study and should be communicated to all stakeholders in an efficient and timely manner, in order to foster the effective use of evaluation findings.

Reports may also take on descriptive and judgmental information. Stufflebeam (2003)
emphasizes that stakeholders must play a key role in determining evaluation questions, variables and interpretive criteria to ensure continual sharing and dissemination of information and improvements. It is advised that descriptive information be kept separate from judgments in a report, in order to stakeholders understand the value of what factors influenced the evaluation. Judgment-oriented feedback may be viewed as biased but is helpful when directed at identifying strengths and weaknesses. Figure 2-3 provides a summary overview of possible methods that can be used for each stage of CIPP.

According to Stufflebeam (2003), there is no need to conduct all four sections of a CIPP model, as CIPP treats evaluation design as a cyclical process of continually identifying and employing the appropriate means by which to address emergent needs. Evaluators are advised to regularly inform and seek consultation from stakeholders in order to invite reactions and suggestions regarding planned activities throughout the study, regardless of the stage of evaluation.
### Table 2.6

*Information Collection Procedures*

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(Stufflebeam and Shrinkfield, 2007)

**Strengths of CIPP.** While there is no set formula by which to design an evaluation study, when combined with rigorous instructions, the CIPP provides us with a versatile framework that allows the outcomes to be evaluated for improvement of a project. Even though, it was not designed for any specific program or solution (Guerra-López, 2010) it works well for educational program evaluation. CIPP is adaptable, lending itself to use in varying situations as a “...comprehensive framework for guiding formative and summative evaluations of projects, programs, personnel, products, institutions, and systems” (Stufflebeam, 2003). CIPP allows for evaluations to occur at any time during the evaluation so there is no need not wait until the
completion to evaluate (Guerra-López, 2010; Zhang, Zeller, Griffith, Metcalf, and Williams, 2011).

The stakeholder representatives in CIPP evaluations are active, not passive, participants helping to gain and provide information, from whom evaluators gain their information. Stufflebeam (2003) states that stakeholders help “...affirm foundational values; define evaluation questions; clarify evaluative criteria; contribute needed information; and assess valuation reports...” (p.11). All relevant stakeholders must be sought from all levels of influence, they are crucial to providing a thorough and sound evaluation. It is also ethically responsibility to empowers those who may not be represented in other forms evaluation (Stufflebeam, 2003). Even before the first context evaluation begins, Stufflebeam suggests the use of checklists for contractual agreements between the evaluator and stakeholder, followed by further activities for both parties and concluding with a checklist for the final report (Stufflebeam, 2003). An example of the checklist can be found in Appendix A.

**Limitations of the CIPP.** The thoroughness of the CIPP model is also one of its major limitations. From a theoretical perspective, the model is complete, robust, egalitarian, and flexible. Its critics contend that there are several situations exist which prevents evaluations from running smoothly. Organizational politics occurring within and between departments and organizations and therefore often present in the creation (and consequently the evaluation) of a learning space (Robinson, 2002). The requirement of equitable input from all stakeholder groups means that the process of evaluation can be slow, costly and complex (Angelova and Weas, 2008). Finally, it is in practice it is a top-down, managerial model dependent on rational decisions made at a management level, some collaboration is required (Robinson, 2002).
CIPP is not an infallible system, but rather a model to be used by an evaluator. The responsibility and accuracy of any evaluation is determined by the model but the decisions of the organization conducting it. CIPP provides a way to gain evidence-based data, to validate findings and develop a clearer understanding of the process and problems encountered when creating educational programs.

Summary

This chapter discussed the literature that shaped the design of the STEM Academy. Due to the complex nature of education, the constructivist, hybridity and third space theory serve as the theoretical framework of the Academy and the study. The Context/Input/Process/Product (CIPP) model will be used as the evaluation model. The relevance of the CIPP Model was analyzed for decision-making and accountability in this study.
Chapter 3: Research Method

The problem this study addressed is that improving the development and sustainability of STEM programs in rural areas via STEM schools-within-a-school academies is often negatively impacted by a lack of appropriate formative program evaluation. Previous study findings point to the fact that program evaluations create value and that incorporating evaluation into program design from creation throughout implementation has a positive impact on program development and sustainability (Frechtling, 2010; Jayaratne, 2016; Shavelson, 2018; Wilkerson & Haden, 2014).

The purpose of this qualitative study was to use perceptual data and formative evaluation methods as a means to investigate strategies for supporting the development and sustainability of a fledgling STEM academy at a rural high school in the Piedmont region of North Carolina. Formative program evaluation, sometimes referred to “utilization focused” evaluation, assesses the worth of a program while program activities are still forming (Wilkerson & Haden, 2014). It includes a range of formal and informal assessment procedures that take place during the course of program implementation and support the development and improvement of the program throughout its life cycle (Jayaratne, 2016; Shavelson, 2018). The data used to inform the study was culled from open-ended surveys, focus groups, and a large archival data set which was used to investigate the perceptions of administrators and educators on the best methods for supporting the development and sustainability of the program. The records included represent the perceptions and work product of teachers and administrators from a small, rural, public high school in the piedmont of North Carolina.

This study addressed the following three research questions:
RQ1. What distinguishing features of the creation and subsequent implementation of the HSTEM Academy were perceived as salient for program development and sustainability by respondents?

RQ2. How did perceptions of the STEM program vary among respondents who entered at different points in the implementation?

RQ3. How did perceptions of the STEM program vary among different subsets of respondents?

This research was undertaken to elicit and examine the perspectives of secondary STEM teachers and administrators by examining anonymized respondent records after respondents had taken part in focus groups and survey sessions around their work in the STEM academy. In direct response to the research questions and literature review, this qualitative, formative evaluation study was conceived to seek out and to make the perspectives of secondary STEM educators paramount to its design. Qualitative methods emphasize multiple voices, multiple perspectives, multiple interpretations, and the investigation of multiple truths and were therefore the methodology best suited to examining the perspectives of STEM educators (Creswell, 2013).

Defining the Sample

The first step in the process was defining the sample. Defining the sample required both attention to the key indicators for the formative evaluation so as to ensure the data sampling process produced a net wide enough to illuminate important aspects of the key indicators, but myopic enough to be manageable based on the limited time and fiscal resources available to the researcher. This step in the process also included clearly determining the parameters which created bounding for the study including the time period of implementation as well as which
respondent records and artifacts would be included or excluded based upon pre-determined
criteria. This helped the investigator narrow the possible data sources which needed to be
considered for the evaluation.

Sampling techniques facilitate the evaluation process when programs have large
numbers of members (i.e. many students, teachers, parents, and other interested stakeholders)
and voluminous amounts of artifacts that take a significant time to review. Assessing the entire
student or teacher population via census might have been possible as the students and teachers
participating in the program throughout the three years averaged 200 or less members; however,
the inclusion of the planning year and its subsequent documentation such as needs assessments,
budgets, and curriculum review added to the richness of the evaluation while at the same time
increasing its complexity and unwieldiness.

In addition to the response records represented by open-ended survey responses and
focus group transcripts, the investigator reviewed hundreds of pages of documents produced by
the teachers, school leaders, and district administrators during the course of the three-year
implementation. During the course of the study, the data set was mined via stratified sampling
techniques to determine teacher inclusion with nine total teachers or 20% of the educators being
selected for the study. Stratified sampling involves the investigator dividing the population
under study into separate groups, called strata (Tipton et al., 2014). Then, a probability sample
is drawn from each of the pre-defined groups within the population. Stratified sampling has
several advantages over simple random sampling. For example, using stratified sampling allows
the investigator to reduce the sample size required to achieve a given precision and conversely,
it may also be possible to increase the precision within the same sample size should the
necessity arise (Tipton et al., 2014).
The smaller number of administrators allowed for a census of their group and all three of the school leaders’ surveys and focus group responses were included. The archival data included 947 pages of artifacts that were either used for program planning or generated during the course of the previous 3 years of implementation. The primary and secondary data analysis was oriented from the lenses of STEM education, program evaluation, and professional development for STEM educators and will provide the STEM education community and interested stakeholders with an updated and specific understanding of how secondary STEM programs in rural settings might be improved to ensure growth and sustainability.

The procedures for the study consisted of (a) clearly identifying the phenomenon to be studied and ensuring that it was an issue of abiding concern and therefore worthy of study, (b) collecting data in the form of perceptual surveys, interview transcripts, focus group transcripts, and archival artifacts as described above (Burniske & Meibaum, 2012), (c) computer aided qualitative content analysis as a method of text analysis (Kohlbacher, 2006) using Qualitative Data Analysis software to reduce and condense (d) triangulation by two other researchers to validate the relationships between the data and the categories for describing the perspectives encoded within the data, (e) development of textural and structural descriptions, (f) and the combining of textural and structural descriptors (Creswell, 2013; Saldana, 2015; Vaismoradi et al., 2016).

The conceptual framework that supported the study was selected because of its relevance to the research questions and influenced how data were analyzed and interpreted to address the research questions. The three theories that comprised the conceptual framework and supported the analysis of the data were: Constructivist Theory as explicated by Slavin (2019), Piaget (1967), and Vygosty (1978); The Theory of Change as described by Wilkerson & Haden.

The introduction in Chapter 3 restates the problem, purpose, and research questions greater detail follows, where the research method and design are thoroughly examined and explained, along with the context of the study, study instruments, and methodology. The data collection process along with the analysis and interpretation procedures will also be detailed. In addition, this chapter provides a description of methodological assumptions, limitations, and delimitations related to the current study. Chapter 3 will conclude with an in-depth review of the ethical assurances and a summarization of the study and research methodology.

**Research Method and Design**

In response to a review of the literature, a qualitative study was designed to collect and analyze data while also addressing the gaps in the research literature relating to the issues surrounding formative evaluation of STEM programs in rural settings. The study design and methodology were for the purpose of using the CIPP formative evaluation model (Context, Input, Process and Product) as described by Stufflebeam (2005) in combination with perceptual data yielded from teachers and administrators to create a narrative about the program creation and subsequent implementation as well as to provide feedback for future improvements.

**Data mining and the data warehouse.** Data mining unearthed uninvestigated aspects of the identified phenomenon. The data set was generated in two parts. The first portion of the data set was generated by the local education agency as a part of its pre-implementation activities during the spring of 2017. These documents were generated prior to the beginning of this investigation and therefore will be referred to as archival data in this chapter and subsequent
others. The data were collected solely for non-research purposes during the academic school years of 2016, and 2017 for the purposes of developing a STEM implementation at High School “C.” The second portion of the data included perceptual data generated via open-ended surveys, focus groups, and interviews with leaders and educators in the district as well as implementation documents generated after the launch of the STEM academy implementation.

The respondent records included in the review were selected via stratified sampling techniques. Defining the sample required attention to the key indicators necessary for formative evaluation. This was to ensure the data sampling process produced a net wide enough to illuminate important aspects of the key indicators, but narrow enough to be manageable based on the limited time and fiscal resources available to the investigator. This step in the process also included clearly determining the parameters which created bounding for the study including the time period of implementation as well as which respondent records and artifacts would be included or excluded based upon pre-determined criteria. This helped the investigator narrow the possible data sources which needed to be considered for the evaluation.

Sampling techniques facilitate the evaluation process when programs have large numbers of members (i.e. many students, teachers, parents, and other interested stakeholders) and voluminous amounts of artifacts that take a significant time to review. Assessing the entire student or teacher population via census might have been possible as the students and teachers participating in the program throughout the three years averaged 200 or less members; however, the inclusion of the planning year and its subsequent documentation such as needs assessments, budgets, and curriculum review added to the richness of the evaluation while at the same time increasing the complexity of the analysis and extending the time necessary for its completion.
Prior to receiving the data set, the principle investigator shared the member requirements for the respondent records and the school district data manager conducted an ad hoc query of the district data warehouse to identify documents meeting the required criteria. The subsequent dataset was then anonymized and transmitted to the researcher via the secure server. Via the sampling techniques, the respondent record pool was narrowed from an original data set of 17 respondent records to 13 selected records which represented a group of educators that were alike in their shared experience of the STEM academy program, and therefore represented a community of interest. This sampling technique for respondent record inclusion was most effective for selecting pertinent records for cross-case analysis within this study, and it increased the likelihood of transferability (Creswell, 2013b). Each respondent record served as its own case. The other 947 archival documents included within the investigation were culled from the thousands of documents generated during the course of the three-year implementation, and selected based on their inclusion of particular a priori codes, developed prior to the study based on keywords from the literature review and the theoretical frameworks. All of these documents were a part of the data set, which was housed in a password protected data repository on a secure server at the organization’s district offices. Per the final NCSU approved IRB application, this data set was restricted to the document types described in Table 3.1.

Qualitative design as a methodology was determined to be the most appropriate for this study because the study did not focus on specific or pre-defined variables regarding the findings. Instead, this qualitative study achieved its purpose by addressing research questions designed to mine and make meaning of the implicitly and explicitly stated perceptions of the participants (Dowd, 2015; Yin, 2013). The findings of the study were based on themes that emerged during content analysis process (Kohlbacher, 2006). This open-ended approach
provided the researcher with an opportunity to acquire perceptual data in an unobtrusive, non-threatening, manner (Yin, 2013).

To ensure trustworthiness of the proposed study, quality measures were addressed to protect internal validity, support transferability, sustain credibility, and provide for confirmability (Lincoln & Guba, 1986; Stake, 2013; 2006). Credibility was addressed via the analytic processes of expert review, triangulation of multiple data points, pattern matching, and review of the literature as it related to this study’s research questions (Yin, 2014). Further augmenting credibility was the deployment of the qualitative analysis software program Dedoose version 8.2.14 which was used to provide a detailed account of the activities and research decisions made throughout the course of this study (Miles, Huberman, & Saldana, 2013; Talanquer, 2014; Yin, 2014).

Transferability was addressed through the detailed discussion of sampling techniques, the gathering of representative data, developing copious descriptions, and clearly expressing the assumptions that will be important to the research process (Yin, 2014). One of the goals of this study was that the research design and findings serve as an example for researchers and practitioners in similar situations and contexts to make comparisons and transfer insights (Saldaña, 2015). To enhance confirmability, steps were taken to ensure that the study’s findings were the result of codes and themes arising from the review of the records and archival documents and not the perspective of the researcher (Yin, 2014). Confirmability indicates the degree to which the research findings can be replicated and therefore corroborated by others. Measures were taken to integrate multiple data points and maintain chronological documentation demonstrating the custody, control, transfer, analysis, and disposition of the electronic artifacts. Dedoose version 8.2.14 supported in documenting these measures.
**Evaluation of data using the CIPP framework.** CIPP is a systematic approach to program analysis. This format was chosen because effective evaluation practices stipulate that the researcher selects data collection methods that align to the program’s duration and intended outcomes. To ensure that the formative evaluation provided actionable feedback and practices that the organization could continue to use after the conclusion of the study, it the investigator aligned the data collection practices with the intended outcomes of the program (Fixsenet, 2005; Wilkerson & Haden, 2014). Additionally, formative evaluation practices are most appropriate for nascent programs of shorter for the purpose of planning and continuous improvement (Jayaratne, 2016). In the context of a newly launched program, the data collection techniques need to provide as much rigor as possible while keeping in mind the limited time, resources, and previous evaluation activities (Wilkerson & Haden, 2014). It is the most appropriate for triangulation and for adding both breadth and depth to examine the issues surrounding the development of the STEM Academy (Guerra-Lopez, 2010; Hollingworth, 2018).

**Materials and Instrumentation**

In order to address the voluminous amounts of data generated both before and during the implementation, it was necessary to review myriad documents in a formal analytic manner. Content and thematic modes of analysis and interpretation via the lens of multiple theoretical frameworks provided a way to make meaning of and connect the numerous data sources. In this way, perspectives of both the teachers and leaders who participated in this study were identified.

To enhance the trustworthiness of the study, the investigator included multiple methods of triangulation which served to illuminate the emergent themes such as the crisis of leadership caused by the departure of high level administrators and the knowledge gap created by lack of appropriate professional development. These insights were revealed as a result of triangulation.
of complementary theories, triangulation of several modes of data analysis including Content Analysis (Miles, Huberman, & Saldana, 2013), Critical Discourse Analysis (Fairclough, 1992; Henderson, 2005), and Thematic Analysis (Aronson, 1995). Respondent records were initially compared through cross-case analysis and compared with the numerous artifacts types represented in table 3.1.
### Document Review Categories

#### Planning Documents
- *Initial Implementation Program (April 2017)*
- *Initial Logic Plan*
- *Implementation Plan Rev. (March 2018)*
- *Implementation Plan Rev. (August 2019)*

#### Open Ended Survey Responses
- Participant #1
- Participant #2
- Participant #3
- Participant #4
- Participant #5
- Participant #6
- Participant #7
- Participant #8
- Participant #9
- Admin Participant #1
- Admin Participant #2
- Admin Participant #3
- Admin Participant #4

#### Transcripts
- *Focus Group 1 (participants)*
- *Focus Group 2 (administrator 1)*
- *Focus Group 3 (administrator 2, 3, 4)*

#### Grant Program Documents
- *SREB Professional Development Grant*
- *SREB Submission Guidelines*
- *Governor’s Innovation Grant (2017)*
- *Governor’s Innovation Grant (2018)*

#### School Board Minutes
- *Jan ----, 2017, 2018, 2019, 2020*
- *Feb ----, 2017, 2018, 2019, 2020*
- *Mar----, 2017, 2018, 2019, 2020*
- *May 2017, 2018, 2019*
- *Jun 2017, 2018, 2019*
- *Jul 2017, 2018, 2019*
- *Aug 2017, 2018, 2019*
- *Sep 2017, 2018, 2019*
- *Oct 2017, 2018, 2019*
- *Nov 2017, 2018, 2019*
- *Dec 2017, 2018, 2019*

#### HR Retention/Attrition Reports
- *High School A (administrators)*
- *High School B (administrators)*
- *High School C (administrators)*

#### HR Retention/Attrition Reports (Teachers)
- *SY 2017/2018*
- *SY 2018/2019*
- *SY 2019/----*

#### Student Retention/Attrition Reports
- *SY 2018/2019*
- *SY 2019/----*

#### Transcripts
- *Focus Group 1 (participants)*
- *Focus Group 2 (administrator 1)*
- *Focus Group 3 (administrator 2, 3, 4)*

#### Budgets
- *AMSTA Budget Formulas*
- *School Budget (2016/2017)*
- *School Budget (2017/2018)*
- *School Budget (2018/2019)*
- *School Budget (2019/2020)*

#### Calendars/Schedules
- Masters Schedules
- *School Master Schedule (2015)*
- *School Master Schedule (2016)*
- *School Master Schedule (2017)*
- *School Master Schedule (2018)*
- *School Master Schedule (2019)*
- *School Master Schedule (2020)*
- *2016/2017 Calendar*
- *2017/2018 Calendar*
- *2018/2019 Calendar*
- *2019/2020 Calendar*

#### Standards/Curriculum Documents
- *NC Biology Standards*
- *NC Chemistry Standards*
- *Earth & Environmental Standards*
- *Environmental Science Standards*
- *Physical Science Standards*
- *Science, Technology, Engineering, & Mathematics CTE Career Clusters*
- *Next Generation Science Standards (2013)*
- *Project Lead The Way PLTW Engineering Curriculum (2013)*

#### Government Documents
- *Remarks by the President in the State of the Union Address—White House Office of the Press Secretary (2013)*
- *President’s Council of Advisors on Science & Technology (2012)*
- *President’s Council of Advisors on Science & Technology (2013)*

#### Planning Documents
- *Professional Development Plan*
- *SY 2016/2017*
- *SY 2017/2018*
- *SY 2018/2019*
- *SY 2019/----*

#### Empirical Research
- *Edrogan and Stuessy’s Modeling Successful STEM High Schools in the United States: An Ecology Framework (2015).*
There was also triangulation via verification of codes and theme entries by several experts within the fields of both STEM education and implementation science (Male, 2016; Vaismoradi et al., 2016). Two experienced investigators both of whom have earned graduate degrees in a STEM related field and are experienced administrators and professional developers, contributed to code validation and the development of the code tree (Bates et al., 2019). The purpose of the development of the code tree was to support thematic analysis. The code trees are represented in tables in appendices D and E and helped to describe the context and categorize both the respondent records and the organization’s discourse as represented by the other artifacts. Finally, there was theory triangulation to demonstrate whether the prevailing theories of constructivism, third space, or professional development for STEM educators could have predicted, explained, or supported the interpretation of the findings. Data analysis provided direction for interpretation, theory validation, development of propositions, as well as support for the rationale for this study (Yin, 2014).

The materials and instrumentation that were used in the study included the following: (a) the researcher, who served as analyst and interpreter; (b) content experts; (c) Miles, Huberman, & Saldana, 2013’s (2013) coding protocol and the Adapted Steps for Critical Discourse Analysis (see Table 3.2); (d) artifacts from the 2017 pre-implementation year, and artifacts generated during the 2017, and 2018, and 2019 school year’s STEM academy implementation program; (e) open-ended survey responses; (f) transcripts from focus groups and interviews and; (g) Dedoose version 8.2.14, a qualitative analytic software program.
Table 3. 2

*Adapted Steps for Critical Discourse Analysis, Based on Fairclough’s Model (1992)*

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Selection of text or text excerpts</td>
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<td>2</td>
<td>Identify words or phrases that reveal the text’s attitude toward its subject (tone/mood)</td>
</tr>
<tr>
<td>3</td>
<td>Consider how the text or text excerpt includes or excludes readers from a community of interest or practice based on wording that is marginalizing or inclusive (e.g. disabled persons vs differently-abled persons)</td>
</tr>
<tr>
<td>4</td>
<td>Search for assumed interpretations that the text has already made (e.g. text that assumes its readers agree that one particular method of reading instruction is superior over another such as synthetic phonics vs analytic phonics)</td>
</tr>
<tr>
<td>5</td>
<td>Consider text form and production and think about the context of the text’s creation</td>
</tr>
<tr>
<td>6</td>
<td>Examine the form of the text (e.g. print vs electric, open access vs password protected) and consider who has access and who does not; analyze quotations and borrowed language</td>
</tr>
<tr>
<td>7</td>
<td>Examine the ways in which the text reveals context, culture, climate, and traditions</td>
</tr>
<tr>
<td>8</td>
<td>Consider the ways in which cultural norms may exist locally, nationally, or internationally for a particular community of interest or community of practice</td>
</tr>
<tr>
<td>9</td>
<td>Determine wither norms are being held by a culture or sub-culture (e.g. Do the special educators in general represent a sub-culture? Do the special educators within this particular context form sub-culture with its on cultural norms?)</td>
</tr>
</tbody>
</table>

**Coding.** Following the conclusion of data retrieval, the data was compiled, and Miles, Huberman, & Saldana, 2013’s coding processes as well as a modified Faircloughian Discourse Analysis model was used to classify and organize data in Dedoose version 8.2.14, a computer assisted qualitative data analysis software (CAQDAS) program. Respondent records were numerically coded and assigned numerical label pseudonyms that were used throughout the duration of the study. Each de-identified respondent record file was labeled with the appropriate pseudonym and placed in the numerically coded folder representing the discipline the teacher taught and the year they entered the STEM program implementation.
Following completion of data entry, collected materials were kept in a passcode protected external storage device and kept in a fire-proof safe in the investigators’ home. After data entry in Dedoose, the de-identified respondent records destroyed, per the request of the cooperating district. Following completion of the study, all remaining physical data was shredded and destroyed. The computer-based data will be stored on the external hard drive for up to 7 years in the researcher’s fire-proof safe. This supports the chain of evidence that enhances the dependability of the study.

Assumptions

The data retrieval and evaluation of the current research study was based upon six critical assumptions. They were as follows: First, the researcher would be granted continued access to the site, High School “C” which was under study and accompanying data sets. Second, the Superintendent and members of the local school board as well as the site principal would grant permission to use data generated by their school sites for this research study. Third, the selected respondent records would be appropriately de-identified, while leaving in place their personal demographic characteristics (e.g. years of service, educational attainment, licensure area, etc.) and that their identified characteristics would be representative of the population under study. Fourth, the selected respondent records would represent participants that had an understanding of the current STEM educational programming. Fifth, the respondent records represented honest responses to the surveys and focus groups questions and that they were in no way influenced by way of tangible, intangible, real, or perceived incentives or possible retribution. Ensuring this assumption was met proved to be a limitation of the study as the surveys were administered prior to investigator meeting with the teachers.
Data collection. The research protocol was developed based upon the aforementioned assumptions which allowed for the stratified sampling technique used to determine teacher inclusion with nine total teachers or 20% of the educators being selected for the study. The smaller number of administrators allowed for a census of their group and all four of the school leaders’ surveys and focus group responses were included. For the collection of the artifact data, a sample was chosen based on the breadth, length, and complexity of the artifacts. There were nearly 3000 pages of documents, multi-media, videos, and work product that were either used for program planning or generated during the course of the previous 3 years of implementation; 947 pages of artifacts, or approximately 30% of the available artifacts, were included within the investigation which were culled from the thousands of pages generated during the course of the program and selected based on whether the document included particular a priori codes developed prior to the study based on keywords from the literature review and the theoretical frameworks (see Appendix E for the code tree used to make these determinations).

Limitations

The first three phases of the CIPP evaluation model were conducted as opposed to the evaluation in its entirety because these cycles best served the purpose of this study. The sample was not representative of any larger population of rural teachers or STEM teachers. This study was confined to interviewing a purposeful sample current STEM Academy teachers and district as well as school level administrators in the local education agency where the rural high school “C” was located.

As in any research project, bias is inherent. The responsibility and accuracy of any evaluation is determined not by the model, but by the decisions of the organization conducting
CIPP provided a way to gain evidence-based data, to validate findings, and develop a clearer understanding of the process and problems encountered when creating STEM educational programs. A key problem in evaluation research is the courtesy bias, where-in respondents tend to tell researchers what they (are perceived to) want to hear (or what the respondents would like them to communicate) (Bavinck, 2008). The strategies for tackling bias at the level of the individual evaluation are being systematic, transparent, and reflexive. Being systematic involves having (and publishing) a clear research plan outlining the nature and sources of data and specifying the design of instruments and protocols for fieldwork and analysis.

To avoid researcher effects, Miles and Huberman (1994) suggest: (a) stay on-site as long as possible, (b) use unobtrusive measures where possible, and (c) make sure the research intentions are unequivocal for informants. In addition, the research site can affect the researcher. To minimize these effects, Miles and Huberman (1994) suggests: (a) avoid "elite" bias by including lower-status informants, (b) spread out site visits, (c) triangulate data, and (d) keep research questions firmly in mind. A specific limitation to this study was that there were no continuity of the researcher’s presence in the classrooms as student level data was excluded from the project late in the investigation by request of the senior level district administrators. According to Miles and Huberman (1994), the inclination is to make inferences (possibly erroneous) that connect any gaps. Since this type of research is interpretive and value laden, the researcher’s interpretations and biases will naturally play a key role in the analysis of this research.

The researcher serves as educational administrator in the rural school district and was privy to information about the new initiative. This could be a source of potential bias. However,
the benefit of this program evaluation outweighs this limitation, and the evaluation of the STEM Academy provided additional insight into program needs and areas for improvement.

**Delimitations**

To ensure that this study would align to the articulated questions, maintain integrity in terms of its purposes, and remain reasonable in scale, several delimitations were included to bound the study, narrow the scope, and maintain clarity (Stake, 2013). This was accomplished by making data retrieval time-bound and disallowing entries into the dataset that did not fall within the time span between March of 2017 and March of 2020. The location was also bounded as only High school “C” within the local education agency was considered, limiting participation within a pre-set geographical boundary.

Most qualitative case studies that take steps to ensure a very small and defined group allow for almost no transferability to the wider population (Firestone, 1993). However, given that the sample was not randomly selected and given the protocols for careful selection of participants and the protocols put in place for the triangulation of data, the credibility of this study was substantially strengthened and therefore findings should be highly transferable to similar contexts and situations (Firestone, 1993).

Statistical research was not appropriate for the subjective analyses of participant perspectives, and research questions were not answerable by quantifying terminology such as how much or how many. However, the researcher expected strong themes to emerge that would support the LEAs efforts to improve their evidence-based practices around program evaluation and professional development practices for STEM educators and allow other rural districts of similar size, demographics, and context to replicate the practices with positive outcomes (Firestone, 1993).
Ethical Assurances

Prior to collecting data, the completed North Carolina State University Institutional Review Board (NCSUIRB) application and addendum documents were submitted, along with site and data collection permission letters. Consent was received from ABC County Schools (a pseudonym) Superintendent of Schools to retrieve de-identified data from the 2017-2020 related to the STEM academy at High School “C”. Permission was likewise requested from participating principal to access aggregate student data generated from the STEM academy implementation. The site permission requests was emailed to the participating principal which defined eligibility requirements, risks and benefits, confidentiality protocol, and the voluntary status for participation to ensure school and respondent record anonymity and protection from harm. The district was informed of their right to refuse or withdraw participation.

The aforementioned processes protected against invasion of privacy through re-identification and breaches of confidentiality. All efforts were made to maintain transparency and no verbal assurances or written communications were made for the purposes of manipulating or deceiving district leadership, school leaders, or teachers. No identifying data was collected by the researcher, with the exception of randomly computer generated identification numbers and to protect anonymity. The site names and participants’ names were replaced with computer generated identification numbers. The identities of participants were not a part of the data set nor entered into the qualitative analysis software. Email addresses were not to be included in the respondent records and were scrubbed from emails and other subsequent documents prior to the data being accessed by the investigator. The researcher’s physical copies of archival records were destroyed following data entry into
Dedoose. No additional copies of the records were created and the originals were retained by the local education agency. No compensation was provided for anyone associated with this study, but a copy of the research findings will be given to the district upon completion of the investigation and made available upon request for interested parties. In accordance to NCSU’s IRB process, carefully designed protocols and procedures, and honest and regular communication between the researcher and the senior leadership of the district under study, a wide-range of possible negative events were avoided and all reasonable actions were undertaken to produce minimal risk.

Summary

The purpose of this qualitative study was to use perceptual data and formative evaluation methods as a means to investigate strategies for supporting the development and sustainability of a fledgling STEM academy at a rural high school in the Piedmont region of North Carolina. The data used to inform the study was culled from open-ended surveys, focus groups, and a large archival data set which was used to investigate the perceptions of administrators and educators on the best methods for supporting the development and sustainability of the program. The records included represent the perceptions and work product of teachers and administrators from a small, rural, public high school in the piedmont of North Carolina. Prior to receipt of all signed consents for district and site participation, district leaders were provided with informed consent documents that defined eligibility requirements, risks and benefits, confidentiality protocol, and the voluntary status for participation to ensure school and participant anonymity and protection from harm. After retaining approval for the NCU IRB, 13 respondent records and 947 other documents were selected. The document data was a part of an aggregate data set pulled from the bounded time period of March of 2017 to March 2020.
Data ranging from open-ended surveys, focus group transcripts, emails, school board meeting minutes, district-level and site-level implementation plans, professional development agendas, and standards documents, to name a few, were entered into Dedoose along with other relevant archival data, to determine themes and patterns within and across cases (van Manen, 2016). Expert review and debriefing of the research processes provided multiple perspectives, dependability, and confirmability of data findings (Yin, 2014). Credibility was maintained through triangulation of data which included supporting archival documents, and the cross-case analysis of the 13 respondent records (Stake, 2013; Yin, 2014). Respondent records and other documents were comparatively analyzed to examine emergent themes, and categorization of data, which will allow for literal and theoretical replication and interpretation (Firestone, 1993; Yin, 2014).
Chapter 4: Findings

The purpose of this qualitative study was to use formative program evaluation methods to investigate the perceptions of secondary school leaders and educators on the best methods for supporting the continued development and sustainability of a fledgling STEM academy at a rural high school in the Piedmont region of North Carolina. STEM educators increasingly understand the importance and value of incorporating evaluation into program design from creation through implementation (Wilkerson & Haden, 2014). A formative program evaluation is defined as a range of formal and informal assessment procedures that take place in process, or during the course of a program, to help determine and improve program outcomes (Smith & Branstetter, 2016). Formative program evaluations, also known as “utilization focused evaluations”, are particularly apt for activities such judging the worth or impact of a program, diagnosing potential problems in the early stages, and monitoring adaptations and adjustments throughout the life cycle of an implementation since they can be conducted at any phase during the instructional design process (McClintock, 1984).

Program implementation is a process that unfolds over time in a series of stages that are sequential but also require interactive cycles of reflection and revision. In this sense, they can be conceptualized as four stages that overlap. Those four stages include: (1) exploration, (2) installation, (3) initial implementation, and (4) full implementation (Fixsen, Naoom, Blase, Friedman, & Wallace, 2005; Permanency Innovations Initiative Training and Technical Assistance Project, 2013). Formative evaluation of the program takes place during the third stage of the program cycle, initial implementation.

Specifically, this study was undertaken to address the following research questions:
• RQ1. What distinguishing features of the creation and subsequent implementation of the STEM Academy were perceived as salient for program development and sustainability by respondents?
• RQ2. How did perceptions of the STEM program vary among respondents who entered at different points in the implementation?
• RQ3. How did perceptions of the STEM program vary among different subsets of respondents?

Chapter 4 includes the following three sections: results (where the results of the study have been aligned to answer the research questions and address the emergent themes), evaluation of the findings, and summary. In the trustworthiness of data section, an overview is presented of the data collection and analysis process. Additionally, there are descriptions of the data by type, demographic descriptions of the survey respondents, demographic descriptions of the STEM academy members, and finally characteristics of the STEM program itself.

The results of the study are presented in a combination of tables and narrative in the results section. The interpretation of results in accordance with the defined conceptual framework is presented in the evaluation of findings. Within the chapter summary, key points are addressed that emphasize the importance of the study’s findings.

**Credibility via triangulation.** The participant data as well as the archival documents employed were generated during the data collection period stipulated within the approved North Carolina State University IRB application. The participant data collection period ranged from August 2019 to March of 2020. Many of the archival documents employed for the document review portion of the study were developed prior to the undertaking of this study at the impetus of the senior leadership within the local education agency (LEA) as a partial response to
accountability requirements internal to the organization as well as agencies external to the organization such as grant funders, corporate partners, and the North Carolina Department of Public Instruction. The array of archival documents used for this investigation spanned the years of the program’s pre-implementation year which was from June 2016 until the present.

In order to address the voluminous amounts of data, most of which were qualitative in nature, it was necessary to review a number of documents that made up this STEM academy’s system of discourse in a formal analytic manner. Archival modes of analysis and interpretation via the lens of multiple theoretical frameworks provided a way to make meaning of and connect the disparate data sources. In addition to the archival modes of analysis, all of the data was codified via thematic analysis by identifying preselected apriori codes present in the relevant literature which also appeared in either the documents or the participant responses. In vivo codes within the documents and participant responses were also identified when responses appeared multiple times across different participant responses or different archival documents. The preselected apriori codes as well as the in vivo codes used to determine themes may be found in the code tree in Appendix E. The purpose of the development of the code tree was to support thematic analysis. The code tree helped to categorize both the respondent records and the archival artifacts.

To enhance the trustworthiness of the study, the investigator included multiple methods of triangulation which served to illuminate concepts such as the crisis caused by multiple changes in leadership and teacher attrition, issues around subject integration as well as curriculum and design, and lack of clarity around program objectives and goals. These insights were revealed as a result of triangulation of several modes of data analysis including content analysis (Miles, Huberman, & Saldana, 2013), critical discourse analysis (Fairclough, 1992;
Henderson, 2005), and thematic analysis (Aronson, 1995). Respondent records were initially compared through cross-case analysis and paralleled with archival artifacts. There was also triangulation via verification of codes and theme entries by several experts within the fields of both implementation science and STEM education (Male, 2016; Vaismoradi et al., 2016). Two experienced investigators, both of whom have earned graduate degrees in STEM disciplines and organizational leadership contributed to code validation.

Finally, all of the data was evaluated based on the outputs and outcomes of the original Logic Model which codified the organization’s Theory of Change. Appendix F visually represents the organization’s Logic Model for the current implementation. The development of the logic model was used by program developers to clarify the processes for program development and implementation as well as make cause-and-effect connections about how the program moved from activities to outputs and outcomes (Hollingworth, 2018). Responses from participant surveys, focus group transcripts, and secondary student data, as well as the archival documents, were used to address the proposed outputs and outcomes as part of the formative evaluation. Each of the outcomes are connected to indicators which are measurable information was used to determine if the program was implemented as expected and to corroborate or refute the perceptions expressed by the participants in survey responses or focus groups.

Indicators included data such as teacher attrition, aggregate student grade data, attendance, and disciplinary data. Data analysis provided direction for interpretation, theory validation, development of propositions, as well as support for the rationale for this study (Yin, 2014). In this way, perspectives of both the educators and the leaders who participated in this program were not identified, contradictions between stated and enacted practices were revealed, and power dynamics pertinent to the program development and sustainability were illuminated.
All of the aforementioned contributed to the uncovering of the perceptions expressed within the participant surveys as well as teasing out the program’s procedural and pedagogical practices which were embedded within the archival data (Ventresca & Mohr, 2017).

Finally, there was theory triangulation to demonstrate whether the prevailing theories related to STEM education could have predicted, explained, or supported the interpretation of the findings. To glean the perceptions of the STEM educators and administrators as it related to program development and sustainability, triangulation of both theory and the various data points was necessary and promoted the understanding of the phenomenon (Fusch, Fusch, & Ness, 2018). Data analysis provided direction for interpretation, theory validation, and development of propositions, as well as support for the rationale for this study (Yin, 2014).

Prior to this investigation, during the years of 2016 and 2017, the organization embarked upon a pre-implementation planning year, or an exploratory phase, to use the formative evaluation terminology (Fixsen et al., 2005). Artifact #18 outlined the plan for the STEM implementation to the local school board and other stakeholders. The specific aims of the program included (1) developing a STEM academy based on the “school within a school” model to improve the educational opportunities of the students within the LEA and (2) to increase enrollment at one of the counties three high schools, thereby lessening the infrastructural strain at the other two sites caused by overcapacity enrollment and creating a more equitable division of fiscal and human resources across the district.

Although the logic model and implementation plan for the program listed school year 2017-2018 as year one of implementation, in order to be able to consider the pre-planning documents as a part of the artifact review, the sample needed to include data from the pre-planning year as well. This not only added to the span of time considered by the investigation,
but also increased the number of possible participants to be considered for sampling purposes as school board members, business and industry partners, and parents all provided input on the initial plan for implementation which was presented to the school board as well as the community at large.

Effective evaluation practices stipulate that one selects the appropriate data and data collection methods to align to the program’s duration and intended outcomes. However, more often than not the evaluation budgets for STEM programs are minimal. To ensure that this formative evaluation provided tools and practices that the district could continue to use after the conclusion of the study, it was important that the investigator aligned the data collection practices with the intended outcomes of the program, and maximized the evaluation offerings while minimizing the time and expense necessary to analyze the data and report on findings. In order to accomplish this, the investigator chose sampling techniques which offered a balance between rigor and future applicability. In general, the more rigorous the evaluation study, the more justified evaluators are in making causal claims regarding program effectiveness. In order to do this appropriately, rigor typically involves costly and complicated randomized control trials or quasi-experimental designs (Rossi et al., 2003). However, this level of rigor is more appropriate for more well-established STEM programs of longer duration which have already been in the regular practice of using evidence-based evaluation techniques for planning and continuous improvement. In the context of this fledgling program, the data sampling techniques needed to provide as much rigor as possible while keeping in mind the limited time, resources, and previous evaluation activities.

The results of the study have been aligned to answer the research questions and address the emergent themes. The investigator determined that the information gleaned from the
aforementioned data sources justified its inclusion and therefore sampling would be the more effective technique for the participant data and an appropriate tradeoff. This allowed for the inclusion of thick, rich data while also including an appropriate cross section of data from participants to triangulate with data obtained from artifacts. With this in mind, a stratified sampling technique was employed in this study, where-in participants were sorted into homogenous groups and then a random sample was selected from each group.

Due to additional restrictions on data collection after a recent leadership change, disaggregated student information was disallowed for use in the study. Only aggregate data and publicly available disaggregated data were permitted for use on the student participants. Therefore, the focus of this study was shifted towards two groups: STEM teachers or educators, and the administrators or school leaders who had direct contact and oversight of the STEM academy program. This left the two much smaller homogenous groups of educators and leaders. The response rate for the teacher surveys was 9 of 17 or 53% while the administrator response was 4 of 4 or 100% with all three building level administrators responding as well as the responsible central office administrator. The stratified sampling technique was used to determine teacher inclusion with nine total teachers or 20% of the educators being selected for the study. The smaller number of administrators allowed for a census of their group and all four of the school leaders’ surveys and focus group responses were included.

For the collection of the artifact data, a sample was chosen based on the breadth, length, and complexity of the artifacts. There were many pages of documents, multi-media, videos, and work product that were either used for program planning or generated during the course of the previous 3 years of implementation; 947 pages of artifacts, or approximately 30% of the available artifacts, were included within the investigation which were culled from the hundreds
of pages generated during the course of the program and selected based on whether the
document included particular a priori codes developed prior to the study based on keywords
from the literature review and the theoretical frameworks (see Appendix E for the code tree
used to make these determinations). A priori codes are codes that are developed before
examining the current data. Using a priori codes is frequently referred to as a "deductive" form
of analysis, while building the codes during the analysis would be in vivo or "inductive"
(Fereday & Muir-Cochrane, 2006). Most of these documents were a part of the privately held
data set, which was housed in a password protected data repository on a secure server at the
organization’s central offices. Some of the documents such as empirical literature, standards
documents, and student demographic data were available publicly via the World Wide Web or
in public data suppositories such as the public library. Several pieces of empirical literature
were included as part of the citations associated with the Logic Model and the implementation
plan. Programmers and staff were asked to read these documents as a part of their professional
development activities and their review was listed as a part of the activities within the original
Logic Model. One such document was Edrogan and Stuessy’s *Modeling Successful STEM High
included documents such as the National Science Board’s *Science and Engineering* Indicators
(2012) and the *Next Generation Science* Standards (2013). Student demographic data included
information such as age, race, free/reduced lunch status, aggregate grade point averages, and
attrition/matriculation rates. Per the final NCSU approved IRB application, this data set was
restricted to the following:
• Open-ended perceptual surveys from educators and teacher leaders of which there were thirteen, 9 from teachers and 4 from school leaders (see the survey questions in Appendix F)

• Transcripts from focus groups held with educators and teacher leaders. The teacher focus group included 9 participants and lasted for approximately 90 minutes. There were two school leader focus groups. The first of which consisted of the two assistant principals and the current interim STEM coordinator. The head of school was interviewed separately from the assistant administrators.

• Interviews from the school leaders. The head of school did not participate in the focus group; for fear that her presence would influence the responses of her subordinates. The central office administrator was interviewed separately for this same reason.

• Demographic data collected via the survey instruments

• Professional development agendas associated with the STEM Academy

• Professional articles, journal articles, and texts which were provided to respondents or referenced by developers during the course of the STEM implementation

• PowerPoints from the professional development trainings

• Meeting minutes and agendas generated by the STEM academy professional learning community

• Sample lesson and unit plans written by participants and trainers during course of the program implementation

Table 4.1 describes the document categories used to organize the data for review.
# Table 4.1

## Document Review Categories

### Planning Documents
- Initial Implementation Program (April 2017)
- Initial Logic Plan
- Implementation Plan Rev. (March 2018)
- Implementation Plan Rev. (August 2018)

### Open Ended Survey Responses
- Participant #1
- Participant #2
- Participant #3
- Participant #4
- Participant #5
- Participant #6
- Participant #7
- Participant #8
- Participant #9
- Admin Participant #1
- Admin Participant #2
- Admin Participant #3
- Admin Participant #4

### Transcripts
- Focus Group 1 (participants)
- Focus Group 2 (administrator 1)
- Focus Group 3 (administrator 2, 3, 4)

### Grant Program Documents
- SREB Professional Development Grant
- SREB Submission Guidelines
- Governor’s Innovation Grant (2017)
- Governor’s Innovation Grant (2018)

### School Board Minutes
- Jan 2017, 2018, 2019, 2020
- Feb 2017, 2018, 2019, 2020
- Mar 2017, 2018, 2019, 2020
- Apr 2016, 2017, 2018, 2019
- May 2016, 2017, 2018, 2019
- Jun 2016, 2017, 2018, 2019
- Jul 2016, 2017, 2018, 2019
- Aug 2016, 2017, 2018, 2019
- Sep 2016, 2017, 2018, 2019
- Nov 2016, 2017, 2018, 2019
- Dec 2016, 2017, 2018, 2019

### HR Retention/Attritions Reports (Teachers)
- SY 2016/2017
- SY 2017/2018
- SY 2018/2019
- SY 2019/----

### HR Retention/Attritions Reports (Administrators)
- High School A
- SY 2016/2017
- SY 2017/2018
- SY 2018/2019
- SY 2019/----

### HR Retention/Attrition Reports
- High School B
- SY 2016/2017
- SY 2017/2018
- SY 2018/2019
- SY 2019/----

### HR Retention/Attrition Reports
- High School C
- SY 2016/2017
- SY 2017/2018
- SY 2018/2019
- SY 2019/----

### Budgets
- AMSTA Budget Formulas
- School Budget

### Calendars/Schedules
- School Master Schedule (2015)
- School Master Schedule (2016)
- School Master Schedule (2017)
- School Master Schedule (2018)
- School Master Schedule (2019)
- School Master Schedule (2020)
- 2016/2017 Calendar
- 2017/2018 Calendar
- 2018/2019 Calendar
- 2019/2020 Calendar

### Standards/Curriculum Documents
- NC Biology Standards
- NC Chemistry Standards
- Earth & Environmental Standards
- Environmental Science Standards
- Physical Science Standards
- Science, Technology, Engineering, & Mathematics CTE Career Clusters
- Next Generation Science Standards (2013)

### General Documents
- Remarks by the President in the State of the Union Address—White House Office of the Press Secretary (2013)
- President’s Council of Advisors on Science & Technology (2012)
- Report to the President: Engage to excel: Producing one million additional college graduates with degrees in Science, Technology, Engineering, & Mathematics

### Government Documents
- Professional Development Plan
- SY 2016/2017
- SY 2017/2018
- SY 2018/2019
- SY 2019/----

### Government Documents
- District Strategic Plan
- SY 2016/2017
- SY 2017/2018
- SY 2018/2019
- SY 2019/----

### Government Documents
- School Improvement Plan
- SY 2016/2017
- SY 2017/2018
- SY 2018/2019
- SY 2019/----

### Government Documents
As a result of the aforementioned sampling techniques and the selection criteria, 9 educator records, 3 school leader records, and 947 artifacts remained at the conclusion of the selection process. These sampling techniques were most effective for selecting pertinent records and artifacts and increased the likelihood of future applicability and transferability (Creswell, 2013b).

Table 4. 2

Demographics of Educator Respondents

<table>
<thead>
<tr>
<th>Respondent Number</th>
<th>STEM Teaching Experience</th>
<th>Previous General Teaching Experience</th>
<th>Gender</th>
<th>STEM Program Entry Year</th>
<th>Graduate Degree Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>00 Years</td>
<td>09 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>N/A</td>
</tr>
<tr>
<td>#2</td>
<td>00 Years</td>
<td>20 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>Family &amp; Consumer Science</td>
</tr>
<tr>
<td>#3</td>
<td>00 Years</td>
<td>02 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>N/A</td>
</tr>
<tr>
<td>#4</td>
<td>02 Years</td>
<td>12 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>N/A</td>
</tr>
<tr>
<td>#5</td>
<td>01 Year</td>
<td>22 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>Science Education</td>
</tr>
<tr>
<td>#6</td>
<td>02 Years</td>
<td>14 Years</td>
<td>Male</td>
<td>Year 02</td>
<td>School Administration</td>
</tr>
<tr>
<td>#7</td>
<td>04 Years</td>
<td>04 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>English</td>
</tr>
<tr>
<td>#8</td>
<td>00 Years</td>
<td>00 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>N/A</td>
</tr>
<tr>
<td>#9</td>
<td>00 Years</td>
<td>01 Year</td>
<td>Female</td>
<td>Year 03</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Extensive care was taken to anonymize the participant records such that neither the investigator nor the school district itself could re-identify participants. However, the demographic data that persisted with each record revealed a number of salient factors and several demographic sub-groups emerged. Group 1 consisted of 5 records (#1, #2, #4, #5, and #6,) and represented educators who were veteran teachers, characterized by 7 or more years of general teaching experience. Of this group, one record (#5) represented a respondent who had previous formal training in STEM at the graduate level and more than 7 years of experience specifically in the area of STEM education. Of note was the fact that record #5 included in vivo codes that were synonymous with the patterns of response of participants who had no formalized STEM training outside of the professional development program offered by the
district and were characterized as novices based on having less than 7 years of formal teaching experience. Respondent #5 could not articulate the purpose(s) of the STEM program, did not believe that the quality or quantity of professional development provided for the program was appropriate, and took issue with program decisions that did not reflect collaborative leadership or decision making. These sentiments were echoed by the respondents #3, #8, and #9. The demographic data for group 1 is reflected in Table 4.3 below.

### Table 4.3

**Demographics of Veteran Educator Respondents**

<table>
<thead>
<tr>
<th>Respondent Number</th>
<th>STEM Teaching Experience</th>
<th>Previous General Teaching Experience</th>
<th>Gender</th>
<th>STEM Program Entry Year</th>
<th>Graduate Degree Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>00 Years</td>
<td>09 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>None</td>
</tr>
<tr>
<td>#2</td>
<td>00 Years</td>
<td>20 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>Family &amp; Consumer Science</td>
</tr>
<tr>
<td>#4</td>
<td>02 Years</td>
<td>12 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>None</td>
</tr>
<tr>
<td>#5</td>
<td>01 Year</td>
<td>22 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>Science Education</td>
</tr>
<tr>
<td>#6</td>
<td>02 Years</td>
<td>14 Years</td>
<td>Male</td>
<td>Year 02</td>
<td>School Administration</td>
</tr>
</tbody>
</table>

Group 2 consisted of 4 records (#3, #7, #8, and #9) and represented educators who were novice teachers, characterized by less than 7 years of general teaching experience. Of this group, only one record (#9) represented a respondent who had previous formal training in STEM at any level, with a degree in biology at the undergraduate level. The respondents represented by these records could not clearly articulate the purpose(s) of the STEM program, did not believe that the quality or quantity of professional development provided for the program was appropriate, and also took issue with program decisions that did not reflect collaborative leadership or decision making as stated on their open-ended survey responses. Of note was the fact that all of these respondents thought the academic and enrichment activities provided by the program were adequate and served the target population, but were unable to clearly define the population targeted at the onset of the program as evidenced by both their
survey responses and focus group responses. Each participant was provided a packet upon their arrival for the focus group which included the disclosure statements from the IRB application and the invitation letter were numbered and these numbers were used to identify participant responses during the focus groups, rather than to use teacher names or physical characteristics. The demographic data for group 2 is reflected in Table 4.4 below.

**Table 4.4**

*Demographics of Novice Educator Respondents*

<table>
<thead>
<tr>
<th>Respondent Number</th>
<th>STEM Teaching Experience</th>
<th>Previous General Teaching Experience</th>
<th>Gender</th>
<th>STEM Program Entry Year</th>
<th>Graduate Degree Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>00 Years</td>
<td>02 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>None</td>
</tr>
<tr>
<td>#7</td>
<td>04 Years</td>
<td>04 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>English</td>
</tr>
<tr>
<td>#8</td>
<td>00 Years</td>
<td>00 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>None</td>
</tr>
<tr>
<td>#9</td>
<td>00 Years</td>
<td>01 Year</td>
<td>Female</td>
<td>Year 03</td>
<td>None</td>
</tr>
</tbody>
</table>

Group 3 consisted of 3 records (#4, #5, and #9) and represented educators who had formal training in a STEM field, either at the undergraduate or graduate level. Of this group, only one record (#9) represented a respondent was not a veteran teacher. Respondent #4 pointed out one of the glaring gaps in the program implementation which was that although STEM ostensibly stands for science, technology, engineering, and mathematics, there was only one technology teacher and no engineering teachers included as a part of the academy staff. In fact, the respondents represented by this sample only included one educator with any technology training or teaching experience. No teachers indicated having had previous business or industry experience prior to coming to teach within the STEM academy. When the investigator looked at the census of the entire population of educators in the STEM program and in the school at large, only 3 other teachers had technology training or teaching experience, representing less than 1 percent of educators in the STEM academy itself and less than 8% in the wider population.
Additionally, there were no engineering classes and the only other technology program represented was the Automotive Technology Course which was housed within the CTE suite of courses and not available to STEM students. The demographic data for group 3 is reflected in Table 4.5 below.

**Table 4.5**

Demographics of Educator Respondents with Formal Training in a STEM Field

<table>
<thead>
<tr>
<th>Respondent Number</th>
<th>STEM Teaching Experience</th>
<th>Previous General Teaching Experience</th>
<th>Gender</th>
<th>STEM Program Entry Year</th>
<th>Degree Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>02 Years</td>
<td>12 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>BA Computer Science</td>
</tr>
<tr>
<td>#5</td>
<td>01 Year</td>
<td>22 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>BA Biology, MSED Science Education</td>
</tr>
<tr>
<td>#9</td>
<td>00 Years</td>
<td>01 Year</td>
<td>Female</td>
<td>Year 03</td>
<td>BS Biology</td>
</tr>
</tbody>
</table>

Group 4 consisted of 3 participant survey records and represented teacher leaders who had direct contact with or direct knowledge of the STEM academy program and its development and subsequent implementation. One respondent had been present for the entirety of the implementation but not the planning year, another was new to the school and district, and another was new to the STEM program having been assigned as an interim leader due to the departure of the former Academy Director. Each of the respondents had very different views of the program from a leadership perspective which seemed to have been impacted by the implementation year in which they arrived to the program. The administrator represented by record #9 had been a part of the implementation since the inaugural year and had a very positive perception of the program and its impact on students. The participant mentioned that the “STEM students made good grades and had little to no behavioral issues.” Per Kasza and Kelly (2017) some of the indicators of successful program implantation were student achievement, retention, matriculation, and attendance that outpaced the students in the traditional or
comprehensive high school. Table 4.6 reflects some of these indirect student indicators. The demographic data for the group 3 school leaders is reflected in Table 4.5 below.

**Table 4.6**

**Demographics of Administrator Respondents**

<table>
<thead>
<tr>
<th>Respondent Number</th>
<th>STEM Teaching Experience</th>
<th>Previous General Teaching Experience</th>
<th>Gender</th>
<th>STEM Program Entry Year</th>
<th>Graduate Degree Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>00 Years</td>
<td>00 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>School Administration</td>
</tr>
<tr>
<td>#2</td>
<td>00 Years</td>
<td>00 Years</td>
<td>Female</td>
<td>Year 01</td>
<td>School Administration</td>
</tr>
<tr>
<td>#3</td>
<td>00 Years</td>
<td>00 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>School Administration</td>
</tr>
</tbody>
</table>

**Table 4.7**

**Indirect Student Indicators for SY 2018-2019**

<table>
<thead>
<tr>
<th></th>
<th>Non-STEM students grade point average</th>
<th>STEM students grade point average</th>
<th>Attrition Rate for Non-STEM students</th>
<th>Attrition Rate for STEM Students</th>
<th>Disciplinary Infractions for Non-STEM Students</th>
<th>Disciplinary Infractions for STEM Students</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>9th</strong></td>
<td>2.1</td>
<td>3.32</td>
<td>16%</td>
<td>2%</td>
<td>172</td>
<td>2</td>
</tr>
<tr>
<td><strong>10th</strong></td>
<td>2.51</td>
<td>3.09</td>
<td>2%</td>
<td>7%</td>
<td>33</td>
<td>1</td>
</tr>
<tr>
<td><strong>11th</strong></td>
<td>2.73</td>
<td>3.55</td>
<td>--</td>
<td>--</td>
<td>16</td>
<td>0</td>
</tr>
</tbody>
</table>

*Grades are on a 4.0 scale*

Group 5 consisted of 6 records and represented both teachers and teacher leaders entering in Year 2 of the program implementation, while Group 6 consisted of 7 records with teachers and teacher leaders entering at Year 3 of the implementation. As none of the original teachers present at the onset of the implementation were present within the sample, there was no Year 1 implementation group. After the inaugural year of the implementation, the original STEM academy coordinator as well as one of the school leaders departed the district. This speaks to another glaring issue within the program implementation which seems to be a difficulty in retaining human capital. Only 2 of the respondents or one-third, in this group reported having taken part in determining the STEM-based curriculum or participating in the
professional develop offerings over the summer which included visiting an existing, established STEM academy in a county with a similar student demographics. Table 4.7 represents the movement of teachers in and out of the academy in school years, 2017/2018, 2018/2019, and 2019, 2020.

**Table 4.8**  
**STEM Academy Teacher Attrition by School Year**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher A</td>
<td>Teacher A</td>
<td>Teacher A</td>
</tr>
<tr>
<td>Teacher B</td>
<td>Teacher B</td>
<td>Teacher E</td>
</tr>
<tr>
<td>Teacher C</td>
<td>Left the LEA</td>
<td>Left the LEA, Replaced Teacher D</td>
</tr>
<tr>
<td>Teacher D</td>
<td>Moved to another school in the LEA</td>
<td>New, Replaced Teacher D</td>
</tr>
<tr>
<td>SY 2018-2019</td>
<td>Teacher F</td>
<td>Teacher G</td>
</tr>
<tr>
<td>Teacher A</td>
<td>New, Replaced Teacher C</td>
<td>New to STEM</td>
</tr>
<tr>
<td>Teacher B</td>
<td>Left the LEA</td>
<td>Teacher L</td>
</tr>
<tr>
<td>Teacher E</td>
<td>New, Replaced Teacher D</td>
<td>Teacher M</td>
</tr>
<tr>
<td>Teacher F</td>
<td>New, Replaced Teacher C</td>
<td>New to STEM</td>
</tr>
<tr>
<td>Teacher H</td>
<td>Left the LEA</td>
<td></td>
</tr>
</tbody>
</table>

The respondents that participated in the summer professional development in the neighboring county seemed to perceive the current implementation as more effective and better reaching the target population. This was evidenced by statements on the open-ended survey such as the following: “The Summer PD in ______ county was very helpful. I used the information I learned there this year…” Another respondent shared in the survey document, “We do a very good job of reaching the target population.” When this same respondent was asked to describe the target population during the focus group, she seemed to struggle with an
answer. This respondent indicated that the program targeted first generation college students and females. However, per document #18 which outlined the STEM implementation plan, students were targeted high grades, high achievement scores, consistent attendance, and few to no behavior infractions. One respondent, who did not participate in the summer PD offering, went as far as to assert that the curriculum for the program was never discussed or reviewed. Another shared that the only portion of the process that they had participated in and had knowledge of was being asked to sit briefly on a committee to hire a new academy director. Almost every respondent across groups mentioned that they perceived that the departure of the founding academy director had been detrimental to the program and in her absence the professional development opportunities and activities for students had suffered and diminished.

One might infer from these responses that part of the issue around lack of clarity around the purpose and goals of the program as well as necessary professional development innovations to sustain in it were as a result of a crisis of leadership occurring as a result of the departure of the founding director. This may perhaps speak to a larger systemic issue wherein the activities and outcomes were not well articulated verbally or encapsulated in a written form, such that the program could maintain viability once key implementers departed. Logic models suggested by the Theory of Change framework predict this type of infrastructural and instructional decay when programs suffer from high rates of teacher and administrative turn-over. Table 4.8 outlines the major events and key changes that have occurred over the life cycle of the implementation.
The respondents in group 6 shared the same confusion around program purposes and expressed not being a part of the process used to help determine the curriculum, save for 1 respondent. However, these respondents did not seem to know why they were not a part of the curriculum planning process and none attributed it to the change in leadership. Two of the respondents expressed dismay about the professional development offerings and described them as “trial and error” or “non-existent.” The demographic data for groups 5 and 6 are reflected in Tables 4.9 and 4.10 below.
Table 4.10

Demographics of Respondents Entering at Year 2 of the Program Implementation

<table>
<thead>
<tr>
<th>Respondent Number</th>
<th>STEM Teaching Experience</th>
<th>Previous General Teaching Experience</th>
<th>Gender</th>
<th>STEM Program Entry Year</th>
<th>Graduate Degree Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2</td>
<td>00 Years</td>
<td>20 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>Family &amp; Consumer Science</td>
</tr>
<tr>
<td>#4</td>
<td>02 Years</td>
<td>12 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>None</td>
</tr>
<tr>
<td>#5</td>
<td>01 Year</td>
<td>22 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>Science Education</td>
</tr>
<tr>
<td>#6</td>
<td>02 Years</td>
<td>14 Years</td>
<td>Male</td>
<td>Year 02</td>
<td>School Administration</td>
</tr>
<tr>
<td>#7</td>
<td>04 Years</td>
<td>04 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>English</td>
</tr>
<tr>
<td>#13</td>
<td>00 Years</td>
<td>00 Years</td>
<td>Female</td>
<td>Year 02</td>
<td>School Administration</td>
</tr>
</tbody>
</table>

Table 4.11

Demographics of Respondents Entering at Year 3 of the Program Implementation

<table>
<thead>
<tr>
<th>Respondent Number</th>
<th>STEM Teaching Experience</th>
<th>Previous General Teaching Experience</th>
<th>Gender</th>
<th>STEM Program Entry Year</th>
<th>Graduate Degree Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>00 Years</td>
<td>09 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>None</td>
</tr>
<tr>
<td>#3</td>
<td>00 Years</td>
<td>02 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>None</td>
</tr>
<tr>
<td>#8</td>
<td>00 Years</td>
<td>00 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>None</td>
</tr>
<tr>
<td>#9</td>
<td>00 Years</td>
<td>01 Year</td>
<td>Female</td>
<td>Year 03</td>
<td>None</td>
</tr>
<tr>
<td>#11</td>
<td>00 Years</td>
<td>00 Years</td>
<td>Female</td>
<td>Year 03</td>
<td>School Administration</td>
</tr>
</tbody>
</table>

Results

Open-ended survey results for research question 1. Three of the nineteen survey questions were particularly relevant to the research questions and purpose of this study. Table 4.11 includes the three relevant questions, numeric responses, and sample quotes.

- RQ1. What distinguishing features of the creation and subsequent implementation of the STEM Academy were perceived as salient for program development and sustainability by respondents?
Table 4. 12

**STEM Program Perception Survey Data, Addressing RQ1**

<table>
<thead>
<tr>
<th>Questions</th>
<th>Numeric Responses &amp; Codes</th>
<th>Sample Quotes</th>
</tr>
</thead>
</table>
| Q1 What process did you use to determine the current STEM-based curriculum? | • 11 of 13 Respondents answered the question  
• 3 of 13 Respondents listed state or national standards as one of the methods used for curriculum development  
• 3 of 13 Respondents reported teaming or collaboration as a method used for curriculum development  
• 4 Respondents mentioned attending training in a neighboring county as a part of curriculum development activities  
• 3 Respondents listed N/A as their response | • “District Stem Directives”  
• “…NC Standard Course of Study Essential Standards…”  
• “I do not feel I know enough about the program to make useful suggestions.”  
• “I am unaware…Never was the curriculum itself discussed or reviewed…”  
• “We had committee meetings to plan out our STEM program and higher a coordinator”  
• “Group discussion, trial & error…”  
• “Self-Study”  
• “NA” |
| Q4 Is the target population adequately reached by STEM activities?         | • 1 Respondent declined to respond                                                       | • “The -------- community is an important target population…and with a diverse class that is representative.”  
• “I don’t believe students are fully engaged it more that they are pushed by parents and whatever system was in place to recruit.”  
• “The cohorts are diverse.”  
• “I do not know enough about the program to answer.”  
• “The school size has limited some scheduling of options.” |


**Table 4.12 continued**

- “Inhibitors—time and opportunities outside of _____ county…need staff (coordinator position).”
- “Schedule was bad last year, STEM teachers did not have common planning which I think is important for coordination…STEM coordinator was also not clear on expectations.”

| Q6 From your perspective, what is the main purpose of the STEM Academy program? | 1 Respondent declined to respond | • “To provide a program in STEM in a _____ county high school.”
| | | • “To introduce children to various STEM fields.”
| | | • “More rigorous and relevant classes.”
| | | • “Provide students with a unique learning opportunity in _____ county.”
| | | • “?”

*Italicized words or phrases =a priori, in vivo, or descriptive codes*
Open-ended survey results for research question 2. Five of the nineteen survey questions were particularly relevant to the research questions and purpose of this study. Table 4.12 includes the five relevant questions, numeric responses, and sample quotes.

- RQ2. How did perceptions of the STEM program vary among respondents who entered at different points in the implementation?

### Table 4.13

**STEM Program Perception Survey Data, Addressing RQ2**

<table>
<thead>
<tr>
<th>Questions</th>
<th>Numeric Responses &amp; Codes</th>
<th>Sample Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 What process did you use to determine the current STEM-based curriculum?</td>
<td>• Respondent entered Year 2</td>
<td>“I was not in _____ county schools when it was chosen…I believe it was to create a school within a school model”</td>
</tr>
<tr>
<td></td>
<td>• Respondent entered Year 1, and was the only one to use the personal pronoun “we” in reference to program planning.</td>
<td>“We had committee meetings to plan out our STEM program &amp; hire a coordinator…”</td>
</tr>
<tr>
<td></td>
<td>• Respondent entered Year 1</td>
<td>“Use course curriculum in conjunction w/National STEM Standards.”</td>
</tr>
<tr>
<td></td>
<td>• Respondent entered Year 3</td>
<td>“I am unaware…Never was the curriculum itself discussed or reviewed…”</td>
</tr>
</tbody>
</table>
Table 4.13 continued

Q2 Describe how the teachers were prepared to teach in the STEM Academy?

<table>
<thead>
<tr>
<th>Respondent entered Year 2</th>
<th>“To my understanding teachers received on-site professional development.”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondent entered Year 1</td>
<td>“I was prepared by attending a weeklong PD at the STEM Leadership Academy Workshop and by mentoring from other teachers &amp; admin.”</td>
</tr>
<tr>
<td>Respondent entered Year 3</td>
<td>“Not sure.”</td>
</tr>
<tr>
<td>Respondent entered Year 1, second semester</td>
<td>“There was PD opportunity in August that I couldn’t attend.”</td>
</tr>
<tr>
<td>Respondent entered Year 1</td>
<td>“The last year and a half teachers were offered the opportunity to attend STEM training in the summer at a STEM School…Teachers this last summer enjoyed it. The past two-year school years they also attended various 1 or 2 day trainings.”</td>
</tr>
<tr>
<td>Respondent entered Year 1</td>
<td>“I was not pleased with the training because another teacher was supposed to do it and I was put in at the last minute. “</td>
</tr>
<tr>
<td>Respondent entered Year 1</td>
<td>“Some teachers were sent to PD others only got training through PLC..”</td>
</tr>
<tr>
<td>Question</td>
<td>Year 1 Description</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Q3 Do you perceive that teachers were adequately prepared to deliver quality STEM instruction?</td>
<td>Respondent entered Year 2</td>
</tr>
<tr>
<td></td>
<td>Respondent entered Year 3</td>
</tr>
<tr>
<td></td>
<td>Respondent entered Year 1</td>
</tr>
<tr>
<td>Q4 Is the target population adequately reached by STEM activities?</td>
<td>Respondent entered Year 3</td>
</tr>
<tr>
<td></td>
<td>Respondent entered Year 2</td>
</tr>
<tr>
<td></td>
<td>Respondent entered Year 3</td>
</tr>
<tr>
<td></td>
<td>Respondent entered Year 2</td>
</tr>
</tbody>
</table>
Table 4.13 continued

<table>
<thead>
<tr>
<th>Respondent entered Year 2</th>
<th>“Schedule was bad last year; STEM teachers didn’t have common planning which I think is important for coordination. STEM coordinator was also not clear on expectations…schedule and coordinator had been replaced.”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondent entered Year 1</td>
<td>“Many are not satisfied we have heard their concerns and are working to address them…Their complaints including communication, activities, support…”</td>
</tr>
<tr>
<td>Respondent entered Year 1</td>
<td>“Tough to say. Feedback on my own class has been pretty positive.”</td>
</tr>
<tr>
<td>Respondent entered Year 1, exited semester 2 of Year 1</td>
<td>“I don’t believe students are fully engaged…it more that they are pushed by parents and whatever system was in place to recruit…”</td>
</tr>
<tr>
<td>Respondent entered Year 2</td>
<td>“Not sure, I only taught STEM biology for one semester last year.”</td>
</tr>
<tr>
<td>Respondent entered Year 2</td>
<td>“There has been some dissatisfaction because of some internal changes this year but I think attitudes and perceptions are changing back for the positive.”</td>
</tr>
<tr>
<td>Respondent entered Year 2</td>
<td>“Parents appear to be satisfied lately but with the change in leadership last semester, parents were definitely upset.”</td>
</tr>
</tbody>
</table>
| Respondent entered Year 1 | “Some students seem to enjoy STEM classes while others say they no longer want to be in STEM…students appear to want clearer
Open-ended survey results for research question 3. One of the nineteen survey questions was particularly relevant to the research questions and purpose of this study. Table 4.14 includes the relevant question, numeric responses, and sample quotes.

- RQ3. How did perceptions of the STEM program vary among different subsets of respondents?
**Table 4. 14**

*STEM Program Perception Survey Data, Addressing RQ3*

<table>
<thead>
<tr>
<th>Questions</th>
<th>Numeric Responses &amp; Codes</th>
<th>Sample Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q6 From your perspective, what is the main purpose of the academy?</td>
<td>• Respondent is a novice level teacher, master’s degree, entered Year 2 of implementation</td>
<td>• “To introduce children to the various STEM Fields and help them reach their potential.”</td>
</tr>
<tr>
<td></td>
<td>• Respondent is a veteran level teacher, graduate degree, entered Year 1</td>
<td>• “More rigorous &amp; relevant classes.”</td>
</tr>
<tr>
<td></td>
<td>• Respondent is an administrator, entered Year 2 of implementation</td>
<td>• “I believe to increase the competitiveness of our school and attract students.”</td>
</tr>
<tr>
<td></td>
<td>• Respondent is an administrator and entered Year 2 of implementation</td>
<td>• “I was not in ____schools when it was chosen…I believe it was to create a school within a school model.”</td>
</tr>
<tr>
<td></td>
<td>• Respondent is a veteran teacher, graduate degree, entered Year 1</td>
<td>• “To provide a program in STEM in a ____high school.”</td>
</tr>
<tr>
<td></td>
<td>• Respondent is a veteran teacher, bachelors level, entered Year 2</td>
<td>• “To encourage &amp; educate students in the STEM fields while fostering positive multicultural relationships.”</td>
</tr>
<tr>
<td></td>
<td>• Respondent entered Year 1, and was the only one to use the personal pronoun “we” in reference to program planning.</td>
<td>• “?”</td>
</tr>
<tr>
<td></td>
<td>• Respondent entered Year 1</td>
<td>• “District directives…”</td>
</tr>
<tr>
<td></td>
<td>• Respondent entered Year 3</td>
<td>• “Additional opportunities to recruit students, possibly from the Charter School!”</td>
</tr>
</tbody>
</table>

*Italicized words or phrases =a priori, in in vivo, or descriptive codes

Question 6 from the instrument seemed to best encapsulate the varied group of respondents perceptions of the STEM program.
Theme I: Lack of Clarity & Cohesion

Much ambiguity still surrounds STEM education and how it is most effectively implemented. As a logic model is developed, programmers typically use this opportunity to clarify inputs, activities, outputs and outcomes. This process is also used to as a part of the program description. It would seem that the present program suffered from a lack of clarity around its purpose, target audience, and theories of action. Even participants who entered during Year 1 of the implementation were confused as to the purpose of the program as is demonstrated by responses in Table 4.12 and Table 4.13. When responding to Question 6: From your perspective, what is the main purpose of the academy? Respondents were quoted as sharing sentiments such as “More rigorous & relevant classes.” Although rigor and relevance are always an important aim of educational endeavors, whether tacitly or explicitly stated, the point here is that this response was not in alignment with the explicitly articulated purpose of the program as recorded in any of the 3 iterations of the implementation plan. It was telling that even program administrators were confused about the purpose of the program and unable to clearly articulate the target audience. In response to this same question, one administrator responded with the following: “I believe to increase the competitiveness of our school and attract students.” Again, the aforementioned would be an appropriate and worthy aim, but is still misaligned with the description and purpose shared in implementation plans and the various presentations delivered to internal and external stakeholders. During the document review process, the investigator reviewed hundreds of pages of board minutes related to the initial implementation, specifically those recorded during the pre-implementation sessions immediately preceding the implementation in the spring of 2017. After careful manual review as well as queries using the analytic software, there were no references to the phrase
“competiveness”, nor any likely synonyms in the document labeled BM3.13.17 which encapsulated the occasion of board of education approval of the program. Only 2 respondents were able to articulate the purpose of the program as outlined in the initial implementation document and not one single respondent, teacher or administrator, was able to describe the target audience because such was never articulated clearly in any of the program planning documents. In the review of the 947 pages of documents analyzed for the current investigation, the term target audience was only used in the survey questions and focus group questions designed by the investigator and never once used in any of the documents generated before or during implementation. Indeed, it appeared that some of the respondents in the focus group were confused by the terminology and asked the investigator to “…Please repeat that phrase” and “…May you explain what you mean by target audience” as if the focus group were the first time they had heard the phrase uttered aloud.

When logic models are well-designed, they create clarity and cohesion. Per Wilkerson and Haden, logic models provide the “road map” of intended outcomes so that purposes, activities, and deliverables are all focused, coherent, and aligned (2014). In this way, logic models also visually depict the programs “theory of action” and detail how and why programmers believe certain processes and activities will lead to particular outcomes. One must question the Theory of Action of any program where-in participants and program developers are unable to clearly articulate the program’s purpose or target audience.

Theme II: Crisis of Leadership

Table 4.12 clearly demonstrates the crisis in the program development caused by changes in leadership. One respondent shared the following: “…This year has been tumultuous with losing the director. However, in the first two years of the academy there were consistent
STEM based experiences.” Another shared this: “…Parents appear to be satisfied lately but with the change in leadership last semester, parents were definitely upset.” Over and over again, respondents asserted that the change in leadership was the reason for inappropriate professional development, lack of program activities to reach target audiences, poor scheduling, and a lack of student engagement.

Table 4.11 demonstrates that respondents were not even clear about what curriculum or standards they were supposed to be adhering to, despite the fact that well over 200 pages of the documentation included with the initial implementation materials were standards and curriculum documents. In response to the question 1 “What process did you use to determine the current STEM-based curriculum?” “I am unaware…Never was the curriculum itself discussed or reviewed…” This unfortunate response supported the notion that leadership changes drastically impacted the development and sustainability of the program as according to all three versions of the implementation plan training and resources for curriculum design and standards was to have been provided by the site director. During the document review, a professional development agenda from Year 1 labeled “PD Agenda 7.17.17 listed as one of its objectives a review of the NC Essential Standards in Science and Mathematics and the Project Lead the Way Engineering Curriculum. As is demonstrated in Table 4.1, which outlines the categories and types of documents reviewed during the document analysis, these standards as well as the Next Generation Science Standards (2013) were all included as a part of the implementation materials, and yet teachers in the academy seemed to be unaware of the standards by Year 3. Table 4.13 demonstrates, unfortunately, that even one of the program administrators was unsure about what standards and curriculum the program should be following. Kasza and Kelly have written that understanding the key learning objectives of a
STEM academy, as articulated through standards and curriculum, is one of the hallmarks of successful STEM implementations (2017).

However, by triangulating the respondent information with documents from the human resources department (documents HRD23 and HRD24) an emergent concept was illuminated which was not captured in respondent data. It was not just the students who were disengaged. Teachers had become disengaged as well to the point that by the third year of the implementation, only one teacher remained from the initial implementation in school year 2017/2018 as is demonstrated by Table 4.7. This high rate of teacher turnover served to exacerbate the problem of cohesiveness and leadership. Without clear program documents and the subsequent departure of the founding academy director there was no one left who understood what the program was intended to do or who it was intended to serve.

It is not just administrators that provide leadership. Teachers too are leaders, providing stability, continuity, comradesies, and mentorship through their presence and participation (Holloway, Kerr, & Zacharakis, 2019). In addition to the valuable support they provide one another, they also provide feedback to leaders and stakeholders about the health of the program, appropriateness of resources and tools, and the day-to-day perspectives of the target audience members. The departure of the founding teachers of the academy is also demonstrative of the overriding theme of a crisis of leadership.

**Theme III: Lack of Sufficient Training and Professional Development**

When both teachers and administrators admit to not understanding program purposes or being clear about which curriculum the teachers should be following, lack of quality professional development is one of the culprits. Table 4.13 demonstrates that depending on what group respondents represented, their perception of the program development offerings
differed. Respondents entered during Year 1 felt that the professional development was of high quality and met their needs. Respondents entering after the initial year of implementation, whether they were teachers or administrators and despite their status as novice or veteran overwhelming felt that the quality and quantity of the professional development was inadequate. Upon reviewing documents from the human resources department that contained portions of teachers’ comments from the exit interviews (HRD27 and HRD28), it became clear that one of the main reasons teachers left was due to feeling as though they were not adequately prepared to do the tasks required. One direct quote was as follows: “I enjoyed the students but did not feel supported in my efforts by administration.” Another exiting teacher shared this: “The brief summer PD did not prepare me to implement a year-long program of STEM-based activities.” High quality professional development may have served as a deterrent to teacher attrition if one believes the veracity of the statements included within these documents.

In order to make sound decisions about professional development offerings, programmers, teachers, and instructional leaders need solid evidence to support or refute the effectiveness of professional develop as a lever for improving teacher retention and student outcomes. Numerous experts in the field of STEM education name quality professional development as one of the hallmarks of a successful STEM implementation (Ortiz, Weis, & Merritt, 2018). In addition, officials at NASA have written that some empirical evidence that suggests that the collective participation of groups of teachers from the same school, subject, or grade is related to program coherence, a concept related to theme I (Ortiz et al., 2018). A systematic review and meta-analysis was conducted to examine the effects of reform-based professional development on mathematics and science teachers and the results of this study are relevant to the current study in that they suggest that the effects of reform-based professional
development are consistent across settings and teaching populations (Kuehnert, Cason, Young, & Pratt, 2019). This means that the fact that the teachers in this study were in a rural environment does not negate the importance of professional development in improving their knowledge in the field and thereby hopefully encouraging them to stay. Other implications from the study included recommendations for professional development to maximize opportunities to learn in STEM classrooms (Kuehnert et al., 2019).

Chapter 4 included four sections: trustworthiness of data, results, evaluation of findings, and summary. The results of the study were presented in both narrative and table form and aligned to answer the research questions and address the emergent themes. In the evaluation of findings, an overview was presented of the data collection and analysis process, as well as a description of the data by type, and a description of the context and setting of the case. An interpretation of the results in accordance with the defined conceptual framework was also delineated. In addition, the key findings were compared and contrasted with the prior research findings addressed in Chapter 2. The chapter also includes an interpretive summary to situate the study within the extant literature and suggests the impact of this investigation on the field of special education professional development theories, teacher education models for building content and pedagogical knowledge in reading, and the study of knowledge building among adult learners.
Chapter 5: Discussion, Implications, Recommendations, and Conclusions

Chapter 5 includes a review of the problem the study sought to address, a brief discussion of the methodology and study design, and a discussion of the study’s findings. The chapter closes with implications, recommendations for practice and future research, and a conclusion which summarizes the study. In the methodology section, an overview is presented of the data collection and analysis process. In the implications section, the results are addressed within the context of the study and a discussion of the extent to which the results address the study problem and purpose. Additionally, a description of how the study contributes to the existing literature and aligns to the conceptual framework is provided. The recommendations section includes an examination of how the findings of the study could be applied to practice as well as an explanation of how future researchers might build upon the current study.

**Brief review of the problem and purpose.** Providing the skills and knowledge necessary for an increasingly technology driven work-force and society is largely the responsibility of secondary schools, colleges/universities, and the educators that people each of these institutions. The research literature is rich with studies that assert that the single largest school-based factor affecting student academic growth and achievement is the teacher and therefore the skills they impart and nurture have a great impact on students’ ability to navigate this new, largely technology driven world (Goldhaber, 2007; Rivkin, Hanushek, & Kain, 2005; Rockoff, 2004). Yet, studies also reveal that recruiting and retaining quality teachers with the prerequisite skills in rural teaching environments is a great challenge which has serious implications for student outcomes and program quality (National Education Association, 2015; North Carolina General Assembly, 2018). This means that students from poor rural
backgrounds are expected to compete with their metropolitan counterparts for jobs and opportunities without access to the same quality of preparation.

STEM programs in rural areas often struggle to attract and retain qualified human capital as well as engage and retain students. These human resource challenges impact program quality which in turn yields continuous calls for improvement and accountability. Previous study findings point to the incorporation of formative program evaluation throughout the life cycle of STEM implementation as one method to address the aforementioned challenges (Jayaratne, 2016; Shavelson, 2018; Wilkerson & Haden, 2014). Including formative program evaluations can be critical to the success of STEM programs by encouraging adaptation, informing program improvements, and refining program development. The literature related to this topic suggests meaningful implications for the impact of implementation science on the success of STEM programs. More successful programs tend to attract higher quality students and teachers, have higher rates of student and teacher retention, higher rates of student matriculation, and encourage more students to pursue additional education and careers in the STEM fields (Frechtling, 2010). The problem this study addressed is that the urgent need to improve the development and sustainability of STEM programs in rural areas is often negatively impacted by a lack of appropriate formative program evaluation. Specifically, this study was undertaken to address the following research questions:

• RQ1. What distinguishing features of the creation and subsequent implementation of the STEM Academy were perceived as salient for program development and sustainability by respondents?

• RQ2. How did perceptions of the STEM program vary among respondents who entered at different points in the implementation?
• RQ3. How did perceptions of the STEM program vary among different subsets of respondents?

**Study methodology and design.** In order to address the study’s problem, the study’s purpose was aligned to the research questions and study methodology. The purpose of this qualitative study was to use formative evaluation methods as a means to investigate strategies for supporting the development and sustainability of a fledgling STEM academy at a rural high school in the Piedmont region of North Carolina from the prospective of the educators who run such programs. The literature is replete with studies about STEM programs, but few addressed the perceptions of teachers’ rural environments or used formative evaluation as the primary method for discovering challenges, generating solutions, and making recommendations. Program developers can benefit from understanding how and why evaluation can be critical to the success of STEM programs. Once an understanding has been reached about the value of evaluation exercises, programmers must determine what data is necessary, what data collection methods are appropriate, and then how to effectively communicate findings.

One particular methodology that is a research supported, evidence-based practice is formative evaluation. Formative evaluation encompasses a range of formal and informal practices that take place during the course of program implementation and support the continued development and improvement of the program throughout its life cycle. Formative evaluation can diagnose potential problems in their early stages and progress monitor updates and adaptations. Using program evaluation as a methodology early on in an implementation allows programmers to transform vague visions into clearly articulated goals which can be aligned to and attainable outcomes. This alignment creates coherence and a clear path from program purpose, to program activities, and outcome actualization.
Evaluation of the Findings

Irrespective of the form program evaluation takes, it should serve a few main purposes. Those purposes included defining activities and expected outcomes, promoting continuous learning and reflection on practice, providing evidence of impact, and generating recommendations for improvement (Wilkerson & Haden, 2010). In order to effectively administer a program evaluation so that the findings generate value for stakeholders, program developers, funders, and target audiences, it is necessary to first begin by deploying effective practices for designing the evaluation. This includes aligning the evaluation with its intended outcomes, selecting the appropriate evaluation method based on the program’s phase of development, and then effectively communicating the results.

Research question 1 asked the following: What distinguishing features of the creation and subsequent implementation of the STEM Academy were perceived as salient for program development and sustainability by respondents? The educators who responded to the surveys and participated in the focus groups repeatedly spoke to a number of salient features, both directly and implicitly, that seemed to be important in terms of their impact on program development and sustainability. Respondents generated numerous responses when asked about the purpose of the STEM program. A clearly articulated program purpose is a defining feature of any successful program implementation, and yet not one of the thirteen respondents made statements in writing or in the focus groups that were aligned with the stated program purpose listed in document #1, the program implementation plan. The absence of clear purpose endangers program development and future sustainability because a lack thereof makes outcomes a “moving target” that change with each new iteration of purpose.
This theme of a lack of clarity and cohesion was one of the major strands in the findings and seemed to be due to a number of factors. Although needs assessment is a hallmark of successful implementations and listed as a best practice repeatedly throughout the literature, there was no data to support the programmers having ever conducted such (Denby, 2010; Long, 2005). The needs assessment is what drives the development of program purpose and without such, it seemed that different stakeholders held myriad beliefs about this particular program’s purpose. This may perhaps be because stakeholders were not consulted as to what their expectations might be of a STEM academy and whether or not such was necessary in this particular context and situation.

The initial implementation plan written in 2016 listed the program’s purposes as an opportunity to increase enrollment at one particular high school in the LEA that was under-enrolled, create innovative programs and partnerships with local STEM related companies, and provide opportunities for rigor for the county’s youth. However, subsequent iterations of the implementation plan recorded other disparate purposes. Document #2, a revised implementation plan, generated approximately 5 months after the initial plan, mentioned making the school as well as the academy more reflective of the district demographics as one of the program goals. However, this too was ambiguous as it was unclear whether this was a veiled reference to “diversity” and if so, whether this diversity referred to the student or teacher population or in what regards diversity was desired, be it race, gender, socio-economics, ability, or the plethora of other facets of diversity the term encompasses.

Research question 2 asked, “How did perceptions of the STEM program vary among respondents who entered at different points in the implementation?” What was interesting was that respondents who entered the program during year 1 of the implementation seemed to have
responses more closely aligned with the original implementation plan’s stated purpose. However, among respondents who entered the implementation at any point after year 1, many reported “diversity” or “multiculturalism” as a main purpose of the program, with no mention of the other goals which were still codified in the updated implementation plan, while one-third reported “NA” or “I don’t know” when asked to respond in writing about their perception of the program’s purpose. The investigator was unable to locate any documents generated by programmers, other than the implementation plan that mentioned the term diversity. However, at the conclusion of Year 1, the academy director did create an orientation notebook for teachers new to the STEM academy that included several empirical articles about issues of diversity and inclusion and their relationship to STEM education and career fields. This document was located as a result of one of the ad hoc queries made against the district’s data warehouse, which in addition to housing data, also houses documents generated by district employees about district programs. This may be why the perception persisted by more than one-third of the respondents that “diversity” or “multiculturalism” was a primary goal of the program. 

Respondent number #1 shared this: “The main purpose of the program is…fostering positive multicultural relationships.” This same respondent used the word “diverse” three times in their written responses to the open-ended survey questions. Respondent #3 shared this: “Our STEM activities should represent a diverse class, representative of our part of the community.”

There is nothing wrong with multiculturalism or diversity as a program aim, in and of itself. The issue, however, is that there is continued confusion among the program implementers about what the program developers aimed to do with the implementation. Looking to the literature, Wilkerson and Haden (2010) stressed the fact that the creation of a clear logic model creates coherence, cogency, and consistency. The evidence of such would be
that implementers are unified in their understanding of such a fundamental aspect of the implementation as its purpose.

Although the plan did not explicitly state that its purpose was to recruit students, one PowerPoint slide, document #3, listed statistics about how many students in the county had been lost to local charter and private schools. This codified an explicit desire on the part of the implementation designers and programmers to quell this attrition, as federal, state, and local funding follows students out of the door and into these other school settings. Several respondents mentioned that they perceived the program creation to be about decreasing student attrition. Respondent #2 shared: “…Additional opportunities to recruit students, possibly from the Charter School.”

The aforementioned comments once again point back to the theme of lack of coherence and perhaps clear messaging leading to a muddling of program purpose. After hand review and several ad hoc queries, the investigator was never able to discover documents for the program or about the program that made mention of recruiting students from private or charter school settings, and yet this perception persisted among the teachers and leaders in the academy. When this information is juxtaposed against the idea of teacher and student retention, this implicit goal seems to be at odds with both the program’s stated goals and the literature with regards to STEM academies. STEM academies ought not be created primarily for the purpose of recruiting students to a school, but for the purpose of increasing STEM literacy and adding value to students’ lives as well as to the lives of the professionals who serve them (Kasza & Slater, 2017). Writing in 2010, Marshall asserted that one primary purposes of such a program was to develop information about best practice in STEM pedagogy that could be used to improve current programs as well as to help future programs scale and become successful.
These lofty aims help inspire teachers and students and influence their efforts to matriculate and to remain in particular districts. Teacher and student retention directly impact program sustainability. Efforts should not be about competition but about collaboration, both within the school and external to it.

Codes related to collaboration came up continuously throughout the course of the study. The initial electronic analysis of digitized documents related to program development and implementation returned several key words and phrases with high rates of frequency. Collaboration was a term that appeared in over 20% of the 947 pages of documents that eventually came to be a part of the program evaluation. It was mentioned numerous times in all three iterations of the implementation plan across the years of 2016, 2017, and 2018. It was mentioned numerous times in the funding documents submitted to the Southern Regional Educational Board and the Governor’s Innovation grant, two of the main funding sources for the project. It was mentioned repeatedly in the literature cited by program developers as the empirical basis for program development (Atkinson et al., 2007; Erdogan & Sussey, 2015; Marshall, 2010) and it was mentioned no less than 22 times in the respondent records and transcripts of the teacher focus groups. In fact, in Kasza and Slater’s (2017) survey of best practices for secondary STEM academies they listed collaboration as one of the key hallmarks of successful programs. What is however telling is that none of the written survey responses from school leaders at the district or school level use this term even once. This clearly illuminates a glaring disconnect between the literature, the programmers’ aims, and the desires of the teachers.

If teachers want to collaborate but leaders do not see it as a priority, they will not plan and create infrastructure for such. This destabilizes programs and contributes to teacher
attrition. When asked what part they had in program development, 3 of 9 teacher respondents either answered “NA” or shared that they were not asked to collaborate or contribute to program development in any way. Respondent #5 shared this: “We had committee meetings to plan the STEM program until the coordinator left.” This speaks to two overlapping themes. One issue is around teachers’ desire for collaboration not being honored, and the crisis in leadership caused by the departure of the director changing the practices that attracted teachers to the academy in the first place. One must remember that it was not just students who were being recruited to the program, but teachers as well. No teacher complained about salary or student behavior, common stressors for in-service teachers (Hanushek, 2016; Skaalvik, & Skaalvik, 2017), but many lamented the inability to collaborate, have input on programmatic decisions, and have co-planning time with other teachers in the academy. When asked what suggestions they would have made to improve the process of determining the current STEM-based curriculum, Respondent #1 summed it up succinctly in her statements: “Group discussion, collaboration with other members, and PLCs (which is an acronym which stands for Professional Learning Communities, another mode of formal professional collaboration).”

Another theme that was revealed in response to Research Question 2: “How did perceptions of the STEM program vary among respondents who entered at different points in the implementation?” was a lack of clear understanding of or adherence to key learning objectives and standards. Writers of the United States’ curriculum framework Next Generation Science Standards (NGSS) made clear that STEM academies should be perpetuated through the lens of engineering and without such students would take science and math courses with little connection to the interdisciplinary problem solving approach necessary for quality STEM instruction (2013). These soft skills are necessary and per Marshall, best taught through
engineering practices and programs that omit them deprive students of the fullest and most valuable experiences that STEM education can and should offer (Marshall, 2010.) However, the written survey responses, transcripts from focus groups and analysis of master schedules, course descriptions, and teacher syllabi all revealed a startlingly lack of engineering courses and principles within the program implementation under study. Respondent #3 shared: “I used my usual curriculum and added the engineering design process…” This may sound positive on the surface, but numerous experts in the field warn against incorporating engineering as an add-on as opposed to the framework upon which all else is premised. Hoachlander (2011) has written that the current status of STEM in most schools consists of science and math, with technology and engineering being left out or an afterthought. The investigator’s findings at the academy under current study were aligned to the literature in this respect.

In relationship to Research Question 2, the propensity to use something other than the NGSS curriculum framework seemed higher in those teachers who entered the implementation after the inaugural semester. Even among teachers who entered at the second semester of the first year of implementation, there was a higher likelihood to piecemeal instruction together from various sources rather than use the national curriculum codified into program documents as the one the academy would follow.

**Recommendations for Practice**

Researchers, professional developers, teacher leaders, and school leaders need to be clearer about the underlying mechanisms for program development and sustainability so that inputs and activities, whether they be professional development or student enrichment activities, to those proposed causal levers (Wilkerson & Haden, 2014). Leaders in the field agree that without being clear about program purposes and outcomes and how these two related ends can
be reached, we will continue to waste time and money on ineffective activities that do not produce valuable outputs (e.g., students who graduate at higher rates, go on to higher education, and enter STEM career fields). Clearly articulated Theories of Action created through continuous collaboration among all stakeholders will protect against waste, increase teacher retention, and distill practices that lead to stronger, more successful programs (Shannon & Bylsma, 2007; Shavelson, 2018; Shoulders & Krei, 2015). Activities will lack cogency and coherence unless there are clear delineations of what is being done and why (Kennedy, 2016). This is why a well-defined Theory of Change is so critically important. All stakeholders must know both their roles and the goals of the programming innovation. Teachers and students are more likely to stay on with a program when they are clear about the proposed outcomes of their investment of time and energy.

All programming moving forward should be based on the latest empirical research with regards to the curriculum and types of programming activities in which stakeholders participate. Providing new students and teachers research to “review” but that is not actually an integral part of the way implementers plan and do their work with students is a waste of valuable time. After almost 100 years of STEM education and voluminous research in the last 30 years, operating programs using the research-based as well as evidence-based practices should not be optional or an afterthought (Duran, 2013; Thomas, 2010). The indirect student data collected as a part of this study’s results made clear that with just minimal adherence to basic principles, students in the academy saw clear gains in achievement as evidenced by standardized assessment scores and grades and were more likely to remain in school with the attrition rate being lower than the traditional high school that houses the program or the state average. If the program were implemented with high levels of fidelity to best practices, it might see results as astounding as
those in the nation’s most successful STEM programs where STEM students consistently outscore their traditional school counterparts on standardized assessments of science and math and where more than 50% of students go on to STEM disciplines in higher education and almost 50% of that number ultimately graduate from college (Erodogan, 2015).

**Recommendations for Future Research**

The development of the visual Logic Model for the program under study happened only as a part of the program evaluation activities undertaken by the investigator. It did not seem that implementations in narrative form alone offered the type of clarity and cohesiveness necessary for program development and sustainability. It might be beneficial for future scholars and practitioners to address the impact of visual logic models versus narrative plans on program implementation innovations. If this small change in practice yields even moderate benefits, it would be a cost effective way to keep implementation on course and stakeholders informed.

There seems to be a great deal of research in the field as it relates to teacher attrition and retention across urban and rural settings. However, there still remains a dearth of research about the impact of Schools-Within-a School models on teachers’ decision to remain at a school or a district and even less that is specific to rural environments which house STEM focused schools. As the need for a workforce better prepared for STEM careers continues to grow, it will be important to continue research into this phenomenon. Due to urbanization, most Americans in 2020 live in cities (Marcotullio, 2017), but the small minority of U.S. students that continue to reside in rural areas are still entitled to high quality education and must also be prepared for the careers of the future, today.
Conclusion

The traditional approach to education has had positive impacts for some sub-sets of learners but these inauthentic approaches to education privilege some students and limit others. From all the educational research on how people learn, a constructivist framework is necessary to help students learn, yet schools in all their progressive attempts fail to give students an education that reflects the world in which they live. Students are constantly being grouped. They are grouped by academic ability, how they learn, how they read, the language they speak, etc. These groups still do not accommodate various learning styles; in fact, these “learning” groups oppress students by race, class, and gender which is evident by the achievement gaps (Bécares & Priest, 2015; Duncan & Mangnuson, 2005; Quinn, 2015). There is a great need to rethink how traditional high schools operate to better prepare students for the 21st century workforce. STEM academies are one of many approaches to fulfilling this hands-on approach.

The purpose of this qualitative study was to use formative evaluation methods as a means to investigate strategies for supporting the development and sustainability of a fledgling STEM Academy at a rural high school in the Piedmont region of North Carolina. An evaluation of the STEM Academy has relevance for STEM research and applications, as well as for rural education research. There was a need to evaluate STEM education programming at the high school to determine the benefits of the program and implementation as well as to address the dearth of research addressing the challenges of STEM education in rural settings. Further, there was also a need to determine the adaptations and changes necessary to contribute to the continued development and sustainability of the program under study with the ultimate goal of ensuring that the investment of resources was indeed contributing to student achievement.
The findings of the current study as well as the literature that underpinned it made clear collaboration through inquiry, hallmarks of engineering practices, produce positive outcomes for students and the teachers who teach them (Slough, 2013). When these programs are paired with powerful formative evaluation practices that keep the stakeholders informed, and implementation on track, students are more likely to stay and reap the benefits of the instructional environment and teachers are more likely to stay to provide the quality instruction they need (National Education Association, 2015; National Research Council, 2012). Yet, studies also reveal that recruiting and retaining quality teachers with the prerequisite skills in rural teaching environments is a great challenge which has serious implications for student outcomes and program quality (North Carolina General Assembly, 2018; National Education Association, 2015). The difficulty of recruiting and retaining teachers to rural areas means that although students from poor rural backgrounds are expected to compete with their metropolitan counterparts for jobs and opportunities without access to the same quality of preparation. Findings from the current study support the notion that clarity, collaboration, and communication are keys to retaining teachers and school leaders in such environments (Goldhaber, 2007; Rivkin, Hanushek, & Kain, 2005; Rockoff, 2004). Retaining these teachers who hold within them the cumulative knowledge of a program’s history as well as the tremendous investment of costly professional development is key to program development and sustainability. Every time a new teacher or administrator must be trained, it diminishes the resources available for student equipment and activities.

Chapter 5 included a brief review of the problem and purpose of the study, a discussion of the methodology and study design, implications of the findings, recommendations for practice, recommendations for future research, and a conclusion which summarized the findings
of the study. In the methodology section, an overview was presented of the data collection and analysis process. In the implications section, the results were discussed within the context and setting of the study and a description of the extent to which the results addressed the study problem and purpose was provided. Additionally, a depiction of how the study contributed to the existing literature and theoretical models was described. The recommendations section included discussion about how the findings of the study can be applied to practice well as explanations of what future researchers might do to build upon the findings of the current study.
References


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Appendix A: Letter of Site Permission

January 28, 2020

Mr. Williams:

I support your doctoral research and approve your request to conduct such research in 

County Schools.

As the approver for the research, I understand that by doing so, I:

- Authorize the researcher’s use of 2019-2020 documents and archival data related to the STEM Academy or STEM curriculum.
- Confirm that there is no conflict of interest, financial benefit, or dual relationship between [redacted] and Danny T. Williams during the 2019-2020 data collection period.
- Authorize the researchers’ use of the facilities of [redacted] to conduct focus groups after working hours.

Best of luck to you as you complete your research, A Formative Evaluation of a STEM Academy at a rural high school in North Carolina. We look forward to reviewing your findings.

Sincerely,

[Signature]

Dr. [Redacted]
Chief of Academics
County Schools
Appendix B: IRB Approval

Begin forwarded message:

From: Lance Fusarelli <lfusare@ncsu.edu>
Date: November 22, 2019 at 12:16:34 PM EST
To: Dannie Williams <dwilli3@ncsu.edu>
Subject: Fwd: Fusarelli - 16834 - IRB Protocol approved

Dan,

Congrats! You may begin your fieldwork. Keep me in the loop as data collection progresses.

Lance D. Fusarelli, Ph.D.
Professor, Director of Graduate Programs
Educational Leadership, Policy and Human Development
North Carolina State University
6280 Poe Hall, C.B. 7801
2310 Stinson Drive
Raleigh, NC 27695-7801
(919) 515-6507 (office)
(919) 515-6305 (fax)

recent publications:

--------- Forwarded message -------

From: IRB Administrative Office <irb_notifications@ncsu.edu>
Date: Fri, Nov 22, 2019 at 10:32 AM
Subject: Fusarelli - 16834 - IRB Protocol approved
To: <lfusare@ncsu.edu>

Dear Lance Fusarelli:

IRB Protocol 16834 has been approved

Title: A Formative Evaluation of a STEM Academy at a Rural High School in North Carolina

PI: Fusarelli, Lance D.

The project listed above has been reviewed by the NC State Institutional Review Board for the Use of Human Subjects in Research. This project was reviewed via Expedited procedures under Expedited 7.
Appendix C: Interview Questions for STEM Educators & Administrators

Interview for Former Superintendent and STEM Committee Members

1. What is your title and position?
2. What role did you have in the designing and implementation of the STEM Academy?
3. What research was completed to determine the model for the program?
4. Was there a specific reason for the development of the Academy?
5. What was the vision for the school during the design phase?
6. How are the programs that are offered at the school aligned with your original vision?
7. What ways are the schools and community connected?

Interview questions for the district level administrators and the STEM Academy Coordinator

1. Why was a STEM-Based Curriculum chosen?
2. Describe how were the teachers prepared to teach in the STEM Academy. Who conducted the training?
3. Do you feel that the teachers are adequately prepared to deliver quality STEM Instruction?
4. Are STEM activities conducted with the target population?
5. Are there other populations the program should be working with?
6. Is the target population adequately reached by and involved in STEM Academy activities?
7. What do the students think of the services? Are they satisfied?
Interviews with the teachers, coordinator and the principal

1. Describe how you were prepared to teach in the STEM Academy.
2. Who conducted the training?
3. How many times have you had opportunities to participate in the training?
4. Would you like more training on the model?
5. Do you feel that you are adequately prepared to deliver quality STEM Instruction?
6. What other resources were available to assist you after training?
7. What were some of the environmental factors that inhibited the implementation of the curriculum?

For interviews with students and their parents

1. From your perspective, what is the main purpose of the Louisburg High School STEM Academy?
2. Why did you join the Louisburg High School STEM Academy?
3. What did you hope to achieve by applying to the Louisburg High School STEM Academy?
   a. What benefits did you expect to receive as a result of participating in the STEM Academy?
   b. When you applied to the STEM Academy, were you looking for a solution to a specific problem or were you more broadly interested in expanding your knowledge or expertise around the topic of STEM?
4. As you became involved in the STEM, did you discover other reasons for participating that you did not initially anticipate?
5. In what way(s) has the STEM Academy met your expectations and/or needs? In what way(s) has the STEM Academy failed to meet your expectations and/or needs?
### Appendix D: A Priori Coding from Extant Literature

<table>
<thead>
<tr>
<th>A Priori Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>science, technology, engineering, mathematics, professional development, STEM, case study, secondary, secondary data analysis, archival data analysis, formative evaluation, program evaluation, implementation science, rural education, barriers, facilitators, implementation, 21st century learning, college and career readiness, program development, effective pedagogical practices in STEM, career technology education, vocational education, vocational training, CTE, theory of change, logic models, third space theory, active learning spaces, alternative learning settings, vocational schools, educational equity, stratification sampling, homogeneous purposive sampling, implementation, perceptual data, survey tools, educational measurement, educational assessment, qualitative program evaluation, qualitative inquiry, school engagement, hybrid spaces, STEM-rich, equity-oriented, traditional high schools, comprehensive high schools, graduation rates, self-efficacy, cognitive learning theory, cognition, engineering design, higher education, university, matriculation rates, schools-within-a-school, learning space design, project based learning, problem based learning, performance evaluation diversity, rural education, human resources retention, human capital retention, teacher recruitment, teacher retention, teacher attrition, student attrition, at-risk students, critical literacy theory, curriculum, standard,</td>
</tr>
</tbody>
</table>
database repositories, databases warehousing, ad hoc queries, SQL, socket layer protection, and encryption
## Appendix E: Thematic Codes and Excerpt Frequency

<table>
<thead>
<tr>
<th>Thematic Codes</th>
<th>Number of Tagged Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Code: Lack of Clarity &amp; Cohesion</td>
<td>19</td>
</tr>
<tr>
<td>2. Code: Crisis of Leadership</td>
<td>13</td>
</tr>
<tr>
<td>3. Code: Lack of Sufficient Training &amp; Professional Development</td>
<td>14</td>
</tr>
</tbody>
</table>
Appendix F: Cost Projection for the High School “C” STEM Academy Program

<table>
<thead>
<tr>
<th>Needs</th>
<th>Explanation</th>
<th>Cost-Year One (25 new students)</th>
<th>Cost-Year Two (50 new students)</th>
<th>Cost-Year Three (50 new students)</th>
<th>Cost-Year Four (50 new students)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology for 1:1</td>
<td>Students receive devices for use at school/home</td>
<td>$4,500.00</td>
<td>$9,000.00</td>
<td>$9,000.00</td>
<td>$9,000.00</td>
</tr>
<tr>
<td>*Furniture for Classrooms</td>
<td>Vertebrae desks and chairs for collaboration</td>
<td>*$20,247.80 (estimate)</td>
<td>*$20,247.80 (estimate)</td>
<td>*$20,247.80 (estimate)</td>
<td>--</td>
</tr>
<tr>
<td>Furniture for Media Center</td>
<td>Reconfigure media center as collaborative space for student work</td>
<td>$13,869.00</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>STEM Coordinator</td>
<td>Utilizing Existing Position; Additional 2 Months Employment</td>
<td>Approx. $9,000.00</td>
<td>Approx. $9,000.00</td>
<td>Approx. $9,000.00</td>
<td>Approx. $9,000.00</td>
</tr>
<tr>
<td>Summer Professional Development</td>
<td>Includes training, materials, travel, and stipends</td>
<td>$4,500.00</td>
<td>$4,500.00</td>
<td>$4,500.00</td>
<td>$4,500.00</td>
</tr>
<tr>
<td>Through Greene County STEM</td>
<td>Supples and materials for mini-challenges, grand challenges, projects</td>
<td>$5,000.00</td>
<td>$5,000.00</td>
<td>$5,000.00</td>
<td>$5,000.00</td>
</tr>
<tr>
<td>Supplies and materials</td>
<td>Stipends for teachers, materials</td>
<td>$2,500.00</td>
<td>$4,000.00</td>
<td>$4,000.00</td>
<td>$4,000.00</td>
</tr>
<tr>
<td>SREB Professional Development</td>
<td>PBL PD for all staff, job-embedded coaching, leadership coaching, TLMS STEM</td>
<td>**$17,270.00 (approx.) Governor’s Innovation Grant Funded (no cost to district)</td>
<td>**$17,270.00 (approx.) Governor’s Innovation Grant Funded (no cost to district)</td>
<td>**$11,440.00 (District funded)</td>
<td>--</td>
</tr>
</tbody>
</table>

*If programmatic funding cuts are to be incurred, the furniture for classrooms would be adjusted

**This is an estimate based upon current AMSTA planning budget