EXPLORING STEM SCHOOLS AND STUDENT ENGAGMENT: AN EXAMINATION OF STEM INSTRUCTIONAL PEDAGOGY AND STUDENT LEARNING EXPERIENCES

by

VALENCIA HUNTER BRADSHAW

(Under the Direction of Elaine Adams)

ABSTRACT

This study examined three aspects of secondary STEM Schools: (1) the mission and standards of AdvancED, the international school accrediting agency that STEM certified all Schools in the study; (2) the mission statements of 15 secondary STEM Schools; and (3) the published program materials from websites, handbooks, brochures, and news stories that provided a descriptive overview of the STEM Schools. The study purported to determine to what extent the three aspects recommended and supported the use of instructional pedagogy and student learning experiences that facilitated student engagement with STEM. The study examined published physical documents related to each of the three aspects of secondary STEM Schools using computer assisted qualitative data analysis software (CAQDAS). The research design was a summative quantitative content analysis. The AdvancED mission and standards as well as the STEM Schools' mission statements and program materials were available online at their various websites.

The investigation for the study used the core competencies and instructional design components of the Global STEM Alliance STEM Education Framework. The core competencies included critical thinking, problem-solving, creativity, communication, collaboration, data literacy and digital literacy and computer science. The instructional design components included research based pedagogy, STEM content integration, real-world application, project or problem-based learning, assessment and technology integration. These components provided the framework for the coding used in the CAQDAS examination.

The analysis revealed that STEM Schools' were aligning student learning experiences and instructional pedagogy with national priorities for STEM education which include recruiting students from underrepresented groups, providing rigorous, inquiry-based learning experiences and partnering with business, industry, and communities to provide holistic and authentic STEM learning. All STEM Schools in the study incorporated content knowledge, competency skills and thinking strategies in their program materials, however, only 20% of the STEM Schools included this information in their mission statements. Student learning experiences accounted for 72% of the coded themes for the program materials aspect and were coded most frequently for 80% of the STEM Schools in the study. These STM Schools were characterized as "inclusive high schools" (ISHS), and operated with open enrollment policies based on student interest.

INDEX WORDS: Authentic, Critical thinking and problem-solving, engagement, STEM, Inductive based learning, problem-based learning, project-based learning, case-based learning, content analysis, mission statement, real-world application

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DEDICATION

This dissertation is dedicated to the absolute love of my life, Felix Bernard Bradshaw. Thank you for being patient, understanding, encouraging and supporting me throughout this journey and to our children, Jamelia, Deramus, Tara, Quallan, Malcolm, Joshua, Bernesha and Briana for allowing me the time and space to complete this task.

I also dedicate this dissertation to the first love of my life, my mother, Mary Elizabeth Hunter. I am so proud to have been a part of your life! You taught me to love hard and unconditionally and to believe all things are possible through our faith in our Lord and Savior, Jesus Christ. Your life was an open book and taught me to be persistent in all life endeavors and to never give up when things looked impossible. You were an excellent example of a mother, grandmother, aunt, and friend. I miss you tremendously!

Mom, I'm ready -- I graciously accept your mantle.

Two roads diverged in a wood, and I –

I took the one less traveled by,

And that has made all the difference.

Robert Frost

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Selah! The end of a 13-year journey. Thank you to my Lord and Savior Jesus Christ who remains constant in my life. I would also like to thank my family and extended family including Pastor James Murkison, Lady Valerie Murkison and Jackie Foulds who spent countless hours listening to my ideas, proofreading, providing feedback, and supporting me through this journey. I could not have done it without you.

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Thank you to my principal, Dr. Duke Bradley, III and my Academy Director, Dr. Ava Debro for giving me the opportunity to serve as our school's STEM Coordinator and for inspiring me to complete this journey.

I officially started this doctoral endeavor January 2012; however, my journey began seven years earlier when I opened the pages of a book titled, "Dare to Desire" by John Eldredge - my life was forever changed. The book helped me to understand that I was living a script written for someone else – "only offering the parts of me that were approved, living out a careful performance to gain acceptance." It was at this point that I applied to graduate school and invited my heart along in my life's journey.

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CHAPTER 1

INTRODUCTION

The past decade has ushered in what some may call an all-out STEM-a-palooza or STEM mania, an obsession with the need to address the United States persistent anxieties about 21st century global competitiveness in knowledge, innovation and technology (Sanders, 2009). The acronym for science, mathematics, engineering and technology – SMET -- was first coined in the 1990's by the National Science Foundation (Bybee, 2010; Force, 2014; Heil, Pearson, & Burger, 2013; Sanders, 2009). In 2001 the National Science Foundation (NSF), changed the acronym from SMET to STEM because one of its program officers thought SMET and "smut" had similar sounds and might invoke the same pejorative connotation (Bybee, 2010; Sanders, 2009). The NSF wanted to draw increasing attention to subjects they believed were necessary to educate our now, scientifically literate society and needed some type of recognizable trademark or catch-all phrase to make this happen (Heil, Pearson, & Burger, 2013). The STEM acronym has taken on a life of its own and has become a generic label for any event, policy, program or practice related to one or a combination of any of the STEM disciplines (Bybee, 2010).

Employers, policy makers and educators have readily embraced the connectedness of the four disciplines that make up STEM. However, one of the challenges with the popularization of the acronym is the possible desensitizing of its importance to 21st century innovation and competitiveness, economic expansion and education teaching and learning (Raising the Bar, 2013). Closely aligned to the above challenges are the three most widely accepted goals for U.S., K-12 STEM education: increase advanced training and careers in STEM fields, expand the STEM capable workforce, and increase scientific literacy for all students (National Research Council [NRC], 2011).

Importance of STEM

New technologies and STEM knowledge lie at the core of our ability to manufacture better, smarter products, improve health care, preserve the environment, and safeguard national security (Holdren, Marrett, & Suresh, 2013). Individuals prepared with the skills and knowledge to invent, build, install, and operate those new technologies are essential to the U.S. economy. The measurement of the United States' health in relation to its science, technology, engineering and mathematics innovations depend not only on a STEM workforce, but also on a public that understands the role of STEM in addressing societal issues and is prepared to use STEM knowledge in personal and professional settings (Bybee, 2010; Force, 2014; Holdren et al., 2013). Outside of STEM careers, other fields increasingly require employees to have a good foundation in STEM disciplines. A basic understanding of STEM topics and concepts is also necessary beyond the workplace for citizens to make informed decisions on issues that are increasingly at the center of local and national political debates, such as environmental regulation (Bybee, 2010; Force, 2014; Holdren et al., 2013). STEM literacy is critical when it comes to making sound personal consumer choices, from health-care decisions to purchases at the grocery store (Bybee, 2010; Force, 2014; Holdren et al., 2013). A scientifically and computationally literate society is necessary for evaluation of personal and societal issues that rely on science and technology underpinnings.

Workforce Demand

An educated workforce with strong literacy skills is a powerful determinant of a nation's opportunity for economic success. Market sectors with high growth rates show a direct correlation to a STEM literate and skilled workforce (OECD, 2013). The "war for talent" has been described as the central battleground for 21st-century businesses. With growing pressure from international competition and the rapid pace of technological change, perhaps the most important resource for businesses is a competitive workforce (Michaels, 2001). Maintaining a skilled and capable workforce has positioned the United States as an innovation leader and major global competitor. Survival in this global, knowledge-based economy demands a different type of workforce (Career Technical Assessment Collaborative, 2011). In this economy, companies need employees that know what to do with knowledge, information, and technology. The new system of doing business favors judgment, intuition, creativity and insight. The new workplace requires employees with higher order technical skills and other skills necessary for workplace survival in the 21st century including the ability to learn on one's own, to gather and synthesize information, to work effectively in teams, to solve problems, to communicate effectively (written and verbally), and to manage time, money, and responsibilities (Institute for a competitive workforce, 2008). To remain a world leader as economies worldwide grow increasingly knowledge-intensive and interdependent, it is critical for the United States to continue to invest in the development of a skilled STEM workforce capable of handling 21st century scientific and technological innovations (Holdren et al., 2013; Texas Workforce Investment Council, 2015).

Developing a skilled STEM workforce comes with the challenge of addressing the skills shortage for careers in science, technology, engineering, and math (Manyika, Lund, Auguste; Welsh & Welsh, 2011). In fact, many current organizations are finding that they are not able to compete in the 21st century due to many workers lacking the necessary skills to help their companies grow and succeed (21st Century Workforce Commission, 2000). From a macro view, skill shortages and gaps may potentially lead to a loss of competitiveness for organizations as skilled employees bid up wage rates and productivity rates lower in industries with a shortage of skilled workers (Centre Europe'en pour le De’velopment de la Formation Professionnelle [CEDEFOP], 2010). This has become a major policy issue as skills shortages have stifled economic recovery and growth and some industries are struggling because they can't take full advantage of emerging business opportunities without the right workforce in place (Kaleba & Gragg, 2011). The skills shortage is defined as the misalignment of the skills needed for 21st century employment versus those skills possessed by prospective workers (American College Testing [ACT], 2011).

STEM Literacy

Nobel Peace prize winner, physicist, Leon Lederman defines “STEM literacy” in a knowledge-based economy as “the ability to adapt to and accept changes driven by new technology work with others (often across borders), to anticipate the multilevel impacts of their actions, communicate complex ideas to a variety of audiences, and perhaps most importantly, find “measured yet creative solutions to problems which are today unimaginable" (National Governors Association, 2007, p. 3). Additional research supports STEM literacy as having the ability to read with understanding; to analyze written information; to comprehend informational and complex text; to write clearly; to orally present information and analysis documenting important facts and findings; to compute with competence; to think analytically; to adapt to change; to work in teams; and to use digital technology, communications tools, and/or networks to access, manage, integrate, evaluate, and create information in order to function in a knowledge society" (21st Century Workforce Commission, 2000; Alber, 2013; Jones & Flannigan, 2006; International ICT Literacy Panel, 2002). Secondary STEM education plays a major role in the preparation of students for the workforce by ensuring their readiness for the challenges and opportunities of the future to address U.S. sustainability and an economically viable world (Achieve, 2015; Cogshall, 2012; Partnership for 21st Century, 2010). STEM education should be inclusive, even for students that do not pursue STEM careers; as citizens, they will be asked to evaluate and vote on complex issues that require strong scientific competence. Today's students will also be consumers of ever more-sophisticated technologies (Force, 2014). A STEM literate public needs to make wise choices. Basic, 21st century living will require individuals to have a deep, useable knowledge of scientific and engineering ideas and practices, as well as the creativity, problem solving, and communication capabilities and judgment to apply STEM ideas (Krajcik & Delen, 2017).

Purpose Statement

The availability of federal and other grant monies to public schools in the United States over the past ten years has made establishing STEM Schools and programs a part of our education landscape. Now that the landscape has changed - so should the measures we use to determine students' persistency for the STEM career pipeline (Denmark, 2015; Means, Confrey, House, & Bhanot, 2008; NRC, 2011a). In addition to rigorous academic content, most secondary STEM Schools have adopted project-based learning (PBL) as the foundation for their curriculum design (Hall & Miro, 2016; Patel, Franco & Lindsey, 2014). Project-based learning (PBL) in this context does not refer exclusively to a classroom assignment or activity, rather, it's a description of how the overall curriculum is taught (Bell, 2010; Patel et al., 2014). Project-based learning requires students to actively engage in critical thinking, problem-solving, communication, collaboration, creativity, innovation, and technology integration, preparing them for the real world. This active engagement of students in PBL facilitates the development of students' core competency or essential 21st century skills (Moylan, 2008).

Student engagement plays a pivotal role in students' learning experiences and has been positively correlated to academic achievement (Connell, Spencer, & Aber, 1994; Marks, 2000; Sirin & Rogers-Sirin, 2004). Connell, Halpern-Felsher, Clifford, Crichlow & Usinger (1995), state that student engagement is the only factor that has a direct effect on academic achievement; all other factors, including student-teacher rapport and instructional practices indirectly influence achievement. This achievement not only represents student mastery on various assessments, but also the skills, habits, and self-regulatory abilities that necessitate such success. STEM engagement experiences require students to use higher-order knowledge acquisition and application and is most associated with the literature and research related to critical-thinking and problem-solving (Garrison, Anderson, & Archer, 2000).

The purpose of this study was to examine the evidence of student engagement in STEM Schools. Student engagement in STEM Schools was viewed through the lens of instructional pedagogy and student learning experiences. Student engagement involves the frequency with which students fully and actively participate with learning activities that represent effective, research-based educational practices (Fredricks, Blumenfield & Paris, 2004; Hudson, English, Dawes, King, & Baker, 2015; Parson, Nuland, & Parsons 2014). The behavioral component of student engagement is defined as “active, goal-directed, flexible, constructive, persistent, focused interactions with the social and physical environments” (Furrer & Skinner, 2002, p. 149). In this study, instructional pedagogy refers to the specialized knowledge of teachers for creating effective teaching and learning environments that utilize a range of inductive-based instructional practices specific to STEM education including inquiry learning, problem-based learning, project-based learning, and technology-infused learning (Hudson et al., 2015; Prince & Felder, 2006). Instructional pedagogy also refers to STEM designed curriculum and the professional learning supports necessary to build the STEM instructional capacity of teachers. Student learning experiences refer to learning activities that build students’ STEM content knowledge and focus on real-world, locally relevant, complex, open-ended problems that require problem identification, investigation, and analysis. Specifically, student learning experiences include cooperative/collaborative learning, project and problem-based learning, higher-level questioning, experimental/hands on learning, student independent inquiry/research, student discussions and students as producers of knowledge using technology (Hall & Miro, 2016; Lowther, Ross, & Plant, 2000). Student learning experiences in real-world settings can also extend beyond the classroom, school environment and normal school day to include mentorships, apprenticeships, internships, field trips, student competitive events, research and job shadowing with researchers, business/industry or other community partners.

To understand the place of student engagement in STEM Schools, it was necessary to delineate the role given to instructional pedagogy and student learning experiences that serve as a measure of student engagement, in the mission statement and STEM standard for the Schools' STEM accrediting agency – AdvancED. The STEM Schools' mission statements were also examined for evidence of instructional pedagogy and student learning experiences including cooperative/collaborative learning, project and problem-based learning, higher-level questioning, experimental/hands on learning, student independent inquiry/research, student discussions and students as producers of knowledge using technology. Mission statements should outline the goals and objectives of a STEM School or program and articulate the School's vision in an actionable way. The mission statement describes the current state of the School's STEM program and explains its purpose. Specifically, the mission statement should address: *what* the STEM School does, *who* benefits from the work of the School and *what* benefits are received by students (Evans, 2010). Additional published program materials from school websites, handbooks, brochures, news stories and other descriptive written documents that provided evidence of instructional pedagogy and student learning experiences were also examined. Content analysis of the elements found in the mission statements and the program materials was used to identify commonality and similarity between and among the STEM Schools.

Conceptual Framework

The interrelated concepts and theories that served as a guide for this study all undergird the instructional pedagogies and student learning experiences necessary for secondary STEM Schools that best prepare U.S. students for persistency in STEM in college majors and careers. Miles and Huberman (1994) defined a conceptual framework as a visual or written product, one that "explains, either graphically or in narrative form, the main things to be studied—the key factors, concepts, or variables—and the presumed relationships among them" (p. 18). Miller (1996) stated that there is a plethora of theories that guide education practice through philosophy. Therefore, a combination of theories can provide a philosophic lens through which the vision of a program may be viewed and then becomes the conceptual framework for designing new programs. Critical to the examination and design of STEM education programs is the ability to clarify the theoretical relationships among elements thought to influence the effectiveness of students' persistence in STEM education and STEM careers (Asunda, 2014; Kelley & Knowles, 2016; Lynch, Behrend, Burton & Means, 2013; New York Academy of Sciences, 2016).

Researchers agree that *student engagement* with STEM learning is one of the "key" influencers of students' persistence in STEM education and STEM careers (Holdren et al, 2013; Schweingruber, Pearson, & Honey, 2014; Redmond, Thomas, High, Scott, Jordan & Dockers, 2011; Reider, Dnestis, & Malyn-Smith, 2016). The conceptual framework for this study was designed to show the presence of the critical elements necessary for effective STEM teaching and learning and the promotion of student engagement. The framework is undergirded by the theories of social constructivism, situated cognitive learning, and authentic learning and incorporates the essential STEM education practices outlined in the Global STEM Alliance (GSA) STEM Education Framework (New York Academy of Sciences, 2016). Also acknowledging that STEM engagement experiences are most associated with the literature and research related to critical thinking and problem-solving (Garrison et al., 2000), the researcher chose to frame the study using the Practical Inquiry model (PI). The PI model reflects the critical thinking process from a holistic view and includes creativity, problem solving, intuition and insight (Garrison et al., 2000).

The GSA STEM education framework provides an excellent guide for the implementation and instructional design of a secondary STEM program and reflects current education research in the areas of social constructivism, situated cognition and authentic learning. The framework consists of three essential areas -- core competencies, instructional design and implementation, that support 26 features of quality STEM education that should be considered when evaluating or developing STEM Schools (Lynch et al., 2013; New York Academy of Sciences, 2016). These features are reflected in each of the four quadrants of the conceptual framework as indicators for instructional pedagogy or student learning experiences. See Appendix E for the complete framework and features. The practical inquiry model defines four phases essential to the description and understanding of cognitive presence in an educational context. Garrison, Anderson, & Archer (2000), believe a worthwhile educational experience is embedded within a community of inquiry that includes teachers and students. The model assumption is that learning occurs within the community through the interaction of three core elements – cognitive presence, social presence and teaching presence (Garrison et al., 2000). For purposes of this study, cognitive presence is the extent to which participants in a community of inquiry construct meaning through sustained communication. Social presence describes the ability of participants in the community of inquiry to project their personal characteristics into the community. The teaching presence in a community of inquiry includes the selection, organization, and primary presentation of course content, learning activities and assessment.

The conceptual framework is comprised of four quadrants and two dimensions. The first dimension of the model represents the continuum between action and deliberation or imagination/reflection to experience and practice. The second dimension of the conceptual framework represents the continuum between the concrete and abstract worlds – the perception-conception dimension. To operationalize the conceptual framework for this study, each phase or quadrant is explained in the following paragrpahs:

Phase One is the initiation phase of critical inquiry (bottom left quadrant) and provides a “triggering event” for the students. In this phase teachers present a problem, challenge, dilemma or question that emerges from an experience or is reflective of a real-world occurrence as a triggering event for students. As the facilitator, the teacher’s role is to initiate, shape, and, possibly discard potentially distracting triggering events so that the focus remains on the attainment of intended educational outcomes. This phase is undergirded by the Authentic learning theory which legitimizes traditional classroom content learning by engaging students in real-world, complex problems and solutions using case studies, problem and project-based activities and virtual communities of practice (Lombardi, 2007; Strimel, 2014; Yoshikawa & Bartholomew, 2017). This phase is also supported by the social constructivist theory which is a student-centered approach to learning where students actively assimilate and internalize information to construct new knowledge and meaning based on their social environment, prior knowledge, attitudes and values (Abdal-Haqq, 1998; Educational Broadcasting Corporation, 2004; Dalgarno, 2001; Richardson, Morgan & Fleener, 2012; Zualkernan, 2006). The "shared world" of phase one is collaborative and knowledge-focused (Garrison et al., 2000).

Phase Two is the exploration phase. Students now move back and forth between their private worlds and the social exploration of ideas. This phase starts with students understanding or grasping the nature of the issue, problem, or project before moving to a fuller exploration of relevant information. Exploration takes place in a community of inquiry as students continue to move between the private and shared worlds—that is, between critical reflection and meaning-focused. At the end of this phase, students begin to hone in on the relevant components of the issue or problem. This phase is also characterized by brainstorming, questioning, and exchange of information. Again, we see the application of social constructivism and authentic learning (Garrison et al. 2004). The authentic learning teaching pedagogy in this phase encourages students to explore, discuss and meaningfully construct concepts and relationships, (Holdren et al., 2013; Lombardi, 2007; NSTC, 2013; Pearson, Sawyer, Park, Santamaria, & Van, 2010; Problem-Based Learning, 2014).

Phase Three, the integration phase, is characterized by constructing meaning from the ideas generated in the exploratory phase. During the transition from the exploratory phase, students will begin to assess the applicability of ideas in terms of how well they connect and describe the issue or event under consideration. This phase may require active coaching or facilitation from the teacher to clear up any misconceptions, ask probing questions, and address any additional information to ensure continuing cognitive development, and to model the critical thinking process. Instructional pedagogy is critical in this phase as the teacher is helping to move students out of exploration and into more advanced stages of critical-thinking and problem solving (Garrison et al., 2004). This phase bears out the situated cognition learning theory. Situated cognitive learning supports learning through participation and practice acknowledging that learning and knowing are products of activity within a socially structured world (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Putnam & Borko, 2000). Often when learning is grounded within a situated context, learning is authentic and relevant, therefore representative of an experience found in actual STEM practice theory (Brown et al., 1989; Lave & Wenger 1991; Putnam & Borko 2000). Actively engaging students in this type of learning environment lends itself naturally to interdisciplinary practices needed for STEM education (Lombardi, 2007; Yoshikawa & Bartholomew, 2017).

Phase Four is a resolution of the dilemma or problem either directly or indirectly. Progression to this stage usually requires clear expectations and opportunities to apply newly created knowledge. This phase ends the problem, question or project. Students can now move on to a new problem with the assumption that students have acquired useful knowledge (Garrison & Archer, 2000). Phase four is also reflective of capstone projects that synthesize all STEM learning experiences by allowing students to participate in job shadows, apprenticeships, internships and competitive events. These authentic or real-world projects help expand students' knowledge and give them the opportunity to actively participate in learning that is relevant in society and/or their personal lives (Holdren et al., 2013; Lombardi, 2007; NSTC, 2013; Pearson et al, 2010).

The visual illustration of the conceptual framework for this study is shown in Figure 1.

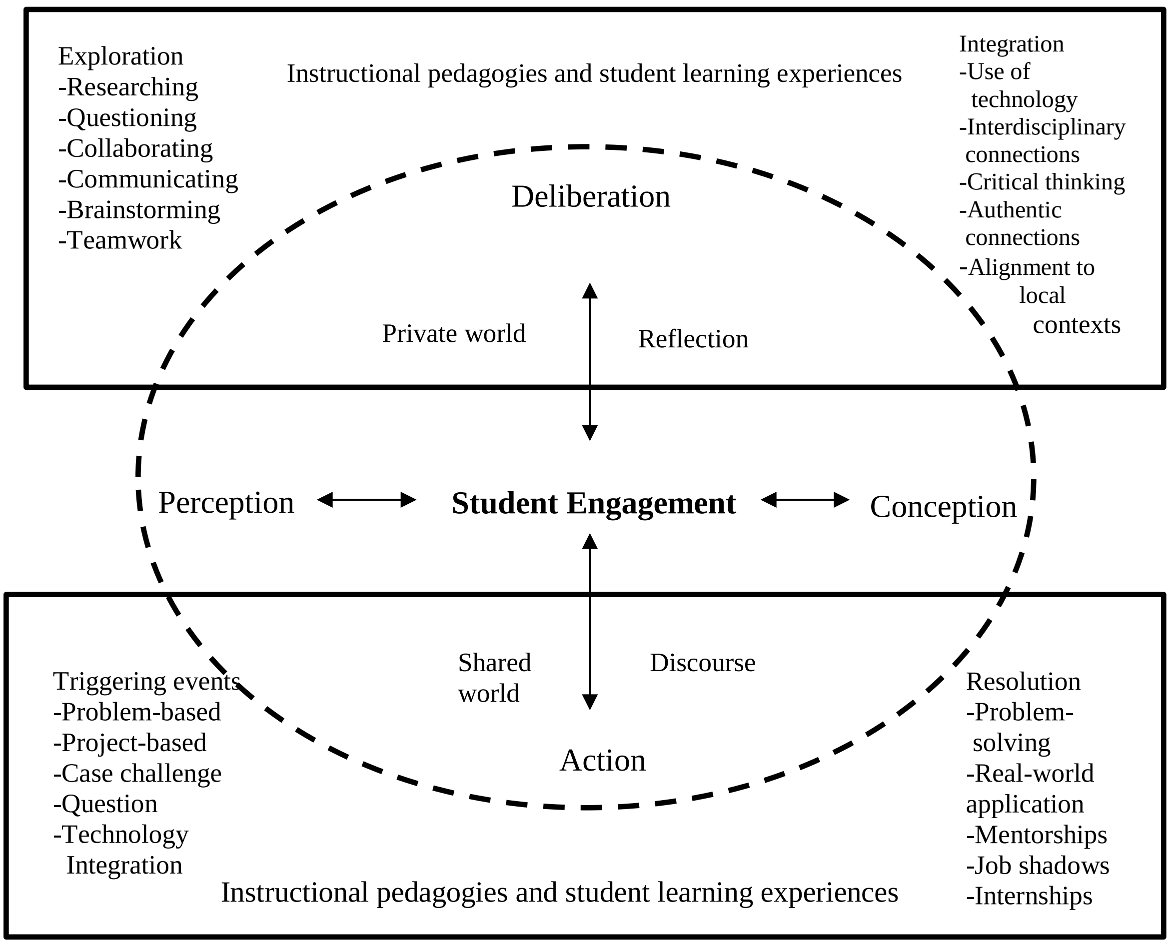


Figure 1 Conceptual Framework

Research Questions

The study was guided by the following research questions:

1. To what extent does the STEM Schools' mission statements include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration?
2. To what extent does the STEM Schools' program materials include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration?
3. Is there evidence in the STEM Schools' program materials to support the conceptual framework indicators for STEM learning experiences including project-based learning, problem-based learning, case-based learning, real-world applications and external learning experiences including mentorships, internships, apprenticeships, job shadowing, and STEM student competitions?
4. Is there evidence in the STEM Schools' program materials to support the conceptual framework indicators for researched-based instructional pedagogies including project-based learning, problem-based learning, performance-based learning and assessment, technology integration, content integration, and the necessary materials and supports for teacher STEM professional development and collaboration with interdisciplinary team?

Significance of Study

Research literature provides a great deal of information on the history of STEM, STEM education, STEM integration efforts, and federal investments in STEM programs (Grasso & Burkins, 2010; Heil, Pearson, & Burger, 2013; Hernandez et al., 2014; Holdren et al., 2013; Schweingruber, et al., 2014; Sanders, 2009). However, what is missing from research is literature that describe an exact model for secondary STEM Schools, what they should do, how they interpret and use the term “STEM,” what their goals are, and thus, what outcomes we can and should expect from them (Grasso & Burkins, 2010; Heil, Pearson, & Burger, 2013; Hernandez et al., 2014; Schweingruber et al, 2014). Without shared contextual language describing a model for secondary STEM Schools, it is difficult to compare impact and outcomes as well as develop a knowledge base that can inform continued growth and improvement (LaForce et al, 2016).

This study examined evidence of student engagement experiences through the lens of instructional pedagogies and student learning experiences which serves as the primary driver for outcomes related to student persistence in STEM education and STEM careers (Connell et al, 1995; Schweingruber et al., 2014). This content analysis is important and can be used by school leaders, teachers, curriculum developers, and policymakers to help guide the development and evaluation or improve existing practices of STEM Schools to provide high-quality instructional programs and materials. Specifically, this study will become invaluable to me as the STEM Coordinator for a magnet Academy that has expanded its program offerings to include STEM curriculum and career pathways. The research behind the different components of the programs are extremely important for the curriculum design of instructional pedagogies and student learning experiences. Additionally, the study can be used to inform future research and suggest a model that will provide stakeholders with a common ground for discussion and collaboration.

CHAPTER 2

LITERATURE REVIEW

The demands of the 21st century, the pace of technological change, changing demographics, the challenges of student engagement and achievement, and growing global competition have all created an urgency to evaluate the effectiveness of the way we educate American students. Policy makers, business groups and employers continue to argue the case for expanding and improving STEM education (Carnegie Corporation 2009; Council on Competitiveness 2005; NGA 2007; NRC 1996, 2007a, 2012a; National Science Board [NSB] 2007; President's Council of Advisors on Science and Technology [PCAST], 2012). Employers are sounding the alarm and continuing to raise concerns about schools not adequately preparing students for careers in high-demand STEM fields. National and international studies continue to show American students lag behind other developed nations and score below many of their counterparts in math and science achievement (ACT, 2016; Wiswall, Stiefel, Schwartz & Boccardo, 2014).

The Organization for Economic Co-Operation and Development (OECD) published data from the Programme for International Student Assessment (PISA), confirm that students in the United States are less proficient in science than many of their global counterparts. Based on results from the 2015 administration of the PISA, an international exam given to 15-year-old students, the United States performed below average in mathematics ranking twenty-sixth out of thirty-five countries. The United States ranked closer to the middle of the pack at seventeenth in reading and twenty-first in science. While the U.S. spends more per student than most countries, this has not translated into better performance. Table 1 provides a snapshot of countries' performance in Science, Reading and Mathematics for the last administration of test. Full tables are included in Appendix B.

Table 1 Snapshot of Performance in Science, Reading and Mathematics

	Science		Reading		Mathematics	
	Mean score in PISA 2015	Average three-year trend	Mean score in PISA 2015	Average three-year trend	Mean score in PISA 2015	Average three-year trend
	Mean	Score dif.	Mean	Score dif.	Mean	Score dif.
OECD average	493	-1	493	-1	490	-1
Singapore	556	7	535	5	564	1
Japan	538	3	516	-2	532	1
Estonia	534	2	519	9	520	2
Chinese Taipei	532	0	497	1	542	0
Finland	531	-11	526	-5	511	-10
Macao (China)	529	6	509	11	544	5
Canada	528	-2	527	1	516	-4
Viet Nam	525	-4	487	-21	495	-17
Hong Kong (China)	523	-5	527	-3	548	1
B-S-J-G (China)	518	m	494	m	531	m
Korea	516	-2	517	-11	524	-3
New Zealand	513	-7	509	-6	495	-8
Slovenia	513	-2	505	11	510	2
Australia	510	-6	503	-6	494	-8
United Kingdom	509	-1	498	2	492	-1
Germany	509	-2	509	6	506	2
Netherlands	509	-5	503	-3	512	-6
Switzerland	506	-2	492	-4	521	-1
Ireland	503	0	521	13	504	0
Belgium	502	-3	499	-4	507	-5
Denmark	502	2	500	3	511	-2
Poland	501	3	506	3	504	5
Portugal	501	8	498	4	492	7
Norway	498	3	513	5	502	1
United States	496	2	497	-1	470	-2
Austria	495	-5	485	-5	497	-2
France	495	0	499	2	493	-4
Sweden	493	-4	500	1	494	-5
Czech Republic	493	-5	487	5	492	-6
Spain	493	2	496	7	486	1
Latvia	490	1	488	2	482	0

Note: Snapshot of performance in science, reading and mathematics. PISA 2015 Results in Focus. Copyright 2018 by OECD. Reprinted with permission.

Roughly 38% of 15-year-olds in the United States expect to work in a science-related career at age 30 compared to 24% of students across the OECD. Most US students, 22%, expect to become health professionals, 13% science and engineering professionals, 2% IT professionals; and 1% science-related technicians and associates

(PISA, 2015). Students in the United States performed better in collaborative problem-solving placing thirteenth out of thirty-two countries. This assessment area dealt with performing tasks with higher cognitive demands, such as taking real-world situations, translating them into mathematical terms, and interpreting mathematical aspects of real-world problems. These results confirm the need for increased focus on pedagogical strategies for critical-thinking and problem-solving strategies in math and science (STEM) fields.

The good news regarding these results is that US students performed better in collaborative problem-solving than would be expected given the scores on the science, reading and math assessments. This could possibly suggest the early development of critical-thinking and problem-solving abilities in 15-year old American students. Across OECD countries, only 28% of students were able to solve straight forward collaborative problems. Students in Estonia, Hong Kong (China), Japan, Korea, Macao (China) and Singapore were top performers in collaborative problem-solving with students in Singapore coming in at number one followed by students in Japan (PISA, 2015). Overall, only 8% of students scored as top performers across OECD countries in collaborative problem solving, meaning that they can maintain an awareness of group dynamics, ensure team members act in accordance with their agreed-upon roles, and resolve disagreements and conflicts while identifying efficient pathways and monitoring progress towards a solution (PISA, 2015). See Table 2 for results of the PISA Collaborative Problem-Solving Assessment.

Table 2

	Collaborative problem solving				
	All students	Relative performance[1]	Boys	Girls	Gender difference (boys - girls)
	Mean score	Score dif.	Mean score	Mean score	Score dif.
OECD average-32	500	3	486	515	**-29**
Singapore	561	16	552	572	**-20**
Japan	552	23	539	565	**-26**
Hong Kong (China)	541	15	523	559	**-36**
Korea	538	20	522	556	**-33**
Canada	535	10	516	555	**-39**
Estonia	535	8	522	549	**-27**
Finland	534	7	511	559	**-48**
Macao (China)	534	11	515	553	**-38**
New Zealand	533	20	513	553	**-41**
Australia	531	23	511	552	**-41**
Chinese Taipei	527	5	513	541	**-28**
Germany	525	14	510	540	**-30**
United States	520	22	507	533	**-26**
Denmark	520	14	509	530	**-21**
United Kingdom	519	12	503	536	**-34**
Netherlands	518	8	504	531	**-27**
Sweden	510	9	489	531	**-42**
Austria	509	13	498	521	**-24**
Norway	502	-5	487	518	**-30**
Slovenia	502	-10	484	521	**-36**
Belgium	501	-4	489	514	**-25**
Iceland	499	15	485	512	**-27**
Czech Republic	499	3	486	512	**-26**
Portugal	498	-5	489	507	**-19**
Spain	496	-1	485	508	**-22**
B-S-J-G (China)	496	-17	486	508	**-22**
France	494	-7	480	508	**-29**
Luxembourg	491	2	478	504	**-25**
Latvia	485	-9	465	505	**-40**
Italy	478	-11	466	489	**-23**
Russia	473	-22	460	486	**-25**
Croatia	473	-12	459	486	**-27**
Hungary	472	-10	459	485	**-26**
Israel	469	-11	459	481	**-22**
Lithuania	467	-15	453	482	**-29**
Slovak Republic	463	-7	448	478	**-30**
Greece	459	-10	444	475	**-31**
Chile	457	-3	450	464	**-14**

Note: Snapshot of performance in collaborative problem solving and attitudes toward collaboration. PISA 2015 Results in Focus. Copyright 2018 by OECD. Reprinted with permission.

Employers, policymakers and educators advocate for teaching that highlight the integration of the STEM subjects, especially because this makes STEM more reflective of real-word issues and more relevant to students. Even with an increased focus on STEM and its importance for citizens in our knowledge and technology intensive, global economy, there is still confusion from policy makers and educators about what constitutes integrated STEM education (Grasso & Burkins, 2010; Heil, Pearson & Burger, 2013; Hernandez et al., 2014; Schweingruber et al, 2014). Since its launch in 2001 the acronym has taken on a life of its own and has become a generic label for any event, policy, program or practice related to one or a combination of any of the STEM disciplines (Bybee, 2010). Employers, policy makers and educators have readily embraced the connectedness of the four disciplines that make up STEM. However, one of the challenges with the popularization of the acronym is the possible desensitizing of its importance to 21st century economic expansion and innovation, education and the creation of a STEM-literate society (Raising the Bar, 2013).

Framing of STEM

To maintain the United States' dominance as a global leader, it is essential that the nation is driven by a continuous flow of STEM knowledge, expertise and labor (Armour-Garb, 2017; NSB, 2015; NSTC, 2009; Reider et al., 2016). To build the repository of qualified STEM professionals in the United States it will take the collaborative effort of the federal government, educational institutions and business leaders. The goal of the combined efforts of all the above stakeholders is to increase workers prepared with scientific and technical knowledge and capabilities, increase U.S. student achievement in math and science and increase efforts to recruit STEM professionals from groups that have been historically underrepresented in science, technology, engineering and mathematics careers like women and minorities (Armour-Garb, 2017; Holdren et al., 2013; LaForce et al, 2016; NSTC 2009).

The United States anxieties about decreasing student achievement and the ability to be globally competitive can be traced back to the 20th century and documented in government reports like **“**A Nation at Risk: The Imperative for Educational Reform (National Commission on Excellence in Education [NCEE], 1983)” and “What Work Requires of Schools: A SCANS Report for America 2000 (SCANS Report, 1992).” Both reports stated that American students were lagging other industrialized nations in math and science achievement and the skilled intelligence necessary to be globally competitive in our knowledge and technology intensive 21st century society (NCEE, 1983; SCANS Report, 1992). Anxieties about the academic achievement of U.S. students, especially related to STEM areas, continued into the 21st century with publications like, The World is Flat (Friedman, 2005) and policy reports including “Prepare and Inspire: K-12 Education in STEM for America’s Future’’ (PCAST, 2010), ‘‘Building a STEM Agenda’’ (National Governors Association, 2007), and ‘‘Rising Above the Gathering Storm’’ (NRC, 2007a).

In July of 2009 president Obama gave a national challenge to reshape America’s education system to prepare students for success in a competitive 21st century economy. In response to the president’s challenge we have witnessed a proliferation of state and federal STEM programs, federal reports and policies, and reform initiatives including Race to the Top, Educate to Innovate and the Federal STEM Education 5-Year Strategic Plan (LaForce et al, 2016; NSTC, 2009; Office of the Press Secretary, 2010). The Race to the Top school grant was backed by a $4.35 billion investment and included a focus on reinvigorating math and science education and promoting other conditions favorable to innovation and reform. States that committed to improving STEM education were assured competitive preference for grant awards. In November 2009, the Obama administration unveiled the "Educate to Innovate" campaign backed by an additional $260 million in public and private investments. Educate to Innovate was designed as a nationwide campaign to move American students from the middle to the top of the pack internationally in science and math achievement over the course of 10 years (LaForce et al, 2016, NSTC, 2009; Office of the Press Secretary, 2010). President Obama stated, "reaffirming and strengthening America's role as the world's engine of scientific discovery and technological innovation is essential to meeting the challenges of this century" (Office of the Press Secretary, 2010, p. 1). The Federal STEM Education 5-Year Strategic Plan was developed as a complement to the other STEM initiatives with the goal of achieving significant, measurable impacts in the following five STEM education priority areas (Holdren et al., 2013, p. 8):Gut

1. Improve STEM Instruction
2. Increase and Sustain Youth and Public Engagement in STEM
3. Enhance STEM Experience of Undergraduate Students
4. Better Serve Groups Historically Under-represented in STEM Fields
5. Design Graduate Education for Tomorrow's STEM Workforce

At the federal level, organizations like the National Science Foundation (NSF) and the National Institute of Health (NIH) support STEM education by offering funding for formal and informal (out-of-school) STEM experiences that reinforce inquiry-based learning (United States Government Accounting Office [GAO], 2005). State level initiatives include funding from organizations such as the Gates Foundation (2015) and the National Governor's Association Center for Best Practices (2011). With this increased national and state funding for building a STEM pipeline, the common reaction from the education community and policy makers has been the creation of distinct secondary STEM Schools and the incorporation of STEM Programs within larger schools (Franco & Patel, 2017; LaForce et al, 2016; NSTC 2009).

Secondary STEM Education

Secondary STEM Schools are designed to offer a more rigorous academic curriculum with a focus on integrated STEM education teaching and learning (LaForce et al, 2016). One of the challenges of integrated STEM education is the absence of a shared definition among schools, educators and policy makers. In fact, there is still little consensus about what “STEM” actually is and what it looks like operationally in secondary education. Some STEM Schools focus on the interdisciplinary nature of STEM, while others take it a step future and focus on the multidisciplinary integration of STEM across all subject areas (LaForce, et al., 2016). Without a shared language to describe integrated STEM education, educators and researchers have not been able to perform comparative studies on the outcomes of STEM Schools. Tsupros, Kohler, and Hallinen (2009) offer the following definition for STEM education, “STEM is an interdisciplinary approach to learning in which rigorous academic concepts are coupled with real-world lessons. Students apply science, technology, engineering, and mathematics in contexts that connect school, community, industry, and the global enterprise, enabling the development of STEM literacy and, with it, the ability to compete in the new economy (pg. 8).” Another definition for STEM education states, “K-12 STEM education encompasses the processes of critical thinking, analysis, and collaboration in which students integrate the processes and concepts in real world contexts of science, technology, engineering, and mathematics, fostering the development of STEM skills and competencies for college, career, and life (Torlakson, 2013 pg. 9)**.**"

In the absence of a shared definition for STEM education, policy makers, researchers and educators agree that if schools are to develop pedagogical models that provide a rigorous, well-rounded education, there needs to be an operational definition of STEM that goes beyond literacy and teaching the distinct STEM disciplines, and focus on student engagement (Franco & Patel, 2017; Hall & Miro, 2016; Kennedy & Odell, 2014; Krajcik & Delen, 2017; Patel et al., 2014). An authentic STEM experience is "a designed experience inside or outside of school in which learners engage directly in doing STEM (Holdren et al., 2013, pg. 8). This broad designation covers a range of commonly referenced notions, from hands-on science, to problem-based learning, to inquiry. Research indicates STEM experiences that engage learners in "active learning" improve retention of information and critical-thinking skills (NRC, 2009; Sivan, Leung, Woon, & Kember, 2000). This study examined evidence of student engagement through the lens of instructional pedagogies and student learning experiences in secondary STEM Schools. Instructional pedagogy and implementation of student learning experiences were examined using an extended version of the Garrison et al. (2000), PI Model and drew upon the evaluation frameworks of the AdvancED STEM Standard (Http://www.advanc-ed.org) and the Global Alliance STEM Education Framework (New York Academy of Sciences, 2016). The instructional pedagogies and student learning experiences were studied in a curricular context utilizing descriptive information ranging from standards and mission statements of accrediting agencies to websites, handbooks, brochures, news stories and other descriptive written documents that provided evidence of student engagement.

Operating as distinct silos, the STEM disciplines describe separate categories of knowledge. However, when the disciplines serve as an interconnected unit the definition expands to include learning strategies and competencies which strongly correlate with skills, abilities, work interests, and work values (Carnevale, Melton, and Smith, 2011). Traditionally math and science received the primary focus from education stakeholders. As the STEM movement gains momentum, educators and policy makers are more deliberately addressing the inclusion of technology and engineering (Raising the Bar, 2013; Grasso & Burkins, 2010; Heil, Pearson, & Burger, 2013; Hernandez et al., 2014; Schweingruber et al, 2014). Many believe these two disciplines were previously overlooked and siloed in the career and technical education arena (Grasso & Burkins, 2010; Heil, Pearson, & Burger, 2013; Hernandez et al., 2014 Schweingruber et al, 2014 & Sanders, 2009). To understand interdisciplinary STEM education, or as many have come to know it, integrated STEM education, lets first define the individual components. Table 3 gives a description of the four STEM disciplines.

Table 3 The Four STEM Disciplines

Science is the study of the natural world, including the laws of nature associated with physics, chemistry, and biology and the treatment or application of facts, principles, concepts, and conventions associated with these disciplines. Science is both a body of knowledge that has been accumulated over time and a process—scientific inquiry—that generates new knowledge. Knowledge from science informs the engineering design process.

Technology, while not a discipline in the strictest sense, comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves. Throughout history, humans have created technology to satisfy their wants and needs. Much of modern technology is a product of science and engineering, and technological tools are used in both fields.

Engineering is both a body of knowledge—about the design and creation of human-made products—and a process for solving problems. This process is design under constraint. One constraint in engineering design is the laws of nature, or science. Other constraints include time, money, available materials, ergonomics, environmental regulations, manufacturability, and reparability. Engineering utilizes concepts from science and mathematics as well as technological tools.

Mathematics is the study of patterns and relationships among quantities, numbers, and space. Unlike in science, where empirical evidence is sought to warrant or overthrow claims, claims in mathematics are warranted through logical arguments based on foundational assumptions. The logical arguments themselves are part of mathematics along with the claims. As in science, knowledge in mathematics continues to grow, but unlike in science, knowledge in mathematics is not overturned, unless the foundational assumptions are transformed. Specific conceptual categories of K-12 mathematics include numbers and arithmetic, algebra, functions, geometry, and statistics and probability. Mathematics is used in science, engineering and technology.

Note: National Academy of Engineering and National Research Council, 2009.

Now that the separate disciplines that make up the STEM acronym have been identified, it is important to dismiss the siloed descriptions and holistically view the disciplines. The National High School Alliance gives the following description of STEM: “Science, technology, engineering and mathematics (STEM) education is a relatively new mode of thinking about how best to educate high school students for the workforce and for post-secondary education. STEM education is not simply a new name for the traditional approach to teaching science and mathematics. Nor is it just the grafting of “technology” and “engineering” layers onto standard science and math curricula. Instead, STEM is an approach to teaching that is larger than its constituent parts; it is, a “meta-discipline (Kennedy & Odell, 2014, p. 253).”

STEM education is designed to remove the traditional boundaries between the four disciplines, by integrating the four subjects into one cohesive means of teaching and learning. The engineering component focuses on the design process instead of the specific solutions to problems. Utilizing this type of approach helps students explore math and science in a more personalized context, while helping them to develop the critical thinking skills needed for application in all facets of their work and academic lives. Engineering is the method that students use for discovery, exploration, and problem-solving. The integration of technology allows for a deeper understanding of the three other parts of STEM education. It allows students to apply what they have learned, utilizing computers with virtual simulations, game-based learning and specialized and professional applications like Computer Assisted Design (CAD) and computer animation. These types of technological applications allow students to explore STEM subjects in an authentic and practical manner (Kennedy & Odell, 2014).

STEM Schools

Specialized STEM high schools began to emerge in the early 1900's. Earlier STEM Schools served students who were advanced academically in math and science fields. The last decade has seen a rapid increase in non-selective, "inclusive" STEM schools with open enrollment policies due to the national push for more integrated and inclusive STEM education (Franco & Patel, 2017; LaForce et al, 2016; NSTC 2009). Because government and private funding of STEM curricular programs were attractive for Schools, inserting STEM to a school's name became the simple, convenient way to be "STEM." Increased funding has caused an increase in STEM Schools and has created a demand for shared language and guidance about what constitutes "effective" integrated STEM education (Denmark, 2015; LaForce et al., 2016). Simply implementing a new curricular program and inserting STEM to a school's name is not sufficient in and of itself. "In order for schools to have authentic, effective, and sustainable results that meet the needs of all learners, STEM has to be embraced as an integrated, inquiry-based approach that incorporates as a minimum, the four disciplines: science, technology, engineering and mathematics. In doing so by intentional collaborative planning, the results change teaching practices, the curriculum and student learning outcomes" (Denmark, 2015, pg. 3).

Three broad categories of STEM-focused Schools have been identified to meet the overarching goals for U.S. STEM education: selective STEM schools, inclusive STEM Schools, and schools with STEM-focused career and technical education. The Inclusive STEM school design was specifically created to meet the need of a shared language for integrated STEM education (LaForce et al., 2016; NRC, 2011a). It was important for this study to identify and examine the different types of STEM Schools across the United States because they generally do not operate according to the same model. Even Schools designated as “inclusive”, display variations in their guiding philosophies and operations as well as in the students they serve (Gnagey & Lavertu, 2016). This study used content analysis to examine evidence of student engagement experiences through the lens of instructional pedagogy and student learning experiences across multiple school approaches to STEM education.

Selective STEM Schools. As the name implies, these schools have selective admission criteria and are typically organized around one or more of the STEM disciplines. Selective Schools usually have smaller enrollment numbers and cater to highly talented, motivated students with a track record of above average achievement in STEM related subjects (NRC, 2011a). These specialized schools are heavily funded and include a support system of expert teachers, advanced curricula, sophisticated laboratory equipment, and apprenticeships with scientists. Teachers are provided with research-based professional development and supplementary programs to help undergird their teaching pedagogy (NRC, 2011a).

Inclusive STEM Schools. Inclusive STEM Schools have emerged as one of the solutions addressing the need for a shared definition of integrated STEM education providing a rigorous STEM education to students of all socio-economic, demographic, and achievement backgrounds (LaForce et al, 2016; Peters-Burton, Lynch, Behrend & Means, 2014; Riley, McCann, & Woods, 2013). One of the trademarks of inclusive STEM Schools is the open enrollment policy which enable them to serve a broader and often more diverse population of students (Means et al., 2008; NRC, 2011a). Many inclusive STEM Schools are instructionally designed to build the capacity of their students, operating on the idea that “math and science competencies can be developed through authentic STEM experiences that provide rigor and relevance. The open enrollment policy of inclusive STEM Schools allows more access for traditionally underrepresented students giving them an opportunity to develop these competencies to become full participants in areas of economic growth and prosperity (Means et al., 2008; LaForce et al., 2016; NRC, 2011a).

Inclusive Schools place a greater emphasis on research-based engagement experiences that increase persistency in STEM education and careers instead of outcomes related to standardized testing metrics used at selective STEM Schools to measure the effectiveness of student learning (Means et. al, 2008; Scott, 2009). For inclusive STEM Schools the examination of math and science test scores may not always be the most effective measure of success. There are many additional factors assessed when preparing secondary students for the STEM pipeline beyond student academic achievement. Through a series of formal and informal STEM engagement experiences students develop a set of STEM core competencies. These competencies or outcomes can be assessed by examining students’ persistency in STEM education and/or career (Armour-Garb, 2017; Cappelli, 2015; Fayer, Lacey, & Watson, 2017; Raising the Bar, 2013; Noonan, 2017; NSB, 2015; Reider et al., 2016; Texas Workforce Investment Council, 2015). For purposes of this study we define the term “outcome” as a persistent change for an individual that remains after STEM school graduation. This now changes the narrative of how we measure the success of STEM Schools and provides another comparison tool to use with selective secondary STEM Schools.

Inclusive STEM school goals are designed to align with federal and state reform efforts related to STEM workforce readiness, interest and engagement, 21st century competencies, STEM literacy, and the ability to make connections among STEM disciplines (Schweingruber et al., 2014; LaForce & Noble, 2017). Another trademark of inclusive STEM Schools is the deliberate inclusion of STEM's technology and engineering disciplines which link at least one career pathway to the students' program of study. This is again in contrast to highly selective Schools where the focus is mainly math and science academic achievement, not student career interests (Schweingruber et. al, 2014; LaForce et al, 2016).

STEM-Focused Career and Technical Education Schools. STEM-related career and technical education (CTE) is mainly on the secondary level and typically takes place in career academies or as a curriculum focus in comprehensive high schools. STEM-focused CTE education is part of CTEs larger goal of educating students based on the 16 national career clusters which includes a STEM cluster. Due to the inherently authentic and engaging nature of CTE education, many students have explored STEM-related career options which resulted in them persisting in school and career versus becoming a drop out statistic (NRC, 2011a). Research supports the decrease in high school drop-out rates when teachers make learning relevant by placing academics within the context of issues and problems from the world of work (Clayton, Hagan, Ho, Hudis, & ConnectEd, 2010). Foundational to CTE is the concept that learning should be relevant, multidisciplinary and connect content with application. STEM-CTE instruction places a heavy emphasis on the use of engineering and technology for design and tools for scientific discovery (NRC, 2011a). In well-designed CTE programs, CTE integrates challenging technical courses and rigorous academics with relevant, project-based learning drawn from the real world. Using an integrated design of core academics and CTE instruction (project based, career relevance focus), creates multiple pathways for students to explore and pursue after high school, allowing them realistic opportunities to go on to either a two- or four-year educational institution or to enter the job market with a wide range of in-demand skills already in hand. CTE career pathways prepare students to be successful by incorporating rigorous academic and technical standards, as well as critical workplace skills such as problem-solving, communication, and teamwork, to ensure career and college success for its students (Career Technical Assessment Collaborative, 2011).

STEM in Comprehensive Schools

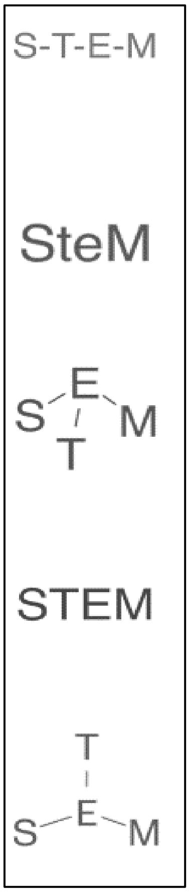
Most of the research on successful STEM education comes from studies done in in "regular" comprehensive high schools (NRC, 2011a). It is difficult to nail down a single focus for comprehensive high schools across the United States because they all have different goals regarding STEM education and implementation. One trend common to most comprehensive secondary schools is their increase in math and science graduation requirements over the past 25 years (NRC, 2011a). This increase shows a desire to strengthen the academic achievement of American students in the areas of math and science. Advanced Placement as well as International Baccalaureate are the most widely known programs in comprehensive high schools for advanced studies in STEM related math and science courses (NRC, 2011a).

Integrated STEM Education

In our 21st century society we interact with rapid technological advancements, innovative new ideas, quality engineered products and globally competitive markets, however, in a large majority of our classrooms students are still taught using 20th century instructional strategies and pedagogies (Miaoulis, 2009; Raising the Bar, 2013). Very rarely do we hear students bring up technology or engineering career fields when asked "what do you to do when you grow up?" This is ironic when you consider today's students are digital natives and have never lived in a non-engineered world (Miaoulis, 2009). So, why do we continue to teach science to K-12 students in isolation emphasizing a natural world perspective representing only 5% of our day-to-day activities? Teaching this way ignores and excludes the other 95% human-made or engineered world. Eliminating some forms of art, everything human made is considered a technology (Miaoulis, 2009). From the buzz of the alarm chime on our cell phones each morning to our light switch being turned off at night, our lives are immersed with technologies ranging from electric tooth brushes to televisions to modes of transportation and entertainment (Miaoulis, 2009). For students to create relevance for classroom learning and build connections between the classroom and their technology intensive world, it is important to teach these STEM concepts in the same integrated manner they experience them daily (Bybee, 2010; Force, 2014; Holdren et al., 2013).

Despite not having a shared definition for integrated STEM education, schools across the country continue to offer what they believe to be quality integrated STEM education teaching and learning (LaForce & Noble, 2017). Providing high quality integrated STEM education requires a collaborative effort among teachers committed to integrating the STEM subjects into one cohesive discipline of teaching and learning. Integrated STEM education is more than a convenient grouping of the four disciplines; it is an interdisciplinary and multidisciplinary applied approach coupled with real-world, problem-based learning (Torlakson, 2013). Integrated STEM education can take on a myriad of meanings for schools depending on their goals, instructional design and desired outcomes. Integrated STEM educational experiences can range from one or several class periods, throughout a single course of study, a school with a robotics program, the pairing of science and mathematics education, the infusion of engineering into academic classes, an informal after-school setting and can include different pedagogical strategies (LaForce et al, 2016; Miaoulis, 2009; Sanders, 2009). Figure 2 shows a range of collaboration and integration models used in STEM Schools.

For purposes of this study the researcher used Tsupros, Kohler, and Hallinen (2009) definition of STEM as a working definition for integrated STEM education: “STEM is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (pg. 82).”



Each disciple taught separately: In science classes, there is a renewed focus on using representations to enhance concept development. In mathematics, teachers could use complex problem solving to challenge their students.

All four disciplines are taught, but more emphasis on one or two: A teacher integrates mathematics and science through a challenge based unit of work where students design a vehicle.

Integration of one discipline into the other three being taught separately: The engineering processes of teamwork, identify and investigate a problem, design a solution, and testing and evaluation is added into some science and mathematics subjects.

Total integration of all four disciplines: Science teacher integrating, T, E and M into science. A school introduces a new STEM elective focusing on designing digital solutions to real world problems.

STEM curriculum is divided into the separate subjects: Technology, science and math teachers design a combined unit and each teacher teaches different components of the unit in their separate subject, and with clear contributions from science, mathematics and technology subjects in solving a common problem.

Figure 2 STEM Integration Models. Adapted from Hobbs, L., Clark, J. & Plant, B. (2018). Successful Students – STEM Program: Teacher Learning Through A Multifaceted Vision for STEM Education. In STEM Education in the Junior Secondary (pp. 133-168). Srpinger, Singapore.

This definition of integrated STEM is more authentic because it mirrors how scientists and engineers work in the world. Krajcik and Delen (2017, pg. 37), state “A richer and more productive manner of thinking about STEM is the integration of science (physics, chemistry, biology, earth and space sciences), engineering, technology, and mathematics to focus on solving pressing individual and societal problems. To accomplish complex tasks such as brain implants, reducing carbon emissions, developing more energy efficient trains, cars and planes, and making use of solar energy, it will be necessary for individuals not only to have a deep usable knowledge in one field, but also knowledge in other fields, so that collaborations to solve pressing complex problems can occur. Individuals will also need the creativity to imagine new possibilities and to synthesize ideas. They will also need to know how to collaborate with individuals who have different expertise than they have." As you can see, developing an integrated knowledge of STEM is critical to 21st century education as it lays the foundation for learning more, solving more and innovating the most.

Student Engagement

To learn STEM, students must engage directly in doing STEM (Holdren et al., 2013). STEM engagement experiences require students to use higher-order knowledge acquisition and application and is most associated with the literature and research related to critical-thinking and problem-solving (Garrison et al., 2000). At the core of the instructional design for STEM learning experiences is inductive-based curriculum and pedagogy. Inductive-based pedagogy is an umbrella term used to encompass a range of instructional methods, including inquiry learning, problem-based learning, project-based learning, case-based teaching, discovery learning and just-in-time teaching (Prince & Felder, 2006). These instructional methods are all student-centered and place a greater responsibility on the student for their own learning. Inductive learning is organic and more akin to the natural style of human learning that comes from real-life experiences involving people, situations and problems (Garrison et al., 2000). This style of learning requires students to be reflective, raise questions and solve problems in and out of class -- to actively engage with the learning.

Student engagement involves the extent to which students fully and actively participate in the process of learning. Research supports a strong correlation between student engagement and a variety of student success outcomes (Fredricks et al., 2004; Parsons, Nuland, & Parsons 2014). In a study conducted by Finn and Rock (1997), low-income minority students were observed as engaged, more likely to be academically successful, achieve passing grades and graduate on time. In another study by Guthrie et al. (2006), increased levels of student engagement supported increased reading achievement. Across the board, student engagement matters and impacts student achievement regardless of the studied content or student demographic (Marks, 2000). It is interesting to note that student engagement decreases as students move from elementary to high school. In a study conducted by AdvancED (http://www.advanc-ed.org), which surveyed 20,494 students across three states, there was a noticeable drop in student engagement across the cognitive, emotional and behavioral domains as students moved from elementary to middle to high school. The largest drop, 25 percent, occurred in the emotional domain. Behavioral engagement refers to a student's efforts in the classroom, while cognitive engagement examines a student's investment in learning, and emotional engagement measures a student's emotions or feelings about the classroom and school in general (Fredricks et al. 2004).

Engaging students and making learning relevant to their lives can enhance motivation for learning and improve student interest, achievement, and persistence (Holdren et. al., 2013; Schweingruber et al., 2014). Students actively engage with STEM experiences in formal classroom and lab settings as well as informal settings like museums, national parks and the internet. The combination of engagement experiences is critical to the STEM learning process and to selection and persistence in STEM careers. By effectively engaging in STEM learning experiences students use cognitive processing to strengthen their knowledge about the connectedness of the subjects, create personal interests and develop positive attitudes toward STEM topics, as well as create improved perception of their ability to participate in STEM (Lombardi, 2007; NSTC, 2013; Pearson, Sawyer, Park, Santamaria, & Van, 2010). STEM school engagement experiences are typically exciting and authentic. Engagement activities are inquiry-based, project-based, problem-based, case-based and include hands-on learning with objects and tools. Researchers agree these type of STEM experiences improve critical thinking, retention of information and student achievement (Holdren et al., 2013; Schweingruber et al., 2014; Lombardi, 2007; NSTC, 2013; Pearson, Sawyer, Park, Santamaria, & Van, 2010).

STEM engagement experiences are those recognizable disciplinary practices that are interconnected across the four disciplines. Table 4 summarizes four interconnecting practices and the corresponding teaching and learning that support their development.

Table 4 STEM Practices

Interconnecting practices	STEM Teaching and Learning Practices
Flexible reasoning skills	• Problem solving • Creativity • Generating own questions • Inquiry
Effective and adaptable use of artifacts	• Conceptual, digital, physical tools • Exploring and investigating artifacts • Using a range of modern tools, digital tools • Being able to use objects of the discipline in flexible ways, such as natural phenomena, representations of the phenomena, and tools that are used to understand the phenomena or complex problems
Proficiency in professional/technical discourse	• Understanding and engaging with the disciplinary representations • Knowing the language • Sharing and communicating • Working in teams
Understanding of the nature of evidence in different settings	• Collect real data in a variety of situations • Using evidence to validate a solution to a problem or justify a decision • Making judgements about the accuracy and reliability of information

Note: Adapted from Hobbs, L., Clark, J. & Plant, B. (2018). Successful Students – STEM Program: Teacher Learning Through A Multifaceted Vision for STEM Education. In STEM Education in the Junior Secondary (pp. 133-168). Srpinger, Singapore.

STEM Pedagogies

STEM teaching and learning can best be described as an inductive reasoning approach to knowledge acquisition. In traditional teaching and learning, a deductive approach is used which typically begins with teaching students general principles and theories, then moves into student application of the acquired knowledge (Sproken-Smith, 2012). Inductive reasoning begins with the application, a complex real-world problem or a set of observations or data to interpret. As students begin to work with the data or real-world problem, they then develop a need for more facts and guiding information (Prince

& Felder, 2006). An inductive approach to teaching and learning is used as an overarching pedagogy that covers a range of instructional methods, specifically those we use in STEM environments – inquiry-based learning (IBL), problem-based learning (PBL), project-based learning, case-based learning, experimental learning, and just-in-time teaching and learning (Prince & Felder, 2006). Several authors use the above terms interchangeably (Prince & Felder, 2016; Speziale et al., 2016; Spronken-Smith, 2012). While there are overlapping qualities, there are also distinctions that separate each instructional pedagogy. As Table 5 shows, there are common features for all the instructional approaches including:

- Student-centered learning which gives more responsibility to students for their own learning;
- Knowledge construction through the fitting of new information into existing cognitive structures;
- Constructivist method of students constructing their own version of reality;
- Always involve active learning - students discussing questions and solving problems;
- Students work in groups or collaborate to solve problems or complete projects;

Inquiry-based learning. Inquiry-based learning originates back to ancient times and is documented in the teachings of Confucius and Socrates. Even in the 17th century, philosophers like Spinoza purported that knowledge is found through the manipulation of ideas instead of the passive transmission of facts (Spronken-Smith, 2012). John Dewey was one of the early proponents of learning by doing. Dewey's practical form of inquiry included three situations, pre-reflection, reflection, and post-reflection. Reflection was the heart of the thinking process but was framed by a perplexing and confused situation initially and a unified or resolved situation at the close (Dewey, 1933). Inquiry-based learning begin to be used and adopted by schools in the 1970's.

Inquiry-based learning is more of a teacher driven instructional strategy and is usually applied when the teacher poses questions, problems or scenarios to students (PBL, 2014). Effective implementation support students in learning to formulate good questions, identify and collect appropriate evidence, present results systematically, analyze and interpret results, formulate conclusions, and evaluate the worth and importance of those conclusions (Lee, 2004).

Table 5 Features of common inductive instructional methods

Feature ↓ / Method →	Inquiry-Based	Project-based	Problem-based	Case-based	Experimental
Questions or problems provide context for learning	1	2	2	2	4
Complex, ill-structured open-ended real-world problems provide context for learning	4	3	1	2	4
Major projects provide context for learning	4	1	4	3	4
Case studies provide context for learning	4	4	4	1	4
Student discover course material for themselves	2	2	2	3	3
Primarily self-directed learning	4	3	3	3	3
Active learning	2	2	2	2	2
Collaborative/cooperative (team-based) learning	4	3	3	4	4

Note: 1 – by definition, 2 – always, 3 – usually, 4 – possibly

Project-based learning. “Project-based learning (PBL) can be defined as a constructivist approach to learning that assists students in gaining a deeper understanding of materials through process-oriented engagement in investigation of real, meaningful problems wherein students respond to a driving question; explore the question in situated, authentic inquiry; collaboratively problem solve; are scaffolded to extend their learning ability; and create a tangible product in response to the driving question” (Hall & Miro, 2016; Krajcik & Blumenfeld, 2006). Using the project-based learning instructional strategy, which provides authentic, real-life experiences to students, contributes to students’ persistency in STEM education and careers (Hall & Miro, 2016; Redmond et al., 2011). Student engagement and skill development measures are more readily viewed through the lens of hands-on, project-based learning compared to passive, traditional, non-inquiry-based instructional methods (Ahlfeldt, Mehta, & Sellnow, 2005). Students demonstrate their understanding of the subject matter through the creation and sharing of a product or project (Bell, 2010). In producing their product or project students use a cross section of skills including literacy and numeracy skills. Through the interdisciplinary process of creating products and projects, students develop a deeper understanding of the content being studied (Bell, 2010).

Problem-based learning. Problem-based learning is initiated by students receiving an open-ended, ill-structured, authentic problem to address. Students typically work in teams to develop a viable solution with teachers acting as guides on the side instead of the source of the information (Dahlgren, 2003; Duch, Groh, & Allen, 2001; Prince & Felder, 2006). Well-designed problems encourage the use of content learned in class and engages the learners in reflective thought, reasoning and higher-order thinking and learning (Prince & Felder, 2006). Problems can range from a single-topic or content specific problem that can be solved over a few days to a multidisciplinary problem requiring several weeks or months to address and solve (Tan, 2003; Weiss, 2003). Problem-based and project-based learning are different pedagogical strategies, but mirror each other in terms of their approach to STEM instruction and learning by actively engaging by doing (Savery, 2006), and has been shown to improve student learning and comprehension of cognitive tasks, such as scientific processes and mathematical problem solving (Satchwell & Loepp, 2002). Table 6 captures the distinctions of problem-based and project-based learning.

Table 6

Project-Based Learning vs. Problem-Based Learning

Similarities	
Both PBLs: • Focus on an open-ended question or task • Provide authentic applications of content and skills • Build 21st Century 4 C's competencies • Emphasize student independence and inquiry • Are longer and more multifaceted than traditional lessons or assignments	
Differences	
Project-Based Learning	Problem-Based Learning
Often multidisciplinary	More often single subject
May be lengthy (weeks or months)	Tend to be shorter
Follows general, variously-named steps	Follows specific, traditionally prescribed steps
Includes the creation of a product or performance	The "product" may simply be a proposed solution expressed in writing or in an oral presentation
Often involves real world fully authentic tasks and settings	More often uses case studies or fictitious scenarios as "ill-structured problems"

Note: Adapted from Larmer, J. (2014). Project-based learning vs problem-based learning vs X-BL. Retrieved from http://www.edutopia.org/blog/pbl-vs-pbl-vs-xbl-john-larmer.

Case-based learning. Case-based learning experiences involve the analysis of historical or hypothetical case studies requiring a solution to a problem or recommendations for addressing an issue. Cases presented to students will typically involve varying degrees of challenge ranging from diagnosing technical problems, making business management decisions to confronting ethical dilemmas (Prince & Felder, 2006). Case studies represent authentic issues and problems encountered in professional practice. The purpose of using authentic problems and real-life data is that students are exposed to and develop experience with situations and dilemmas they may face in their professional careers. Students, therefore gain theoretical and practical knowledge as well as critical reasoning skills which can sometimes challenge their prior knowledge, preconceptions and ways of thinking (Prince & Felder, 2006). Case-based learning and problem-based learning share similar characteristics, however, case studies tend to be more structured with rich contextual details and students are asked to apply theories and concepts that are somewhat familiar to them. Problem-based learning on the other hand, tend to use ill-structured problems that cause students to cognitively acquire ne content knowledge (Lohman, 2002).

Experiential learning. Educators agree experimental learning promotes relevance and application and is based on the assertion that there is a connection between learning and experience (Merriam, Caffarella, & Baumgartner, 2007). Experimental instructional strategies are a way to close the gap between traditional classroom content learning and authentic content learning based on the needs of society for certain workforce competencies (Gibson, Kostecki, & Lucas, 2001). By providing students opportunities to apply theoretical concepts to real-world activities, students are then able to cognitively develop relationships and learn through external participation (Hirschinger-Blank & Markowitz, 2006). The maker movement is one of the newest trends in experimental learning where students learn by doing. This pedagogical strategy actively promotes students working with scientific and technological tools and materials. The maker movement is a celebration of innovation and creativity in which makers of all ages and backgrounds design physical objects or systems that can be used to solve problems in a safe space for fostering student ingenuity (NYC Department of Education, 2015). In his article, "The Promise of the Maker Movement for Education", Martin (2015), defined the maker movement as "a community of hobbyists, tinkerers, engineers, hackers and artists who creatively design and build projects for both playful and useful ends." Makerspaces are being referred to as the 21st century equivalent to shop class or home economics and stress process over outcome and collaboration and experimentation over skill acquisition. It is no longer about everyone making the same finished product, instead, it's about experimenting with the process it takes to make the product (Dougherty, 2012; Hatch, 2014; Martin, 2015).

Community -Based Learning. Another pedagogical strategy used in STEM education and similar to problem-based learning is community-based learning. Community-based learning (CBL) is also called place-based learning. This pedagogical approach is intentionally designed to create and strengthen relationships between schools and their surrounding communities. The approach is founded on the belief that students learn from authentic educational opportunities embedded in using the "community" as a classroom (NYC Department of Education, 2015).

Theoretical Supports for STEM Education

The theoretical supports for STEM education stem from widely accepted research on student learning. This section will explore each of the theoretical underpinnings that support and strengthen the case for teachers to use inquiry-based practices to engage students in the learning of STEM.

Constructivism

Constructivism entered the scene during the latter part of the 20th century and has become a dominant learning theory for education. Constructivist assert that learners create meaning through social interaction and experiences (Duffy & Cunningham 2001; Jonassen 1991; Vygtotsky, 1978). The social constructivist theory is a student-centered approach to learning where students actively assimilate and internalize information to construct new knowledge and meaning based on their social environment, prior knowledge, attitudes and values (Abdal-Haqq, 1998; Educational Broadcasting Corporation, 2004; Dalgarno, 2001; Richardson et al., 2012; Zualkernan, 2006). Knowledge construction is derived from the experiences and views of participants in a specific social context who display and recognize shared cultural meanings that are eventually internalized by the individual. The specific social context or social milieu varies and can range from historical, cultural, and political to face-to-face interactions (Au, 1998; Richardson et al., 2012). In education, the socio-cultural environment is the school and knowledge is constructed in the specific context of the classroom or community where teaching and learning takes place. Students develop new ways of thinking through their interactions with other students, teachers and "instructional tools" (Au, 1998; Bean, 2000; Lombardi, 2007; NRC, 2011b; Novak & Krajcik, 2005; Songer, 2007). In many STEM classrooms, the technology and lab equipment serve as the "instructional tools." Access to and the use of the equipment and technology tools help transform the STEM classroom into an authentic environment where learners actively construct knowledge (NRC, 2011b; Novak & Krajcik, 2005; Songer, 2007). The use of technology in STEM education classrooms connects and integrates content learning with real-world tools making the environment more authentic and relevant to students.

The multimodal and multimedia functions of technology tools not only provide physical accessibility to information, but also increases students' cognitive processing by helping students incorporate new information into their understanding *(*Krajcik & Delen, 2017; Lombardi, 2007*).* The technology tools used in today's STEM classrooms offer students more authentic learning experiences based on experimentation and action (Lombardi, 2007). Internet accessibility has opened a world of information to students allowing them to reconstruct the past, observe phenomena, and use remote instruments to connect learners to the knowledge of members in a community of practice (Lombardi, 2007). "Learning becomes as much social as cognitive, as much concrete as abstract, and becomes intertwined with judgement and exploration, simulating a real-world or work experience (Brown, 1999). Development theorists agree isolated facts and formulae are void of meaning and relevance until students discover what these tools can do for them (Van Oers & Wardekler, 1999). Therefore, learning about engineering and learning to be an engineer are two separate actions with the latter requiring authentic experimentation, experiences and personal connections (Siemens, 2004). Many authors agree that STEM learning requires students to cognitively process information to create new knowledge and new ways of knowing (Bransford, 2000; Kier, Blanchard, Osborne, & Albert, 2014; Lent & Brown, 2013; Schweingruber, et al., 2014).

Situated Cognition Learning Theory

Researchers agree a great deal of STEM disciplinary learning can be grounded within the situated cognition learning theory. Often when learning is grounded within a situated context, learning is authentic and relevant, therefore representative of an experience found in actual STEM practice theory (Brown et al., 1989; Lave & Wenger 1991; Putnam & Borko 2000). Underpinning the theory of situated cognition is the concept that understanding how knowledge and skills are applied is equally as important as learning the skills themselves. Situated cognition and situated learning theories are often referred to interchangeably and theorists now agree they are interdependent and not exclusive of one another (Putnam & Borko, 2000). The theory of situated learning posits that true learning and understanding is situated as it normally occurs and is embedded within activity, context and culture. The situation in which knowledge is learned is inseparable from the material itself (Anderson, Reder, & Simon, 1996; Brown et al., 1989; Lave, 1988; Lave & Wenger, 1991; Greeno, Smith, & Moore, 1992). "Learning and cognition are said to be fundamentally situated in an activity; this activity can shape a student's skills and provide experiences that are important in understanding concepts. It can therefore be assumed that "situations might be said to coproduce knowledge through activity" (Brown et al., 1989, pg. 32).

Cognitive theories are usually considered more appropriate for explaining complex forms of learning like critical thinking, reasoning, problem-solving, and information-processing (Schunk, 1991). Cognitive theories emphasize making knowledge meaningful and helping learners organize and relate new information to existing knowledge in memory. In contrast to early cognitive theories that supported student learning as internalization of transmitted material, situated cognitive learning supports learning through participation and practice acknowledging that learning and knowing are products of activity within a socially structured world (Brown et al. 1989; Lave & Wenger, 1991; Putnam & Borko, 2000). Cognitive theories that only promote information processing do not address the hypertext minds of 21st century learners' and the way students construct knowledge. This individualistic approach was typical of 20th century classrooms that promoted independent learning strategies in contrast to today's complex problems requiring teamwork in environments that enable the free exchange of ideas, distribution of workload, and comparisons among different solution paths (Kay, 2010).

By providing students with opportunities to apply theoretical concepts to real-world problems or projects, students have opportunities to not only learn through internalization, but also through external participation (Hirschinger-Blank & Markowitz, 2006). An underlying premise of situated learning states that all students develop a deeper understanding when constructing knowledge by working with and using ideas in real-world contexts (Greeno & Engestrom, 2014; NRC, 2007b). In most authentic STEM learning environments, external participation involves interacting socially with other team members to address, design, or solve real-world problems. In this sense learners become involved in a "community of practice" with certain beliefs and behaviors. Lave and Wenger, 1991, refer to this unintentional learning as "legitimate peripheral participation." Legitimate peripheral participation states as the learner moves from the periphery of a community to its center, more knowledge is constructed as the learner moves from novice to expert (Lave & Wenger, 1991).

Authentic Learning

Based on the above theories we understand the importance of authentic, contextualized learning. Strobel, Wang, Weber, and Dyehouse (2013), expand this view and outline four principles to consider in the design of such authentic experiences. They believe it is important for teachers to consider which type of authentic experience the students will experience in planned learning experiences. In their research study, Strobel, et al. (2013), analyzed literature that included the concept of authentic in the learning experiences, specifically for engineering education. Their research identified four types of authentic learning categories: context authenticity, task authenticity, impact authenticity, and personal/value authenticity. Strobel, et al., (2013, pp. 146, 148), provided a summary of the categories:

> "After careful reading and discussion of the 59 descriptions and definitions, we categorized them as "Context Authenticity," "Task Authenticity," "Impact Authenticity," and "Personal/Value Authenticity" ...The common theme of all the different authenticity definitions is their relation to real-world experiences.
> Context Authenticity answers the question, What makes a context authentic? This type of authenticity should take place in authentic contexts and resemble daily life experiences. For example, the activity should contain a suspension of disbelief process, such as when watching a movie.

> Task Authenticity answers the question, What makes a task authentic? This type of authenticity focuses on constructivist type learning environments in which students may be challenged to make decisions in practical contexts.
>
> Impact Authenticity focuses on what impacts an authentic experience can deliver and asks, What impacts can an authentic experience deliver outside of school? Finally, Personal/Value Authenticity asks, What makes an experience authentic on a personal level? Personal/value authenticity includes actions that make an experience authentic on a personal level such as self-exploration."

Authentic learning is an instructional approach that seeks to replicate real-world scenarios and/or problems. This teaching pedagogy encourages students to explore, discuss and meaningfully construct concepts and relationships, (Holdren et al., 2013; Lombardi, 2007; National Science and Technology Council [NSTC], 2013; Pearson, Sawyer, Park, Santamaria, & Van, 2010; PBL, 2014). Authentic learning legitimizes traditional classroom content learning by engaging students in real-world, complex problems and solutions using case studies, problem and project-based activities and virtual communities of practice (Lombardi, 2007; Strimel, 2014; Yoshikawa & Bartholomew, 2017). Actively engaging students in this type of learning environment lends itself naturally to interdisciplinary practices needed for STEM education (Lombardi, 2007, Yoshikawa & Bartholomew, 2017). Real-world projects help expand students' knowledge and give them the opportunity to actively participate in learning that is relevant in society and/or their personal lives. Authentic projects help create relevance and answer the age-old student question, "why do we have to learn this?" (Lombardi, 2007; Strimel, 2014). If students construct new knowledge in authentic learning environments, they have a greater propensity to retain the knowledge, thus increasing the probability of what is learned being available for later use *(*Asunda, 2014; Lombardi, 2007). The following ten elements represent the essence of authentic learning and are applicable across disciplinary domains (Lombardi, 2007; Reeves, Herrington, & Oliver, 2002).

- Real-world relevance: Authentic activities match the real-world tasks of professionals in practice as nearly as possible.
- Ill-defined problem: Challenges cannot be solved easily by the application of an existing algorithm.
- Sustained investigation: Problems cannot be solved in a matter of minutes or even hours.
- Multiple sources and perspectives: Learners are not given a list of resources.
- Collaboration: Success is not achievable by an individual learner working alone.
- Reflection (metacognition***)*:** Authentic activities enable learners to make choices and reflect on their learning, both individually and as a team or community.
- Interdisciplinary perspective: Relevance is not confined to a single domain or subject matter specialization.
- Integrated assessment: Assessment is not merely summative in authentic activities but is woven seamlessly into the major task in a manner that reflects real-world evaluation processes.
- Polished products: Conclusions are not merely exercises or sub steps in preparation for something else.

- Multiple interpretations and outcomes: Rather than yielding a single correct answer obtained by the application of rules and procedures, authentic activities allow for diverse interpretations and competing solutions. Even though they may have initial disorientation and frustration, students who actively engage in authentic learning activities are motivated to persevere (Herrington, Oliver, & Reeves, 2003).

CHAPTER 3

METHODS

The method used to examine student engagement through the lens of instructional pedagogies and student learning experiences was summative quantitative content analysis. Specifically, the researcher used quantitative content analysis to describe the qualitative information retrieved from data sources. Content analysis is defined by Borg and Gall (1989), as “a research technique for the objective, systematic, and quantitative description of the manifest content of communication (pg. 357).” A web-based, computer assisted qualitative data analysis software (CAQDAS), Dedoose, was used to facilitate the analysis.

Data sources used for the study included mission statements and additional published program materials from School websites, handbooks, brochures, news stories and other descriptive written documents that provided evidence of instructional pedagogy and student learning experiences. The sample for the study included public, secondary schools STEM certified by AdvancED and located in the southeastern region of the United States.

Purpose Statement

The purpose of this study was to examine the evidence of student engagement in STEM Schools. Student engagement in STEM Schools was viewed through the lens of instructional pedagogy and student learning experiences. Student engagement involves the frequency with which students fully and actively participate with learning activities that represent effective, research-based educational practices (Fredricks et al., 2004; Hudson et al., 2015: Parson, Nuland, & Parsons 2014). The behavioral component of student engagement is defined as “active, goal-directed, flexible, constructive, persistent, focused interactions with the social and physical environments” (Furrer & Skinner, 2002, p. 149). In this study, instructional pedagogy refers to the specialized knowledge of teachers for creating effective teaching and learning environments that utilize a range of inductive-based instructional practices specific to STEM education including inquiry learning, problem-based learning, project-based learning, and technology-infused learning (Hudson et al., 2015: Prince and Felder, 2006). Instructional pedagogy also refers to STEM designed curriculum and the professional learning supports necessary to build the STEM instructional capacity of teachers. Student learning experiences refer to learning activities that build students’ STEM content knowledge and focus on real-world, locally relevant, complex, open-ended problems that require problem identification, investigation, and analysis. Specifically, student learning experiences include cooperative/collaborative learning, project and problem-based learning, higher-level questioning, experimental/hands on learning, student independent inquiry/research, student discussions and students as producers of knowledge using technology (Hall & Miro, 2016; Lowther, Ross, & Plant, 2000). Student learning experiences in real-world settings can also extend beyond the classroom, school environment and normal school day to include mentorships, apprenticeships, internships, field trips, student competitive events, research and job shadowing with researchers, business/industry or other community partners.

To understand the place of student engagement in STEM Schools, it was necessary to delineate the role given to instructional pedagogy and student learning experiences that serve as a measure of student engagement, in the mission statement and STEM standard for the Schools' STEM accrediting agency – AdvancED. The STEM Schools' mission statements were also examined for evidence of instructional pedagogy and student learning experiences including cooperative/collaborative learning, project and problem-based learning, higher-level questioning, experimental/hands on learning, student independent inquiry/research, student discussions and students as producers of knowledge using technology. Mission statements should outline the goals and objectives of a STEM School or program and articulate the School's vision in an actionable way. The mission statement describes the current state of the School's STEM program and explains its purpose. Specifically, the mission statement should address: *what* the STEM School does, *who* benefits from the work of the School and *what* benefits are received by students (Evans, 2010). Additional published program materials from school websites, handbooks, brochures, news stories and other descriptive written documents that provided evidence of instructional pedagogy and student learning experiences were also examined. Content analysis of the elements found in the mission statements and the program materials was used to identify commonality and similarity between and among the STEM Schools.

Research questions

The study was guided by the following research questions:

1. To what extent does the STEM Schools' mission statements include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration?
2. To what extent does the STEM Schools' program materials include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration?
3. Is there evidence in the STEM Schools' program materials to support the conceptual framework indicators for STEM learning experiences including project-based learning, problem-based learning, case-based learning, real-world applications and external learning experiences including mentorships, internships, apprenticeships, job shadowing, and STEM student competitions?
4. Is there evidence in the STEM Schools' program materials to support the conceptual framework indicators for researched-based instructional pedagogies including project-based learning, problem-based learning, performance-based learning and assessment, technology integration, content integration, and the necessary materials and supports for teacher STEM professional development and collaboration with interdisciplinary team?

Research Design

This study employed a summative content analysis research design. A summative content analysis is a synopsis and comparison of key words or content, with the corresponding interpretation of the underlying context (Hsieh & Shannon, 2005). A summative approach to qualitative content analysis starts with identifying and quantifying occurrences of identified words or content in text with the purpose of understanding the contextual use of the words or content (Hsieh & Shannon, 2005; Neuendorf, 2017; Stemler, 2001). The initial quantification of words or content is not an attempt to infer meaning, instead, researchers are exploring word usage to discover the range of meanings a word can have in its normal use. This quantification of the words or content is a necessary step to begin identifying patterns in the data and contextualizing the codes (Morgan, 1993).

The coded text used for this study was taken from public use documents. There are three primary types of public use documents (O'Leary, 2014):

- Public Records: The official, ongoing records of an organization's activities. Examples included student transcripts, mission statements, annual reports, policy manuals, student handbooks, strategic plans, and syllabi.
- Personal Documents: First-person accounts of an individual's actions, experiences, and beliefs. Examples included calendars, e-mails, scrapbooks, blogs, Facebook posts, duty logs, incident reports, reflections/journals, and newspapers.

- Physical Evidence: Physical objects found within the study setting (often called artifacts). Examples included flyers, posters, agendas, handbooks, and training materials.

This study used a combination of all three types of documents and examined mission statements and physical evidence from the STEM Schools' website. The sample of text was chosen to best answer the proposed research questions. Examining these documents allowed the researcher to make inferences about STEM Schools' beliefs, design and gave voice and meaning to the studied content (Stemler & Bebell, 1998). The illustration depicted in Figure 3 details the research design for this study.

Content Analysis

Content analysis is a research technique used to systematically make replicable and valid inferences that compress many words of text into fewer content categories based on explicit rules of coding (Berelson, 1952; GAO, 1996; Krippendorff, 1980; Weber, 1990). Content analysis allows researchers to sort through large text files with a relative amount of ease in a systematic fashion (GAO, 1996). This ability to organize large quantities of text into much fewer content categories is one of the basic appeals of this research method (Weber, 1990). Content analysis uses the process of reviewing various types of media and artifacts to compare what is said and how it is said, then categorizes the key ideas in a written document, such as a report, article or any type of media (GAO, 1996). Content analysis research does not fall neatly into the qualitative or quantitative class of research methods. Kondracki and Wellman, 2002 state that content analysis research is considered quantitative when the process only focuses on counting the frequency of specific words or content. When the content analysis moves beyond word and content frequency to include latent content analysis, it then becomes a qualitative study.

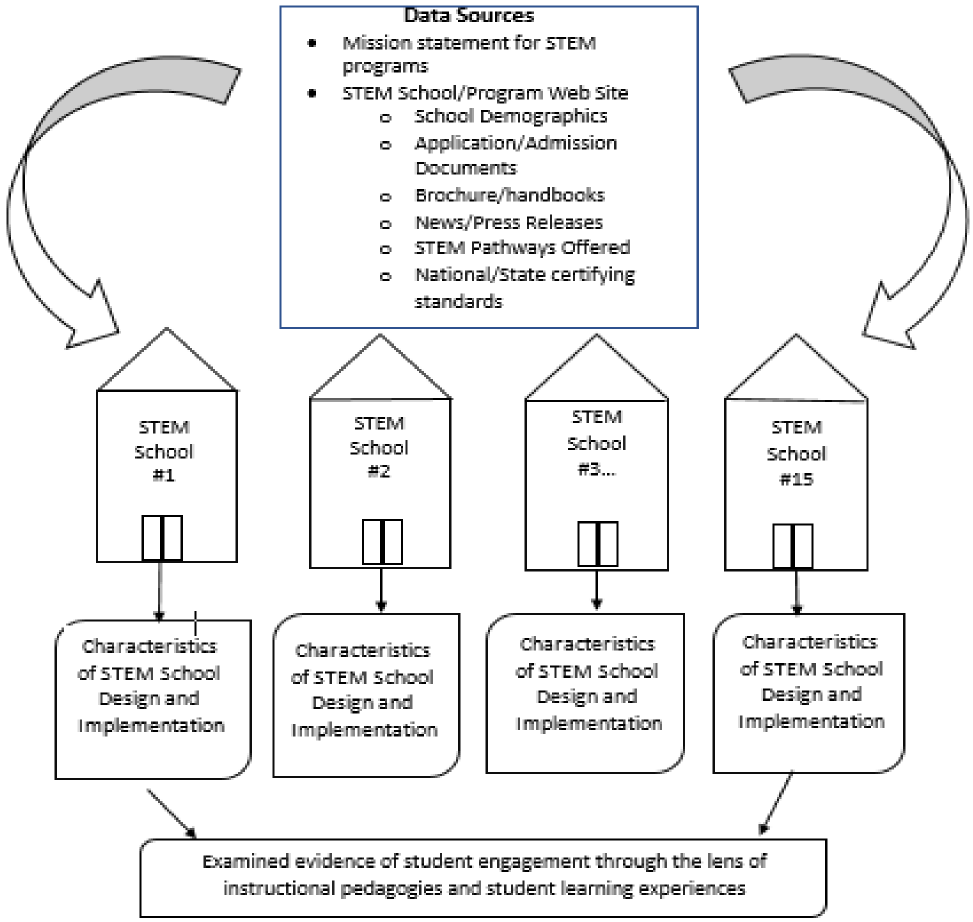


Figure 3 Research Study Design Framework

Latent content analysis is the process of interpreting the content by focusing on the use of alternative terms and discovering underlying meanings of the words or content (Babbie, 1992; Catanzaro, 1988; Holsti, 1969; Morse & Field, 1995). Neuendorf, 2017 states that most content analysis are quantitative and that researchers must distinguish between the quantitative or qualitative nature of the analysis and the quantitative or qualitative attributes of the phenomenon under examination. Simply put, “Very often, a study that might be characterized as ‘qualitative’ is actually quite quantitative—the phenomenon being studied is what is qualitative in nature" (Neuendorf, 2017, pg. 20). For this study the researcher conducted a quantitative content analysis of the qualitative information retrieved from online mission statements, standards, and artifacts of AdvancEd STEM Schools.

Content analysis is an effective tool for examining published information with many advantages over other research methods. Advantages include researchers' ability to examine the interaction of people through a nonintrusive lens (Stemler, 2001; Ungvarsky, 2016). The collection of data with content analysis is free from the bias of respondents reacting or responding in a way that is not organic, responding in a way that pleases the evaluator or vice versa. Content analysis can handle large volumes of information with explicit protocols and procedures that make it possible for multiple evaluators to analyze large volumes of data. This research method provides a consistent, systematic way to extract relevant information increasing its reliability (Ungvarsky, 2016). It also provides an objective opinion of the studied content through concrete data analysis of specific counts of the number of times a concept has been referenced. There are disadvantages to using this method of research as well. Because of its systematic procedures, more human resources are required to adequately collect data, which in turn could outweigh the advantages of using this method. Another major disadvantage of content analysis is the judgement making process when coding the data. This is a subjective process and the potential users of the data may not be comfortable with the judgement of the evaluator (Ungvarsky, 2016).

Dedoose, a computer assisted qualitative data software (CAQDAS), was used to facilitate the content analysis of mission statements and program materials. Dedoose was chosen for its ability to manage multiple tasks related to organizing data sources, segmenting and categorizing data according to themes, searching for and retrieving information, and creating colorful visual representations making it easier to see patterns in the resulting data. The CAQDAS package also allowed the researcher to import different types of data and categorize them according to demographic characteristics (Neuendorf, 2017; Talanquer, 2014). The researcher chose to use the CAQDAS package because it provided several advantages for data analysis. First, it eliminated the tediousness of managing several organizational tasks and allowed the researcher to focus on and react to the data. It provided quick access to different components of the data analysis, including excerpts and coded data. Also, the use of CAQDAS helped direct the researcher's attention to themes and relationships emerging from the analysis. In fact, it allowed the researcher to get closer to the data. (Talanquer, 2014). The CAQDAS package did not perform any core qualitative analysis tasks for the researcher like defining relevant attributes for data sources, identifying and extracting meaningful segments, or automatically building and applying codes to selected text. The CAQDAS packages are designed to aid researchers, not to replace researcher's full control and responsibility for the analytical and interpretative process (Talanquer, 2014). Even with the use of CAQDAS packages, the quality of the results generated is only as good as that of the research design and methods of data analysis.

Procedure

The goal of the study was to examine the evidence of student engagement through the lens of instructional pedagogies and student learning experiences in secondary STEM Schools. The study was conducted using a summarizing, quantitative content analysis.

This technique allowed examination of the written artifacts of the STEM school environment for characteristics of STEM pedagogical practices and student engagement learning experiences (Hsieh & Shannon, 2005; Neuendorf, 2017; Stemler, 2001). The researcher utilized purposeful sampling to select the secondary schools for the study. The use of purposeful sampling allowed the researcher to intentionally select the sites to examine for the study. The standard used for site selection was whether the schools provided “information rich” material for review including the mission statement and program description (Creswell, 2012). All schools have been STEM certified by AdvancED using its evaluative STEM standard and corresponding indicators.

Sample

The population for this study included all AdvancED STEM certified schools across the United States. A list of AdvancED STEM certified schools was obtained from the company’s website and contact with the Georgia Director of Development. The 15 Schools used in the study were chosen from a list of 30 STEM certified schools provided by AdvancED. The researcher eliminated non-secondary schools, private secondary schools and schools that did not provide information rich websites and public documents for review. Additionally, only schools whose primary campus was in the southeast region of the United States were used to achieve an equitable comparison. The schools eliminated from the study were eliminated because the researcher wanted to examine only secondary public schools. Elementary, middle and private schools would not have provided an equitable comparison. The study employed the use of stratified purposeful sampling which focused on characteristics of particular subgroups of interest and facilitated comparisons. The sample was stratified based on the number of STEM certifications held by each school, whether the school was *Selective* in its admission process or *Inclusive* with an open admissions policy and other demographic characteristics like geographic. This sampling method allowed the researcher to choose textual units that contributed to the answering of given research questions (Krippendoff, 2013; Natasi, Hitchcock, & Brown, 2010; Neuendorf, 2017). The purpose for using this type of sampling technique is to capture major variations in key factors in addition to identifying a common core. Each of the strata is comparable to homogeneous sample (Patton, 1990). This sampling technique is particularly useful when studying different models of implementing a teaching and learning strategy (Harsh, 2011).

A summary of the 15 Schools identified are presented in Table 7. A complete summary of each school is provided in chapter four. To maintain the anonymity of the selected schools and locations, identifying information was redacted and each school was given a pseudonym representing a famous scientist or mathematician.

Table 7 Overview of STEM Schools

	Psuedonym	Year Program Est	Locale	Magnet/ Title 1	Model Design	Student Enrollment	Certifications & Affiliations
1	Condorcet HS	2013	Town: Fringe	N/N	Inclusive Career Academy	692	AdvancED
2	Copernicus HS		Town: Fringe	N/N	Inclusive Vocational Center	1,481 STEM -367	AdvancED
3	Descartes HS	2005	Rural: Fringe	Y/N	Selective School-within-a-school	1,773 STEM - 193	AdvancED NCSSS
4	Fibonacci HS	2011	Large: Suburb	N/N	Selective School-within-a-school	362 STEM -161	AdvancED
5	Hypatia HS		Midsize: Suburb	Y/N	Inclusive CTE Center	425	AdvancED
6	Khayyam HS	2000	Large: Suburb	Y/N	Selective School-within-a-school	2,170	AdvancED NCSSS State DOE
7	Lavosier HS	2013	Large: Suburb	N/N	Inclusive School-within-a-school	2,176	AdvancED State DOE
8	Leeuwenhoek HS		Large: Suburb	N/N	Inclusive Technology Center	1,796	AdvancED
9	Linnaeus HS	2011	Large: Suburb	N/N	Inclusive School-within-a-school	1,567	AdvancED State DOE
10	Marconi HS	2002	Large: City	Y/Y	Inclusive School-within-a-school	1,585	AdvancED NCSSS
11	Pythagoras HS		Large: Suburb	N/N	Inclusive School-within-a-school	3,201	AdvancED State DOE
12	Vesalius HS	2008	Large: Suburb	Y/N	Inclusive Whole School	2,009	AdvancED NCSSS
13	Waerden HS		Small: City	N/N	Inclusive School-within-a-school	1,803 STEM – 380	AdvancED NCSSS
14	Wakesman HS		Rural: Fringe	Y/N	Inclusive School-within-a-school	1,389	AdvancED
15	Winogradsky HS		Large: Suburb	N/N	Inclusive STEM Academy	691	AdvancED

Note: 2017 National Center for Education Statistics. Reprinted with permission.

Fifty three percent of the Schools in this study were in large suburban locales. A large suburban area is outside of a principal city and inside an urbanized area with a population of 250,000 or more. The other 47% fell outside of suburban areas and were either located in small and large cities, midsized suburbs and town and rural fringes (NCES, 2017). A midsize city is an urbanized area inside of a principal city with a population between 100,000 to 250,000 residents. Schools located in town/fringe areas are inside an urban cluster that is less than or equal to 10 miles from an urbanized area (NCES, 2017).

The 15 Schools mission statements and program descriptions were examined using the conceptual framework matrix. The words and phrases that are construed to denote (synonyms) or connote (related words) *Student Engagement, Instructional Pedagogies and Student Learning Experiences* were drawn from conceptual framework's suggested evidence for effective STEM learning and instruction. The words, phrases, and context constituted the coding for this study (Neuendorf, 2017). The mission statements as well as published program materials provided from school websites, handbooks, brochures, news stories and other descriptive written documents that provided evidence of student engagement through the lens of instructional pedagogy and student learning experiences were examined for direct and indirect mentions of core competencies, instructional pedagogies and student learning experiences.

Data Collection

Establishing a mission statement was assumed to be central to the STEM accreditation process and therefore it was anticipated that all accredited institutions would have a mission statement to use as a common data source (Bart, 1998; Lipton, 1996; Williams, 2008). The first unit of data collection was mission statements of the 15 STEM Schools. Additional units of data collection included physical written documents from websites in the form of handbooks, brochures, flyers, and presentations which were compiled into the Program Description. By limiting the analysis to existing written evidence, the researcher avoided the bias of misinterpreting the meaning of the spoken word (Neuendorf, 2017). Document analysis was performed utilizing the conceptual framework with a purpose of investigating the use of instructional pedagogies and student learning experiences in secondary STEM Schools. The STEM Schools websites, handbooks, brochures, news stories and other descriptive written documents that provided evidence of student engagement were examined for information and recommendations related STEM instructional pedagogy and student learning experiences. Table 8 details the data sources used for the study.

Data Analysis

To analyze the data for the study content analysis was used to code qualitative data from mission statements and websites. The researcher utilized a CAQDAS package to help code and analyze the data. The conceptual framework was used as a guide for the coding agenda and the three AdvancED STEM domains represented the themes or categories. The researcher first analyzed and counted certain words and phrases used in mission statements to examine the frequency of competency skills developed through STEM engagement. Next, the words and phrases of physical documents from websites, handbooks, brochures, news stories and other descriptive written documents that provided evidence of student engagement were used to examine the frequency of instructional pedagogies and student learning experiences. It was also necessary to analyze direct or rhetorical words to discover conclusions related to the research questions.

Table 8 Data Sources for Research Study

	School	STEM School Website	AdvancED Website	State Website	National Consortium of STEM Schools Website (NCSSS)	Published Documents (applications, handbooks, news releases, video)	National Center for Education Statistics (NCES)
1	Condorcet High School	√	√			√	√
2	Copernicus High School	√	√			√	√
3	Descartes High School	√	√			√	√
4	Hypatia High School	√	√			√	√
5	Fibonacci High School	√	√			√	√
6	Khayyam High School	√	√	√	√	√	√
7	Lavosier High School	√	√		√	√	√
8	Leeuwenhoek High School	√	√			√	√
9	Linnaeus High School	√	√	√	√	√	√
10	Marconi High School	√	√		√	√	√
11	Pythagoras High School	√	√	√	√	√	√
12	Vesalius High School	√	√			√	√
13	Waerden High School	√	√			√	√
14	Waksman High School	√	√			√	√
15	Winogradsky High School	√	√			√	√

Ultimately, the researcher was able to make inferences about the word frequencies and relationship of the learning experiences and instructional practices. The researcher stratified the results on the type of school model, number and type of STEM certifications and varied demographic data. Zhang and Wildemuth's (2009) process for conducting a content analysis was used and employed the following eight steps:

1. Prepare the data:

   The researcher bookmarked websites for all STEM Schools and extracted text to use in the Schools' descriptions and content analysis. The websites provided a plethora of information including brochures, handbooks, news stores and other descriptive documents that provided evidence of student engagement through the lens of instructional pedagogy and student learning experiences. The choice of text was deliberate to ensure content alignment with the research questions.

2. Define the Unit of Analysis:

   The unit of analysis used for the study were mission statements and program materials for the 15 AdvancED STEM certified schools. The study utilized three themes: Student engagement, Instructional pedagogies and student learning experiences. Each theme incorporated several indicators.

3. Develop Categories and a Coding Scheme.

   The coding scheme was developed using words and phrases that supported the conceptual framework. Many of the codes were developed inductively and others emerged during the coding process. Table 9 and Table 10 outline the categories and coding scheme used for study.

4. Test Your Coding Scheme on a Sample of Text:

   The researcher utilized Dedoose, an online software program, to test the coding scheme on a sample of text. The coding theme was found to be consistent.

5. Code All the Text:

   Dedoose, a CAQDAS package, was used to code the mission statements as well as program description excerpts. CAQDAS packages help facilitate the analysis of research data such as text, audio, images, or video; and quantitative data such as spreadsheets, surveys, test scores, ratings or demographics. CAQDAS packages allow researchers to import vast amounts of textual and non-textual data. The program integrates the different types of data into a single project and builds links or cross-references between them. The imported data may contain audio, video, tables, and embedded images. Existing CAQDAS packages do not have the capability to transcribe audio and video files into written documents (Talanquer, 2014). One of the key elements of CAQDAS packages is that data sources can be organized according to known characteristics -- stratified. This enabled the researcher to easily search for, identify, and narrow the focus to subsets of data, which facilitated comparisons (Talanquer, 2014).

6. Assess Your Coding Consistency:

   This step required double checking for coding consistency for the possibility of human error or change in understanding of the coding rules. The systematic inter-rater reliability testing component of Dedoose was used to determine consistency. The coding agenda and rules were given to two independent raters in the STEM field. Coding results were compared with the researcher and found to be consistent. All instances of disagreement were reviewed, discussed and resolved by the researcher and the two independent raters.

7. Draw Conclusions from the Coded Data:

   This stage will allow the researcher to make inferences about the analysis and present the reconstructions of meanings derived from the data. The researcher reconstructed meanings will be presented in chapter four.

8. Report Your Methods and Findings:

   The findings from the analysis will be reported in chapter four and guided by the research questions and goals. Because this study used content analysis the researcher will report frequency counts as well as patterns, themes and categories.

Table 9 Coding Table for Mission Statements

CODING TABLE FOR STEM SCHOOL MISSION STATEMENTS

Words, phrases and context construed to be evidence of Skills, Knowledge and Thinking Strategies in Mission Statements of STEM Schools

UNIT OF ANALYSIS	CATEGORIES (THEMES)	CODING WORDS/PHRASES
Mission Statements	Skills (Core Competencies - 21st Century Skills	Agency & Persistence Collaboration Communication Data Literacy Digital Learning/Computer Science Ethics Leadership Problem-solving Social & Cultural Awareness STEM Mindset
	Content Knowledge	Interdisciplinary knowledge of Science, Technology, Engineering and Mathematics
	Thinking Strategies	Critical Thinking Computational Thinking Creativity Design Thinking

Table 10 Coding Table for Program Materials

CODING TABLE FOR PROGRAM MATERIALS Words, Phrases and Context Construed to Be Evidence of Student Engagement related to Learning Activities, Instructional and Curriculum practices and Stakeholder involvement		
UNIT OF ANALYSIS	CATEGORIES (Themes tied to research questions)	CODING WORDS/PHRASES (Used Contextually)
	Student Learning Experiences	
Program Materials	Rigorous Learning	Analysis Authentic Clarify Collaboration Communication Complex Content knowledge Creative Critical thinking Defend Elaborate Explain Independent Inquiry-based Investigation Locally relevant Open-ended Performance-based Assessments Problem solving Real world application
	Student-centered classes	Empowered Ownership of Learning Personalized Reflective Self-directed Student-centered
	Technology Integration	Data Literacy Equipment Internet Labs Maker spaces Research Technology resources

	Instructional Pedagogies	
Program Materials	Real-world Application	Authentic College & Career Ready Competencies Deep learning Engaging Interdisciplinary Problem-based Transdisciplinary
	Content integration	Common planning Interdisciplinary team Collaboration Professional Learning communities Standard alignment STEM content integration
	Professional collaboration	Common planning Professional learning Teacher STEM certification
	Improvement in instructional practices for STEM-specific disciplines	Instructional practices Research-based Pedagogy Technology proficient
	External and Extended Student Learning Experiences	
Program Materials	Authentic Connections	Adult-world connection College and career ready Core competencies: critical thinking, problem solving, creativity, communication, collaboration, data literacy, computer science Learning outcomes
	Stakeholder Engagement	Business/industry partners Community Family Post-secondary STEM Pipeline
	Extended-day opportunities	After-school STEM programs Apprenticeships Authentic Internships Job shadows Mentorships STEM Summer camps

The research questions and descriptions of the data analysis used to address the questions are presented.

1. To what extent does the STEM Schools' mission statements include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration? The mission statements of STEM Schools were examined to detect mentions of "competency skills" and their synonyms as listed in the coding table. CAQDAS was used to identify the frequency of mentions and inferences related to the comparison of the Schools.
2. To what extent does the STEM Schools' program materials include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration? Websites, handbooks, brochures, news stories and other descriptive written documents that provided evidence of student engagement were examined to detect mentions of "competency skills" and related words and phrases as listed in the coding table. CAQDAS was used to identify the frequency of mentions and inferences that suggested evidence of Schools meeting the AdvancED Standard.
3. Is there evidence in the STEM Schools' program materials to support the conceptual framework indicators for STEM learning experiences including project-based learning, problem-based learning, case-based learning, real-world applications and external learning experiences including mentorships, internships, apprenticeships, job shadowing, and STEM student competitions? CAQDAS was

used to identify the frequency of mentions and inferences that suggested evidence of Schools meeting the AdvancED Standard.

4. Is there evidence in the STEM Schools' program materials to support the conceptual framework indicators for researched-based instructional pedagogies including project-based learning, problem-based learning, performance-based learning and assessment, technology integration, content integration, and the necessary materials and supports for teacher STEM professional development and collaboration with interdisciplinary team? The websites of STEM Schools were examined to detect mentions of "instructional pedagogies" and any related words and phrases as listed in the coding table. CAQDAS was used to identify the frequency of mentions and inferences that suggested evidence of Schools meeting the AdvancED Standard.

Validity and Reliability

This study's research was a quantitative content analysis of qualitative documents or phenomenon, so we look at validity and reliability through both lenses (Neuendorf, 2017). For this study data were collected from different sources to answer the research questions. The researcher initially collected data from mission statements and the standard of the qualifying STEM accrediting agency, AdvancED. To cross validate the findings, the researcher looked for ways the data were implemented in the STEM Schools by comparing website program descriptions, brochures, handbooks, news stores and other descriptive documents that provided evidence of student engagement through the lens of instructional pedagogy and student learning experiences. Triangulation of these data sources allowed the researcher to verify the validity of data collected. To complete the analysis of data and strengthen the validity of the study, the researcher used a CAQDAS package, Dedoose. The CAQDAS allowed the researcher to set up a test to confirm the inter-coder reliability of two independent coders which also strengthened the validity claim. The advantages of using this qualitative software is that it decreased the amount of time the researcher needed to manage tedious tasks and allowed the researcher to focus more time on the data analysis. The CAQDAS package did not independently and automatically decide how to segment code or interpret the data. The researcher retained full control of the analytical and interpretative process. The results from the analysis are a true reflection of the researcher’s research design and method of data analysis (Talanquer, 2014).

Qualitative research studies define and measure validity different from that of quantitative studies. Validity in quantitative studies deal with the extent to which collected data measures what it was intended to measure (Mills, 2011; Creswell, 2012, 2014). Qualitative validity means that the researcher checks for the accuracy of the findings by employing certain procedures, (Gibbs, 2007; Creswell, 2014). Validity is one of the strengths of qualitative research and is based on determining whether the findings are accurate from the standpoint of the researcher, the participant, or the readers of an account (Creswell & Miller, 2000). Validity measurements in qualitative research are essentially concerned with the trustworthiness of the data. Other terms used with qualitative validity are authenticity, dependability and credibility (Creswell & Miller, 2000). The most common practice used for ensuring the trustworthiness of qualitative research is triangulation. Qualitative researchers triangulate multiple data sources of information by examining evidence from the sources and using it to build coherent justification for themes (Glesne, 2006; Hubbard & Power, 2003). In fact, the pairing of quantitative content analysis with qualitative analysis strengthens or triangulates the research (Neueundorf, 2017). This logic supports the research of Gray and Densten (1998), who posits that quantitative and qualitative research may be viewed as different ways of examining the same research problem and that through the triangulation of the methods the researchers claims for validity are strengthened.

Qualitative reliability indicates that the researcher's approach is consistent across different researchers and different projects (Gibbs, 2007). This is similar to quantitative reliability which deals with the external validity of applying results to new settings, people or samples (Creswell, 2014). Yin (2009) suggest that in order to determine reliability, researchers need to document the procedures of their case studies and to document as many of the steps of the procedures as possible. Gibbs (2007) suggested several qualitative reliability procedures:

- Check transcripts to make sure they do not contain obvious mistakes from transcription
- Make sure there is not a shift in the meaning of codes during the process of coding

Ethical Considerations

Ethical consideration in scholarly research should achieve three goals: to ensure the accuracy of scientific knowledge, to protect the rights and welfare of research participants and to protect intellectual property rights (Publication manual of the american psychological association [APA], 2010). The researcher sought approval from the institutional review board (IRB) to conduct a research study using content analysis of secondary STEM school mission statements and program materials. The IRB made a determination that the research did not involve human subjects and did not require the review and approval of the IRB. The IRB correspondence is included in Appendix A. The researcher ensured the accuracy and honesty of the research study by not falsifying data to support the anticipated outcome and giving credit to authors whose words or ideas were used in this study (Creswell, 2014). The researcher also used pseudonyms for each school and redacted the names of their geographic location to ensure the privacy each STEM school.

Method Limitations

This study was subject to two of the limitations common to content analysis as noted by Krippendorf (2004). "Content analysts rarely have the imagination to list all the relevant categories" (p. 185). Academicians, which includes the writers of all of the studied documents, have diverse and broad vocabularies which could lead to very long lists of keywords or words that omit some cues.

A summative approach to content analysis has certain advantages. It is an unobtrusive and nonreactive way to study the phenomenon of interest (Babbie, 1992). It can provide basic insights into how words are actually used. However, the findings from this approach are limited by their inattention to the broader meanings present in the data. As evidence of trustworthiness, this type of study relies on credibility. A mechanism to demonstrate credibility or internal consistency is to show that the textual evidence is consistent with the interpretation (Weber, 1990).

Delimitations

The study was delimited to STEM Schools that have received STEM certification from AdvancED, a national STEM accrediting agency. There are excellent STEM Schools that were excluded from this study based on the above standard. The study also delimits the analysis of mission statements and program materials to schools and programs identified as STEM Schools even though many other schools offer STEM focused instruction through their general curriculum.

CHAPTER 4

RESULTS

Maintaining student engagement in classrooms is a key component to teaching and learning (Ding & Sherman, 2006; Marks, 2000). It is even more important for teachers of STEM subjects to develop the instructional strategies and practices necessary to support active student engagement activities. High-quality, effective STEM Schools and programs should employ instructional practices and curriculum that ensure teacher effectiveness. Curriculum and instruction in STEM Schools and programs help learners develop skills that lead them to think about the world in complex ways (Conley, 2007) and prepare them with knowledge that transcends the academic arena. Research has shown that effective teaching is a key factor in academic achievement of students (Ding & Sherman, 2006). Research also suggest that quality educators must have a variety of quantifiable and intangible characteristics including strong communication skills, content knowledge and instructional pedagogical skills (Baumer et al., 2010). Providing STEM teacher professional development and time for teachers to collaborate are very effective strategies for refining teachers' pedagogical skills (Colbert, Own, Choi, & Thomas, 2008).

The research on STEM education does not support one "correct" way to implement STEM programming. However, research does support early and continuous exposure to STEM education as critical to the sustaining interest and ability in education (NRC, 2011a). The overall goal of STEM education is to help students succeed in a technologically advancing world, not to necessarily make students scientists or engineers (Vasquez, 2014). “A well-defined STEM education programs establishes a culture of inquiry that promotes and supports the development of innovative thinking, engineering design, scientific and digital literacy, computational thinking, problem-solving, and 21st-century skills, which align to State and Common Core Learning Standards” (New York City Department of Education, 2015).

Discussion of Results

The purpose of the current study was to examine the use of instructional practices and student learning experiences in secondary STEM Schools and programs. The comparison included two areas where evidence might be found: published mission statements and program materials from purposefully selected STEM Schools. The data was compiled from physical documents found on the websites of respective Schools. The mission statements and program materials were examined using the competencies referenced in the conceptual framework for the three domains of STEM Learners, STEM Educators and STEM Experiences.

Description of STEM Schools

AdvancEd, an international school accrediting agency, was used as the qualifier for STEM schools selected for this study. STEM principles and concepts were introduced in the later part of the 20th century, however, a framework and criteria from an organization or governmental agency did not exist until AdvancED, an international school accrediting agency, launched a STEM Certification pilot in August of 2014. The AdvancED Standard evaluates student learning experiences and instructional practices for STEM education, regardless of the chosen school model. The Standard provides a proven, research-based framework for the evaluation of competency outcomes of high-quality instructional STEM teaching and learning programs that demonstrate students' STEM literacy necessary for the next level of STEM learning (Denmark, 2015). The framework is comprised of three domains -- STEM Learners, STEM Educators and STEM experiences, that support 11 indicators that must be considered when evaluating STEM Schools (Http://www.advanc-ed.org). See Appendix D for complete standard and indicators.

STEM Learner (Classroom Student Learning Experiences)-- The mission statement for AdvancED establishes the student as the most important focus of the STEM Certification. Institutions and programs geared toward providing a strong STEM education should strive to include all learners, paying close attention to those groups often marginalized in STEM fields. Students should regularly engage in activities that meet the diverse needs and styles of learners in ways that foster independent critical thinking as well as transformative collaboration. Critical thinking is having the ability to reason effectively, use systems thinking, make judgements and decisions and solve problems. Transformative collaboration involves demonstrating the ability to work effectively with diverse teams, exercising flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal and assuming shared responsibility for collaborative work, (Partnership for 21st Century Skills, 2010). In keeping with the nature of STEM, students should make regular use of technology throughout the learning process, from enhanced research and data gathering to innovative experiential learning opportunities. Finally, STEM learners should be encouraged to demonstrate their knowledge through both traditional and nontraditional performance-based assessments (AdvancED, n.d; Denmark, 2015). Traditional performance-based assessments include perform tasks completed in classroom settings including creating products and presentations. Non-traditional performance-based assessments would include evaluations of external experiences including mentorships, internships, and apprenticeships and work-based learning experiences.

STEM Educator (Instructional Pedagogy) -- To maximize students' STEM learning, educators should regularly engage in collaborative planning to develop an interdisciplinary curriculum that emphasizes high-quality problem-based instruction. Educators should empower students by providing them with learning experiences that prepare them for the types of problem solving skills they will need to be successful in their postsecondary endeavors and their future careers. Such high demands on educators can only be met through rigorous, ongoing professional development targeted at continuously improving STEM-based educational practices (Http://www.advanc-ed.org).

STEM Experiences (External and Extended Student Learning Experiences) -- A key focus of national policy initiatives to improve STEM education has been the need to prepare today's learners for the information and technology economy. To educate students who can compete for jobs in a global market, institutions and programs should partner with businesses, post-secondary institutions, and the community at large to provide students with opportunities to engage in STEM learning in real-world settings. Student learning should be further enhanced through involving families and by arranging learning experiences for students that extend beyond the confines of the normal school day and the physical plant of the institution (AdvancED, ND).

The 15 AdvancED STEM certified Schools used for the study are described in detail. Schools were concentrated in the southeastern region of the United States and represented four states. Six of the Schools in the study were classified as magnet schools, one as a Title I school, and one was part of a charter district.

Condorcet High School

The school was newly constructed in 2013 to replace the 1950 construction and now serves 650 students. Condorcet High School prides itself in providing unique student-centered programs for its students through career academies. The programs cultivate student performance and achievement as students prepare for their local and global careers. The school is among the first public schools in its state to proclaim an expansive academy model in which each student has the potential to earn Career/Technical Education credentials. The career academies are small learning communities built around a specific career or college pathway. Demographics for Condorcet High School are listed in table 11.

Table 11 Condorcet High School Demographics

Characteristic	School Data
Locale	Town: Fringe
Magnet	No
Title I	No
Enrollment	692
Race/Ethnicity	Asian: <1% Black: 47% Hispanic: 2% White: 49% Other: 1%
Gender	Male: 47% Female: 53%
Free/Reduced Lunch	55%

National Center for Education statistics, 2017

The mission of Condorcet High School is to accept the responsibility of providing all students with the learning environment necessary to prepare them for the future by guiding them toward their maximum academic, aesthetic, physical, social and emotional potential. Condorcet high school requires all freshmen to begin their high school experience with the Freshman Academy. This gives each student an opportunity to gain transitional skills and then explore the six career academies which include: Industrial Technology Academy, STEM Academy, Medical Science Academy, Business Academy, Human Services Academy, and Arts Academy. The academies are all staffed with former industry-experienced personnel who now educate students and provide expertise, development, and explicit skills in several career areas. Through specialized instruction and real-world experience, students gain the essential skills to be successful in their college and career endeavors. The Engineering career pathway is the focus of interdisciplinary curriculum in the STEM Academy (Condorcet High School, n.d).

Copernicus High School

This school is not a magnet school and does not have an academy just for STEM students. Therefore, the school does not select a certain number of students that will follow a predetermined schedule, but teachers and school leadership instead believe that every student who wants the opportunity to participate in STEM courses should be allowed to do so. The aim of the program is to show students the relevance of what they are learning in the classroom and afford them with opportunities to broaden their knowledge regarding real-world, relevant problems, which can be solved via a strategically-focused approach. Systemic work to create a shared vision of appropriate, challenging STEM instructional design has been a major focus for the school the past five years and has proven to yield tremendous gains with regard to student interest in STEM content and in opportunities to facilitate increased partnerships between the school system and local industry. The goal of the school is to get as many students as possible to "take a bite of the STEM apple." School demographics are shown in table 12.

Table 12 Copernicus High School Demographics

Characteristic	School Data
Locale	Town – Fringe
Magnet	No
Title I	No
Enrollment	1,481
Race/Ethnicity	Asian: 1% Black: 29% Hispanic: 15% White: 49% Other: 6%
Gender	Male: 51% Female: 49%
Free/Reduced Lunch	46%

National Center for Education statistics, 2017

The vision for STEM instruction at Copernicus High School is to provide students with opportunities to “apply principles of science, technology, engineering, mathematics, interpersonal communication, and teamwork to the solutions of technological problems. Copernicus high school currently has 199 students enrolled in the Engineering career pathway, the flagship program for STEM, and 168 students in enrolled in the Architectural Drawing and Design pathway. Classroom instruction has been transformed from a traditional model, where students were merely experiencing instruction through a “sit-n-get” mode, to an integrated approach, where collaborative groups of students work on real-world challenges using newly-acquired content knowledge to explore, design, test, modify, and solve problems that simulate issues one might experience outside of the classroom environment. STEM instruction focuses on project-based learning, requiring students to utilize technological tools, demonstrate skills, solve problems, think logically, and articulate their learning.

Initial STEM projects require students to apply knowledge to solve problems, design solutions, and complete work, in new and unpredictable situations. As students progress through the curriculum, they are required to analyze and solve problems and create unique solutions. Culminating STEM projects require students to think in complex ways to create solutions and take actions that further develop their skills and knowledge. Students completing the Copernicus High School Engineering pathway are afforded the opportunity to work within teams of students to design and build products utilizing industry-grade machinery to produce architectural drawings, competition robots, 3-D models, and much more. This work is further strengthened by the Academy’s partnership with a major local manufacturer which provides 11th and 12th grade students an opportunity to participate in a cooperative internship program. Through this opportunity students work as interns with engineers to address existing challenges within the company and arrive at creative solutions, which they present to a panel of company engineers on a bi-monthly basis. Student teams learn to look at challenges differently. Working alongside the industry's brightest engineering minds, they are given either manufacturing or product development tasks to complete using traditional engineering principles. Students use root-cause analysis to detect production line inefficiencies in addition to identifying the correct mathematical formulas for other tasks. Solving these real-world challenges students gain critical workplace skills, such as project management, decision-making, and teamwork.

At a state-of-the-art production facility, students sharpen valuable hands-on experience working with one of the largest manufacturers in the world. In addition to learning about a variety of engineering disciplines – including industrial, mechanical and electrical engineering – the team's experience how these disciplines are applied every day to meet modern manufacturing and product development objectives. The work completed through the student internships has resulted in the development of several iPhone apps, assembly line down time improvement, streamlined information flow throughout the plant, and many other project improvements. The evidence above is an indicator of Copernicus City School System’s belief in providing students with learning experiences that provide rigor and relevance through inquiry-based activities.

Utilizing the Understanding by Design model, the school has crafted learning experiences that provide students with the opportunity to demonstrate their knowledge and apply it to new situations. Students must be able to take what they have learned and solve new and different problems, instead of merely restating information for a test. To determine if students truly understand the course content, the school assesses whether students can take what they have learned and transfer the skills to challenges that mirror those found in the real world. The successfully mastery of the assessment challenges confirms for the school that students have been prepared to meet the demands of the 21st century.

As the concept of STEM has grown, the school has infused the use of the engineering design cycle and real-world, problem-based activities throughout the curriculum. The school’s STEM committee is comprised of the science, math, and CTAE staff who teach the STEM courses. Staff members collaborate asynchronously through

Google Apps for Education on an as needed basis and quarterly to discuss and design long term STEM opportunities. Each member of the school's STEM Planning Team serves as a coach, and their classroom and units serve as models for other teachers needing assistance in incorporating STEM into their instruction. Copernicus High School educators work to remain on the cutting edge of new technology and innovations in the field. The teachers also develop and foster meaningful business partners who are willing to share their knowledge and experience with teachers and students alike (Copernicus High School, n.d.).

Descartes High School

The STEM program at Descartes High School is an honors magnet program that accelerates and enriches learning experiences for students who are academically gifted and have an interest in STEM related majors and careers. The program began in the fall of 2005 with 17 students who were accepted based on their standardized test scores, middle school teachers' recommendations, and interest in STEM related fields. The program was designed to be a local answer to the national STEM initiative with the belief that "STEM accelerates the learning experience which enable students to pursue advanced placement courses, research, and/or internships in a field of interest (Descartes High School, ND)." Upon completion of the STEM program, students are highly qualified for admission into the most rigorous and competitive university programs. Demographics for Descartes High School are shown in table 13.

Table 13 Descartes High School Demographics

Characteristic	School Data
Locale	Rural: Fringe
Magnet	Yes
Title I	No
Enrollment	1773
Race/Ethnicity	Asian: 4% Black: 35% Hispanic: 3% White: 55% Other: 3%
Gender	Male: 48% Female: 52%
Free/Reduced Lunch	32%

National Center for Education statistics, 2017

The mission of Descartes high supports the belief that the purpose of STEM is to accelerate the traditional curriculum, promote inquiry-style learning across the curriculum, develop literacy in science, technology, engineering, and mathematics. Additionally, the school provides unique opportunities outside the classroom environment for students through independent research, internships, field studies, and respected academic competitions. A major focus for Descartes high school is the integration of studies across the curriculum which include STEM accelerated studies in Algebra II and Humanities. The STEM curriculum is designed to accommodate each student’s interests and abilities. STEM students are distinguished from traditional honors program through their completion of a research course. Each research project is unique and based on the student’s interest which demonstrates the diversity and universal nature of STEM. STEM students begin their research during their junior year. The research courses provide students with unique opportunities to pose a research question and then design and implement an experiment. Students defend and support their results at a series of professional conferences and science fairs. Students are also encouraged to participate in an internship or fellowship to prepare for research. The intern must complete at least 80 hours of work and a daily journal of duties, as well as write a reflection paper which will be submitted to the STEM Committee for review. Students are involved in STEM-related field trips, participate in school events planned for STEM students, and have the opportunity to travel together internationally.

The following courses math and science course selections are offered to the STEM students: Algebra 2 HN, Pre-Calculus HN, AP Calculus AB, AP Calculus BC, AP Statistics, Vector Calculus (USC), Elementary Differential Equations (USC), Physical Science HN, Biology 1 HN, Chemistry 1 HN, Honors Marine Science, AP Seminar, AP Research, AP Biology, AP Chemistry, AP Physics B, AP Physics C, AP Environmental Science, AP Psychology, Human Body Systems HN, Principles of Biomedical Science HN, Medical Interventions and Research HN, Biomedical Innovations & Research HN, Agricultural & Biosystems, Science HN, Animal Science HN, Equine Science HN, Small Animal Care HN, Intro to Veterinary Science HN, Intro to Veterinary Science Research HN. Students are also able to choose from the following STEM career pathways: Computer Science, Computer Programming, Biotechnical Engineering, and Engineering Design & Development (Descartes High School, n.d.).

Fibonacci High School

Fibonacci High School promotes a dynamic learning environment that is dedicated to creating and sustaining the independent learning process. The school’s focus is to help students construct knowledge through projects, hands on activities, and lots of academic debate and discussions that help vest dedicated students in their own success. Teachers are not primarily in charge of dispensing information but rather serve to monitor a structure where students can develop critical thinking skills to access, apply, and investigate relevant topics. Fibonacci High School is a public charter high school which can serve up to 436 students. Admission to the school is conducted through an open lottery enrollment process which is required for charter schools in the state where this STEM School is located. The school has attracted student applicants from across the county and there is a waiting list for enrollment. The school only serves ninth and tenth grade students. Junior and senior students are dually-enrolled students that complete their coursework at the local state college. The school operates on the campus of, and under the direction of a local State College. The goal of the partnership is to provide the county citizens a unique and unparalleled educational opportunity. By opening a collegiate high school in direct partnership with a local State College, students can simultaneously earn a traditional high school diploma and an Associate in Arts degree by taking dual enrollment classes during their junior and senior years. This opportunity is available to students at no cost through an open enrollment process and provides them with an experience rooted in the best available research and educational philosophy. Fibonacci High School demographics are shown in table 14.

The mission of Fibonacci High School is to provide students with an accelerated opportunity to participate in the joys and benefits of a highly relevant and applicable educational experience. The primary focus for the school is Science, Technology, Engineering, and Math (STEM) delivered through experiential and interdisciplinary teaching and learning. This rich and student- centered problem-solving atmosphere will allow students the opportunity to personally construct knowledge in response to the experiences mapped out by their highly qualified and specifically trained teachers. Freshmen and Sophomore students participate in thematic, interdisciplinary instructional units throughout the year. As part of their mission the school connects qualified and motivated students to dual enrollment options. Sophomore students with a 3.5 may qualify to take a single class and Junior and Senior students with a 3.0 are eligible for full time dual enrollment status. The school offers the Biotechnology and Engineering STEM pathways to students (Fibonacci High School, n.d.).

Table 14 Fibonacci High School Demographics

Characteristic	School Data
Locale	Suburb: Large
Magnet	No
Title I	No
Enrollment	362
Race/Ethnicity	Asian: 3% Black: 9% Hispanic: 32% White: 55% Other: 1%
Gender	Male: 42% Female: 58%
Free/Reduced Lunch	<1%

National Center for Education statistics, 2017

Hypatia High School

Hypatia is recognized as a high-performing Career and Technology Education center with a longstanding reputation for innovation and excellence. Hypatia has previously earned the designation of a National Blue-Ribbon School and in 2014 was recognized by the Southern Regional Education Board as a Platinum High Achieving site (top 1%) school in their network of 1200 *High Schools That Work* member sites. The school offers application entry points in the 9th and 11th grades. Students across the community can to apply to the four-year STEM education program or to the two-year STEM/STEAM (arts-integration) career-focused major strands. The school wants the students to embrace the concept that discovery is an intrinsic part of the learning process and requires the use of invention and creativity. Teachers and students at Hypatia strive to create an atmosphere in which innovation is fostered and can fluidly occur, thereby ensuring that this generation is ready for the opportunities of the future in their chosen STEM careers. The staff of Hypatia wants parents and students to feel that the school is a place which fosters and nurtures the potential of young people in ways that can make any dream a reality. Demographics for Hypatia High School are shown in table 15.

Hypatia High School is an AdvancED whole school STEM certified school committed to preparing its students to be college and career-ready global citizens by fostering creativity, innovation, systematic problem-solving, and critical thinking through participation in rigorous and authentically collaborative academic and career experiences. The program design for the school recognizes that students' interests in STEM areas are greatly enhanced when they are offered the opportunity to explore arts and humanities electives to support their interest in pursuing careers in STEAM innovation. The school embraces the concept that discovery is part of the process of science and that opportunities for student invention and creativity are requisite for innovation to occur.

Hypatia also offers students a variety of rigorous academic options designed to prepare students for their post-secondary goals and career goals.

Table 15 Hypatia High School

Characteristic	School Data
Locale	Suburb: Midsize
Magnet	Yes
Title I	Data not available (too new)
Enrollment	425
Race/Ethnicity	Asian: Black: Hispanic: White: Other:
Gender	Male: Female:
Free/Reduced Lunch	

National Center for Education statistics, 2017

The Hypatia High School STEM program scaffolds 21st Century Skills throughout students' four-year journey. The school provides interdisciplinary connections that are paired with a real-world atmosphere which encourages the students to become global citizens ready to contribute in a variety of capacities. Students can direct their own STEM education through flexible scheduling, a variety of accelerated courses, faculty collaboration, and student choice. Examples of collaboration and flexibility are demonstrated through: a project based Physical Science curriculum introducing big ideas with overarching concepts used throughout the content and culminating in a student driven performance based product made with the scientific and engineering design processes; math classes which incorporate multidisciplinary problems on practice, formative, and summative assessments including real world algebraic shopping problems giving students a list of products, an amount of money, prices from various stores and asking students to determine how to shop to be able to attain the most product for their money; pre-calculus and calculus problems incorporate physics fundamentals analyzing amusement park rides and other forces; student 1:1 devices provide tools for curriculum engagement including digital research, interdisciplinary projects, virtual lab experiences, and digital portfolio production in a web based learning environment. The focus strands for STEM pathways include STEM Studies, Advanced Art, Computer Science, Digital Communications, Entertainment Technology, Pre-Engineering, Pre-Medicine, and Theatre (Hypatia High School, n.d.).

Khayyam High School

The Khayyam Academy of Mathematics, Science & Technology is one of six magnet schools in its county. The Academy was established in 2000 and operates as a school-within-a school infused into a 319,000 square foot school campus. The Academy is affiliated with The National Consortium of Secondary STEM Schools (NCSSS) and STEM certified by AdvancED and the it's State Department of Education. Students are admitted through a competitive application process that includes the evaluation of standardized test scores, academic achievements, extracurricular activities, teacher recommendations, and written communications skills. Within the academy, students have many advanced learning opportunities. Academically motivated students transcend traditional curricula and explore post-secondary level courses on the Khayyam campus. Academy students are actively involved in many extracurricular activities, including athletics, fine arts, and school clubs to achieve balance and a well-rounded high school experience. The capstone to the program involves research equivalent to a mini-dissertation with a corresponding internship with a local institution of higher learning, professional group, or business. Students present their research to community leaders, faculty, and Khayyam alumni. Graduates of the Academy perform at the highest academic levels and matriculate at prestigious universities throughout the country. School demographics are shown in table 16.

Table 16 Khayyam High School

Characteristic	School Data
Locale	Suburb: Large
Magnet	Yes
Title I	No
Enrollment	2170
Race/Ethnicity	Asian: 8% Black: 27% Hispanic: 14% White: 49% Other: 3%
Gender	Male: 51% Female: 49%
Free/Reduced Lunch	29%

National Center for Education statistics, 2017

The mission of Khyayam High School is a community of learners committed to students' success. The Academy is nationally recognized for curricular innovation and features a broad-based accelerated curriculum. The school’s program includes rigorous and challenging courses beyond the honor’s level college preparatory curriculum. In addition to being taught at an accelerated pace, students explore ideas in more depth and apply a higher level of cognitive thinking, synthesis, and application. Advanced placement opportunities are offered in mathematics, physical sciences, life sciences, and computer sciences, all of which include extensive laboratory experiences. Additionally, students may choose to experience a full array of engineering technology courses and/or astronomy courses including use of the on-site observatory. All Academy students complete research and a semester internship at a local professional practice, industry, or institution of higher learning. Students interested in academics as well as technology, fine arts, and career opportunities may explore their passions. The STEM career pathway courses include AP Computer science principles and AP Computer science. Students in the Academy are also able to select a fine arts concentration and earn an additional seal and honor graduation cord if they fulfill necessary requirements (Khayyam High School, n.d.).

Lavosier High School

In the fall of 2013, a small group of Lavosier teachers and administrators met to discuss how to improve the STEM experience for students and retain highly motivated and enthusiastic students who were opting to attend one their county's magnet or IB programs. Initially, the STEM academy kept students together in a cohort fashion in STEM Honors Chemistry, STEM Accelerated Math and Foundations of Engineering classes -- three courses that were considered the foundation of the STEM experience. Student cohorts are still in place today, but each year the program is modified based on school visits, professional development and the needs of the school and students. The STEM Academy provides a plethora of opportunities, both in and out of the classroom, for students to expand their understanding of STEM and participate in STEM related instruction and activities. STEM teachers are also STEM learners as they attend conferences and programs to enhance their STEM education knowledge as well as sharing their best practices by presenting to other developing STEM teachers. Demographics for the school are shown in table 17.

Table 17 Lavosier High School

Characteristic	School Data
Locale	Suburb: Large
Magnet	No
Title I	No
Enrollment	2176
Race/Ethnicity	Asian: 6% Black: 10% Hispanic: 7% White: 74% Other: 3%
Gender	Male: 50% Female: 50%
Free/Reduced Lunch	8%

National Center for Education statistics, 2017

The mission of Lavosier high school is to serve the individual needs of students by promoting challenging academic standards in a nurturing environment that produces capable, responsible, productive members of society. The STEM Academy provides students with continual exposure to problems and questions that require students to solve them in unique and creative ways. The two pillars for the inquiry-based approach in the STEM Academy are the Project Lead the Way (PLTW) courses in both biomedical science and engineering and the integration of specialized science and English courses specifically designed for STEM Academy students. The Academy offers students a rigorous four-year program of advanced math, science and career tech courses that prepares students for 21st century jobs in the medical and engineering fields. Students are immersed in project-based learning through integrative course work in science, language arts and mathematics. Students choose STEM electives from the PLTW curriculum for biomedical science or engineering. The STEM Academy has been recognized for its achievements and is STEM certified in its county, at the State level and nationally with AdvancED STEM Certification. The Academy is also a PLTW Distinguished school for its student's mastery of advanced concepts in both specializations. To help provide students with authentic and relevant learning experiences, the Academy works closely with local business partners.

The STEM Academy offers a choice of two pathways for incoming students based on interest: Accelerated Science and Mathematics pathway or Engineering pathway. Each pathway focuses on a specific spectrum of courses designed to enhance student's knowledge and ability specific to that field. Each accepted student must choose a pathway upon entering the program and must remain in that pathway. Due to the rigor and commitment these pathways require, changes between pathways are only allowed in extreme circumstances with the approval from teachers, administrators and counselors. The accelerated science and mathematics pathway provides students with a rigorous schedule of Honors and Advanced Placement courses in both math and science with a focus on the integration of technology with scientific research and design. The engineering pathway provides a focus on content related to the physical sciences including advanced physics, computer science and problem-based learning in engineering (Lavosier High School, n.d.).

Leeuwenhoek High School

Leeuwenhoek High School Center for Advanced STEM Studies is open to all interested sophomores, juniors and seniors in the school district. Based on the district's research of what it takes for students to be successful in the 21st century, the district established what they term, "Schools of the Future – Now." The school wants to empower students to take charge of their own learning, think critically and creatively, communicate effectively, problem solve and collaborate. The goal of the school is to offer students an exceptional opportunity to develop academically while also increasing their competency in 21st century skills. Demographics for Leeuwenhoek High School are shown in table 18.

Table 18 Leeuwenhoek High School

Characteristic	School Data
Locale	Suburb: Large
Magnet	No
Title I	No
Enrollment	1,796
Race/Ethnicity	Asian: 3% Black: 9% Hispanic: 5% White: 80% Other: 3%
Gender	Male: 53% Female: 47%
Free/Reduced Lunch	18%

National Center for Education statistics, 2017

The mission of Leeuwenhoek High School is to build the community through career preparation focused on character, creativity, and craftsmanship. The coursework for the school includes a combination of collaborative studies, project-based learning and industry-based problem solving. Students are connected to the curriculum through the internet and have access to resources beyond the classroom and the normal school day. The curriculum offers unlimited possibilities and opportunities for students who are motivated and self-directed. The Academy is designed to capture students' interests and creative energy by offering students exciting, relevant and rigorous learning opportunities and taking classroom experiences to the world beyond. Every advanced STEM course is designed around national STEM standards. Students focus on preparation for post-secondary study and careers through specialized research projects, internships (semester-length) and externships (shorter in duration). These opportunities motivate students to become academically confident and competent. To be recognized as a graduate of Leeuwenhoek High School students must complete eight credits within the advanced STEM center (Leeuwenhoek High School, n.d.).

Linnaeus High School

The STEM Program at Linnaeus High School was established in 2011 to provide the students of the County with an opportunity to pursue a specialized education in biomedical science, computer science, and engineering. The program provides a problem-based approach to cross-disciplinary learning, an environment of advanced studies, high expectations ensured by quality teachers, effective instruction, cross-curricular planning, competitive courses of study, technology-driven assignments, and academically-based extra-curricular activities. The rigor is accompanied by service learning projects, continual student support, and quality internships. The Linnaeus STEM Academy strives to improve the world via science and service. The school operates off of a six-prong school-wide initiative providing a platform through which a shared vision of academic success and increased student engagement and achievement is expressed. All classroom instruction is designed to include rigorous instructional delivery models and strategies, the use of various technological applications, authentic real-world learning, and diagnostic, formative, & summative assessment approaches. The STEM Academy takes the school's six-prong initiative to the next level by ensuring the integration of technology, establishing adult-world connections, and facilitating self-directed, collaborative research that is immersed in creative and critical thinking. The STEM academy has designed and implemented many interdisciplinary units of study since its beginning in 2011. The STEM Committee reviews applications and admits students based on GPA, standardized test scores, attendance history, disciplinary record, and teacher recommendations. Demographics for Linnaeus High School are in table 19.

Table 19 Linnaeus High School Demographics

Characteristic	School Data
Locale	Suburb: Large
Magnet	No
Title I	No
Enrollment	1,567
Race/Ethnicity	Asian: 1% Black: 53% Hispanic: 23% White: 20% Other: 4%
Gender	Male: 55% Female: 45%
Free/Reduced Lunch	72%

National Center for Education statistics, 2017

The mission of Linnaeus High School is to prepare students, through rigorous and relevant interdisciplinary problem-based content, to be productive and successful citizens of the 21st century's global society by developing a strong work ethic, higher-order thinking skills, critical knowledge in the STEM fields, and advanced problem-solving skill sets. There are no non-STEM subjects at Linnaeus High School. All areas of instruction are connected to the STEM program in some way. In English, for example, students are exposed to APA research guidelines while analyzing science and engineering informational texts. In Social Studies, teachers supplement the standard curriculum with significant historical STEM accomplishments. Several of the career, technical, and agricultural education (CTAE), pathways are directly aligned to STEM careers, while others systematically incorporate technology. The fine arts program offers students an opportunity to explore and apply visual design and sculpture to the biomedical and engineering pathways. The school even offers a STEM-based health & PE course which incorporates timely biomedical and engineering topics. All STEM teachers receive two to three hours of protected common planning time to collaborate, plan integrated lessons, share or co-create STEM activities, plan learning outcomes, evaluate student work, and various other appropriate activities. STEM teachers collaborate to plan academy-wide collaborative projects and lessons which give students opportunities to carry out research, analyze data, design solutions, and participate in debates. To stay abreast of workforce needs in the community, and to best prepare students for the workforce of tomorrow, the Academy has established a STEM Advisory Board comprised of business and industry leaders from the community (Linnaeus High School, n.d.).

Marconi High School

Marconi High School is a public high school named in honor of an African American business man and civic leader who moved to the area in the late 19th century. The school was originally established for African American students in 1934 during the segregation era. Because of desegregation, Marconi High School closed in 1971. The school was reclassified as a junior high school in the year 2000. The current facility reopened in 2002 with community support and struggles to improve academic achievement. The school remains predominantly African American along with its surrounding neighborhood. The magnet school programs at Marconi High School are designed to help students enter career paths in science, technology, engineering, and mathematics. The objective of the school is to give students a balanced and rigorous curriculum leading directly to industry, technical school, or university training. Students take science, mathematics, and technical classes leading to college credit through advanced placement, dual enrollment, and/or articulated agreements. Marconi high school graduates have computer experience and take elective classes in fine art, performing arts, business, and journalism, in addition to participating in clubs and organizations. The demographics for Marconi High School are shown in table 20.

The mission of Marconi High School is to focus combined efforts on becoming lifelong learners. “We shall excel academically, become technologically competent, demonstrate appropriate ethical values, and take our place as competitive members of a global community, thus creating a better society (Marconi High School, ND).” STEM students at Marconi choose one magnet program for their major but are encouraged to explore classes in other magnet programs that may be of interest to them. Magnet students may complete more than one magnet program, although they are only required to complete their major. Taking online classes virtually is recommended so that students can complete all their required and elective classes by graduation. The school offers magnet programs in Biomedicine, Computer Systems Technology, Computer Game Design, and Engineering. Both biomedicine and engineering are Project Lead the Way programs (Marconi High School, n.d.).

Table 20 Marconi High School Demographics

Characteristic	School Data
Locale	City: Large
Magnet	Yes
Title I	Yes
Enrollment	1,576
Race/Ethnicity	Asian: 6% Black: 51% Hispanic: 19% White: 20% Other: 4%
Gender	Male: 59% Female: 41%
Free/Reduced Lunch	68%

National Center for Education statistics, 2017

Pythagoras High School

The mission of Pythagoras High School is to build a community of learners through engaging, relevant, challenging instruction that fosters collaboration and a respect for diversity. Senior STEM students have multiple curriculum options including internships (on and off campus), mechatronics and Advanced Placement Science/ Math/ Computer Science courses as well as a Scientific Research IV class. Pythagoras High

School is STEM certified by its State Department of Education and aims to provide equal access to quality STEM education for all students. This program is an interest-based program where any student who desires to experience science through an engineering lens within a project/ problem-based environment can opt-in.

As part of a 1.2-million-dollar Innovation Project Grant, Pythagoras competed for and was selected as it's County High School Professional Development Laboratory School (PDLS). Since August 2015, Pythagoras High School has provided a digital and physical location for leaders and teachers to "see and experience" effective STEM instruction through blended learning and problem/ project-based learning. The school has welcomed over 100 visitors since the Fall of 2015 from across their district, the state, and even as far as China. Beyond the school level, a team of STEM teachers from Pythagoras High School are part of a K-12 math learning team that meets monthly. In August of 2016, 80 teachers from elementary, middle and high schools, spent half the day in the school's building observing STEM classes, reflecting on grade level and vertical articulation across buildings and learning more about formative assessments (Pythagoras High School, n.d.). Demographics for Pythagoras High School are shown in table 21.

Table 21 Pythagoras High School

Characteristic	School Data
Locale	Suburb: Large
Magnet	No
Title I	No
Enrollment	3201
Race/Ethnicity	Asian: 25% Black: 27% Hispanic: 17% White: 27% Other: 3%
Gender	Male: 49% Female: 51%
Free/Reduced Lunch	32%

National Center for Education statistics, 2017

Vesalius High School

Vesalius states that they do not offer a STEM Academy; they are a STEM school. The school's charge is to foster in every student integrity, self-direction, global perspective, perseverance, work ethic, and interpersonal skills - these are STEM tenants. Vesalius High School positions its students to be creative and innovative thinkers and problem solvers of the future who understand the importance of collaborative teamwork and communication. Vesalius High School opened in 1970 in a rural area. In 2008 they moved into a new 450,000 sq. ft. state-of-the-art facility with cutting-edge technology, science and fine arts labs designed for specific content, and exceptional athletic facilities. The school community is a mixture of suburban, rural, and military families. The school has a diverse student body of approximately 2,000 students from all socioeconomic levels with household income levels ranging from 18% below $10,000 per year to 12% above $75,000 per year. In the past several years the Hispanic population of the school has almost doubled, and the school has seen an increase in lower socioeconomic families and a decrease of higher income families moving into the area.

The school believes one of its greatest strengths is the use of technology in the hands of great teachers, which allows teachers to provide students opportunities to cultivate and shape their own learning. The use of technology permits the teachers to be great orchestrators of learning that involves collaboration, critical thinking and problem solving, research and experimentation; technology allows teachers to become facilitators and learning to be personalized. The combination of being a Google and 1-1 technology school provides avenues for the teachers to engage students through interactive learning with countless apps and programs. Opportunities for collaboration and feedback are extended beyond the school day through digital tools like Google documents, chat, and email. Students and parents have greater access to information, class materials, and virtual learning. The use of technology as a teaching and learning tool opens doors to greater possibilities than ever before for Vesalius' students. Demographics for Vesalius High School are provided in table 22.

The mission of Vesalius High School involves working with its students, families and community, to provide a secure environment and innovative educational experiences that will empower students to achieve excellence and to take responsibility for their lives, their learning, and the world in which they live. Another major strength of the school is the comprehensive nature of the STEM-embedded curriculum, which ensures that every student has multiple opportunities for success. To meet the needs of diverse students, the school offers college prep, honors, and advanced placement courses in all core content areas and in many of the elective areas. The modified block schedule also addresses the diversity of student needs by allowing more opportunities for completion of course work. Students take multiple math, science, and technology courses within each year. The school day is extended with "early bird" and "late bird" classes before and after the regular schedule and by offering students opportunities to take an array of virtual courses. Essential learning for students is based on state and national standards. State adopted texts are utilized and supplemented with additional hard copy and digital texts and technology resources. Classroom experiences are extended with field studies and experiential learning. Teachers employ all levels of Bloom's taxonomy with emphasis on STEM and higher-order thinking skills in student-centered classrooms (Vesalius High School, n.d.).

Table 22 Vesalius High School Demographics

Characteristic	School Data
Locale	Suburb: Large
Magnet	Yes
Title I	No
Enrollment	2009
Race/Ethnicity	Asian: 6% Black: 53% Hispanic: 9% White: 29% Other: 4%
Gender	Male: 52% Female: 48%
Free/Reduced Lunch	35%

National Center for Education statistics, 2017

Waerden High School

Waerden High School was built in 1970 to serve the local community. The objective of the school is to meet the learning needs of students in the classroom and beyond classroom walls. The school's goal is to ensure students are prepared for their futures, are encouraged to become lifelong learners, and are introduced to cultural diversity. The school boasts a highly qualified faculty and staff committed to meeting the diverse learning needs of all students. The school is proud to have the distinction of earning AdvancED STEM Certification recognizing the rigor and substance vital to creating and sustaining superior, student-centered STEM teaching and learning programs. The school is committed to preparing learners for their futures by stimulating students' enthusiasm for STEM disciplines and preparing students to be productive citizens, lifelong learners, and innovative thinkers.

The STEM program at Waerden High School is new, but it is well-received among students. Waerden High School was recently accepted as an associate member of the National Consortium of Secondary STEM Schools (NCSSS). To be accepted as a member of the consortium, schools must have: a science, technology, engineering and mathematics focus, require students to take advanced course offerings in STEM areas, include authentic research school wide, maintain affiliations with local colleges, universities and research facilities, and allow students to participate in external STEM-related competitions. The benefits of being a member of NCSSS include an online profile of the school in the consortium's directory, the opportunity to send students to the Student Summer Research Conference and reduced registration fees for the annual professional conference. Demographics for Waerden High School are provided in table 23.

Table 23 Waerden High School

Characteristic	School Data
Locale	City: Small
Magnet	No
Title I	No
Enrollment	1,803
Race/Ethnicity	Asian: 2.5 % Black: 44% Hispanic: 2.6 % White: 50% Other: <1%
Gender	Male: 49% Female: 51%
Free/Reduced Lunch	41%

National Center for Education statistics, 2017

Waerden High School's mission is to enable its students to become confident, self-directed, and lifelong learners. Students are provided a safe environment, optimal learning conditions, equitable opportunities, consistent support, encouragement, and respect for all. Project Lead the Way courses are used and designed to provide Waerden High School students challenging and innovative learning experiences in an interactive, educational environment. Students are encouraged to critically think, collaborate, communicate, and problem solve to be successful in the classroom and global economy (Waerden High School, n.d.).

Waksman High School

Waksman High School partners with the parents and community to engage and motivate students to develop 21st century skills, while producing responsible citizens who are prepared for future success. All students at Waksman High School's Institute of Research, Engagement and Design are STEM students. One of the school's greatest strengths is in the use of technology resources to conduct research, demonstrate creative and critical thinking, and communicate and work collaboratively. All students are provided Chromebooks and Gmail accounts. Students utilize Google Docs, Google Classroom and other collaboration tools. Students have access to online databases and frequently engage in research assignments. Students also can use digital tools in the makerspace and TV studio to create music, videos, computer applications, and other projects. Demographics for Waksman High School are provided in table 24.

The school's emphasis on project-based learning results in many experiences for students that involve real-world learning and creative problem-solving. This is most evident in the magnet program and in the fine arts and career and technology classrooms. Waksman provides a rich continuous program of STEM-specific professional learning for educators and facilitators. From the beginning, the school administration established a clear vision for a school that engages students to develop 21st century skills of collaboration, creativity, critical thinking, and communication. Teachers receive differentiated and individualized training on technology integration and the use of project-based learning. The use of an interdisciplinary problem-based curriculum that includes a focus on real-world applications is strong at Waksman High School. The regular Wednesday morning professional early planning time is used for cross-disciplinary planning.

Table 24 Waksman High School Demographics

Characteristic	School Data
Locale	Rural: Fringe
Magnet	Yes
Title I	No
Enrollment	1389
Race/Ethnicity	Asian: 0% Black: 77% Hispanic: 5% White: 15% Other: 3%
Gender	Male: 52% Female: 48%
Free/Reduced Lunch	47%

National Center for Education statistics, 2017

Waksman has many partners that support students in their STEM learning through adult-world connections. Academy program students have mentors and internship requirements. Teacher Cadets work with elementary and middle school teachers. Students in health science, emergency services, firefighting, and sports medicine have many opportunities to work alongside professionals in their respective fields. There is an open enrollment policy allowing access to all programs such as firefighting, emergency services, convergence media, computer science, engineering, health science, digital art, sports medicine, and business. The Makerspace is also open to all students and participation in events such as Hour of Code span the school (Waksman High School, n.d.).

Winogradsky High School

The mission of the Winogradsky High School Engineering and Academic Leadership Program is to actively engage students in math and science courses that are enriched with engineering applications to increase students' academic performance in the study of math, science, engineering, and technology related fields at the post-secondary level. The program was designed to encourage students to pursue excellence in science, technology, engineering, and mathematics through a rigorous academic program. All students are expected to do the following: attend summer enrichment camp, attend after-school tutoring and/or test-prep sessions, participate in leadership training, monthly showcase meetings, and community service projects and conduct themselves as leaders inside and outside of the classroom. Demographics for Winogradsky High School are listed in table 25.

Table 25 Winogradsky High School Demographics

Characteristic	School Data
Locale	Suburb: Large
Magnet	No
Title I	No
Enrollment	691
Race/Ethnicity	Asian: 0% Black: 96% Hispanic: 2% White: 1% Other: 1%
Gender	Male: 50% Female: 50%
Free/Reduced Lunch	100%

National Center for Education statistics, 2017

The Academy's focus includes a rigorous curriculum based on high standards with the expectations that all students will achieve at high levels in math and science. A direct partnership with a major University and Technical College widens course offerings, to include PLTW pre-engineering courses. The engineering focus is designed to accomplish increased student achievement in the math and science areas and increased student success in traditionally underrepresented fields of study at post-secondary institutions. Teachers of Winogradsky High School work with the post-secondary faculty to receive training that will prepare them to teach PLTW courses. Students have opportunities to participate in the most challenging high school courses and are encouraged to take college level courses during their high school career. The high quality of professional dialogue between the post-secondary institution and Winogradsky High School faculty members help to accelerate student achievement (Winogradsky High School, n.d.).

Findings Related to Research Question 1

The question was posed "To what extent does the STEM Schools' mission statements include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration? The researcher coded mission statements representing 15 STEM Schools ranging from 55 text characters to 376 text characters. Computer assisted qualitative data analysis (CAQDAS) of the mission statements using the keywords in the coding table for mission statements disclosed 89 mentions of keywords as shown in Figure 4. The coding agenda for mission statements was divided into three areas: Skills, Knowledge and Thinking Strategies. Words, phrases and context construed to be evidence of these keywords were coded.

Code Applications

Media \ Codes	Content Knowledge	Core Competencies	Collaboration	Communication	Creativity	Critical thinking	Data literacy	Digital literacy and	Problem solving	Supporting Attributes	Agency and Persistence	Ethics	Leadership	STEM Mindset	Social and cultural	Thinking Strategies	Totals
Winogradsky High School									1				1	1		1	4
Waksman High School														1	1		2
Waerden High School	1											1			1		3
Vesalius High School												1	1		1		3
Pythagoras High School			1											1	1		3
Marconi High School								1				1	1		1		4
Linnaeus High School	1		1			1			1			1		1	1	1	8
Leeuwenhoek High School	1				1				1			1			1	1	6
Lavosier High School	1														1		2
Khayyam High School																	
Hypatia High School	1		1					1						1			4
Fibonacci High School																	
Descartes High School	1						1							1	1		4
Copernicus High School			1	1				1	1					1			5
Condorcet High School															1		1
Totals	6		4	1	1	1	1	3	4			5	3	7	10	3	

Figure 4 CAQDAS Screen Capture Code Application of Mission Statements Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

Mission statements were examined further through the stratification of STEM Schools by School Type. The school type stratification revealed two schools with a "Selective" design. Selective designed STEM Schools admit students based on strict academic and assessment requirements. The remaining 13 Schools were "Inclusive" STEM Schools designed with an open admissions process based on student interest in the STEM subjects. Figure 5 shows the stratification based on "School Type."

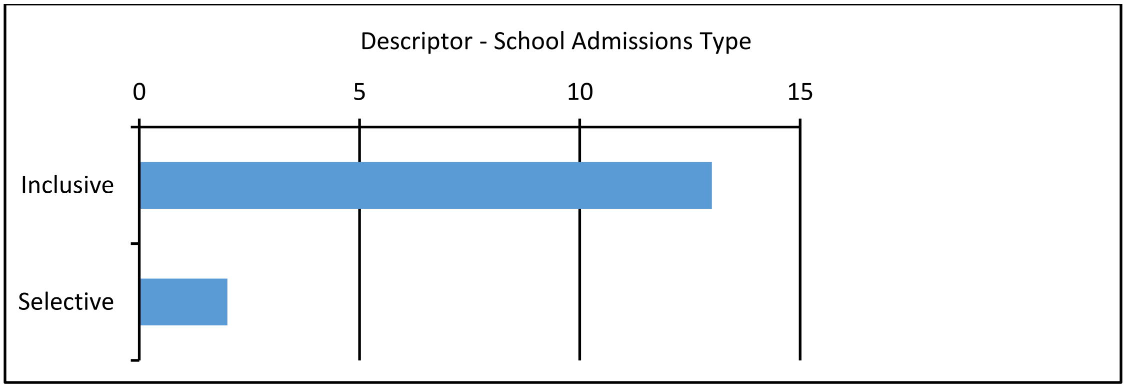


Figure 5 CAQDAS School Type Stratification
Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

To continue to show variation in the data, the mission statements were stratified on the number of STEM certifications/Affiliations awarded to each School. All 15 Schools in the study were AdvancED STEM certified. AdvancED STEM certification was used to qualify STEM Schools for the study. The AdvancED national STEM certification was established to provide schools and programs within schools with a research-based framework and criteria for their awareness, continuous improvement, and assessment of the quality, rigor, and substance of a STEM educational program. AdvancED STEM Certification is a mark of distinction and excellence for those institutions and programs that are granted the certification. In addition to the institution's completion of the STEM specific diagnostics, the STEM Certification Reviewer examines evidence, conducts observations, interviews stakeholders and participates in the External Review Team's deliberations during the on-site phase of the process. AdvancED STEM Certification should reflect a School's ongoing commitment to STEM education. Four Schools had dual certifications with AdvancED and their State Board of Education.

An additional four schools were affiliated with the National Consortium of Secondary STEM Schools (NCSSS) and one STEM School had all three designations.

The NCSSS is an alliance of specialized high schools in the United States whose focus is to foster, support, and share the efforts of STEM-focused schools whose primary purpose is to attract and academically prepare students for leadership in mathematics, science, engineering, and technology. The Consortium supports unique professional development programs for STEM teachers and unique learning experiences for students (NCSSS, 2018). To be accepted as a member of the consortium, schools must: have a science, technology, engineering and mathematics focus; require students to take advanced course offerings in STEM areas; include authentic research school wide; maintain affiliations with local colleges, universities and research facilities; allow students to participate in external STEM-related competitions and pay an annual membership. The consortium boasts higher than US average SAT and ACT scores for member schools. Figure 6 illustrates the stratification.

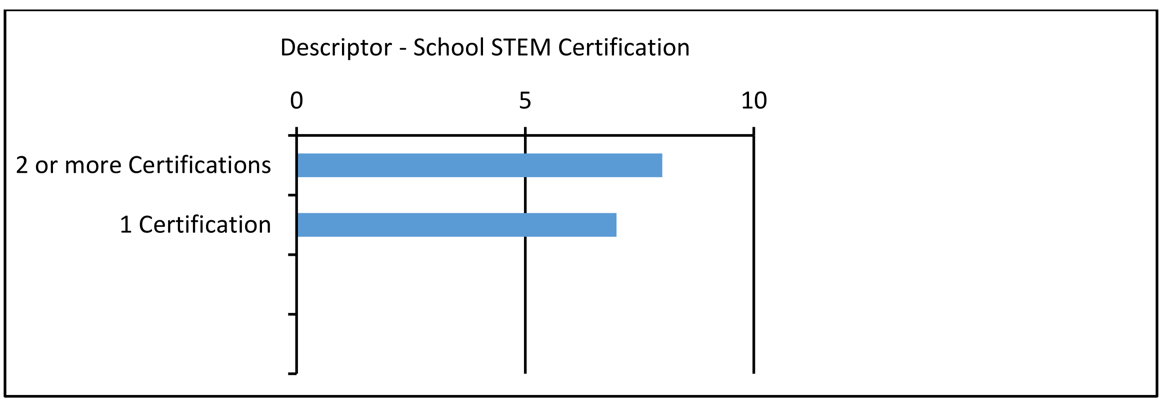


Figure 6 CAQDAS Stratification of Schools by STEM Certification
Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

The final stratification of mission statements examined data related to the Locale of the STEM Schools. The researcher wanted to examine school practices to see if a correlation existed between STEM programs and industry needs of the local community. Figure 7 illustrates the Locale stratification results.

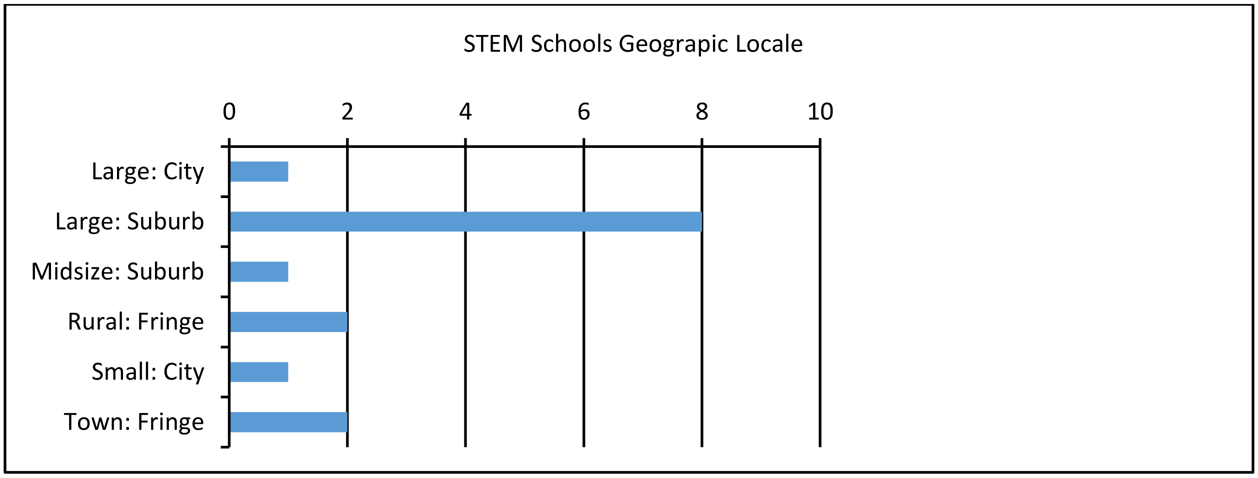


Figure 7 CAQDAS Geographic Locale of STEM Schools
Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

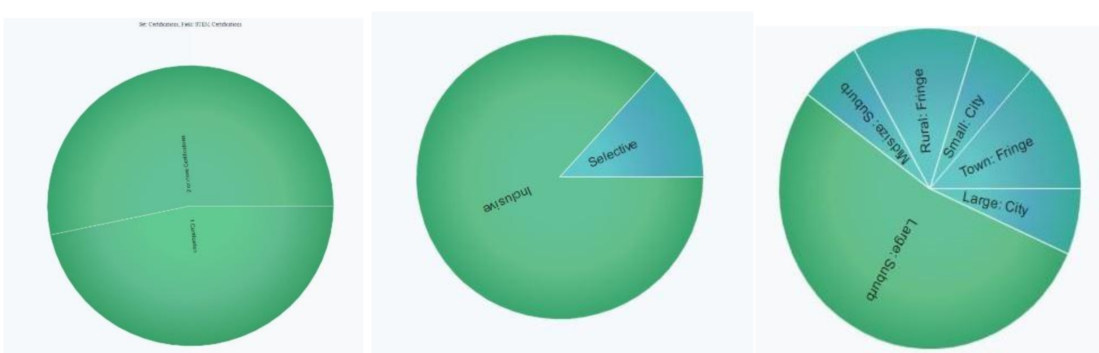
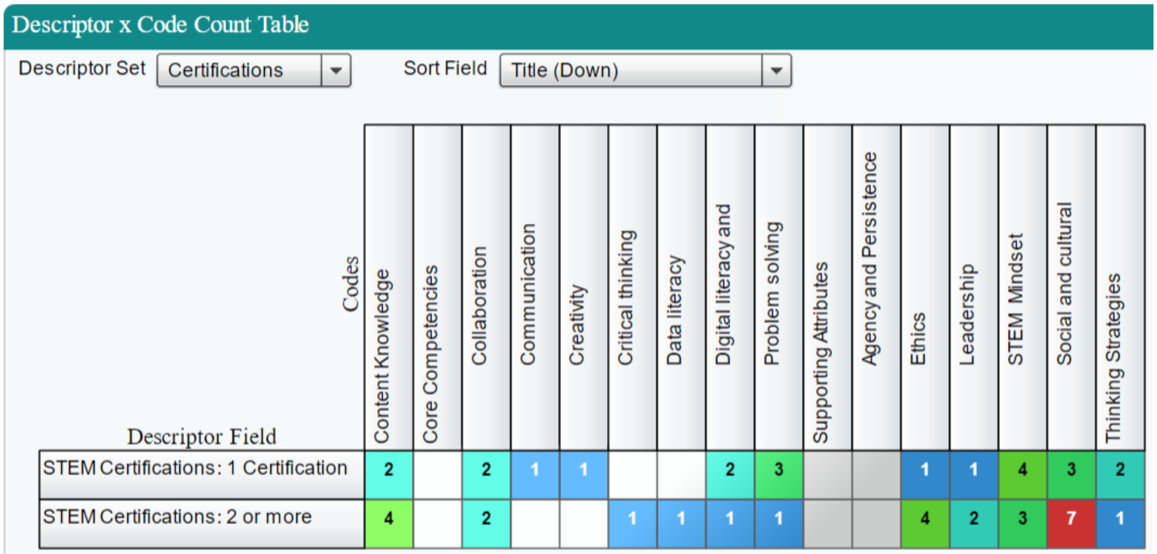


Figure 8 CAQDAS Screen Capture – Descriptor Charts for Mission Statements
Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

Figures 9 and 10 are visual illustrations of the frequency of codes for mission statements based on all the three stratifications – awarded certifications, school type and geographic locale.

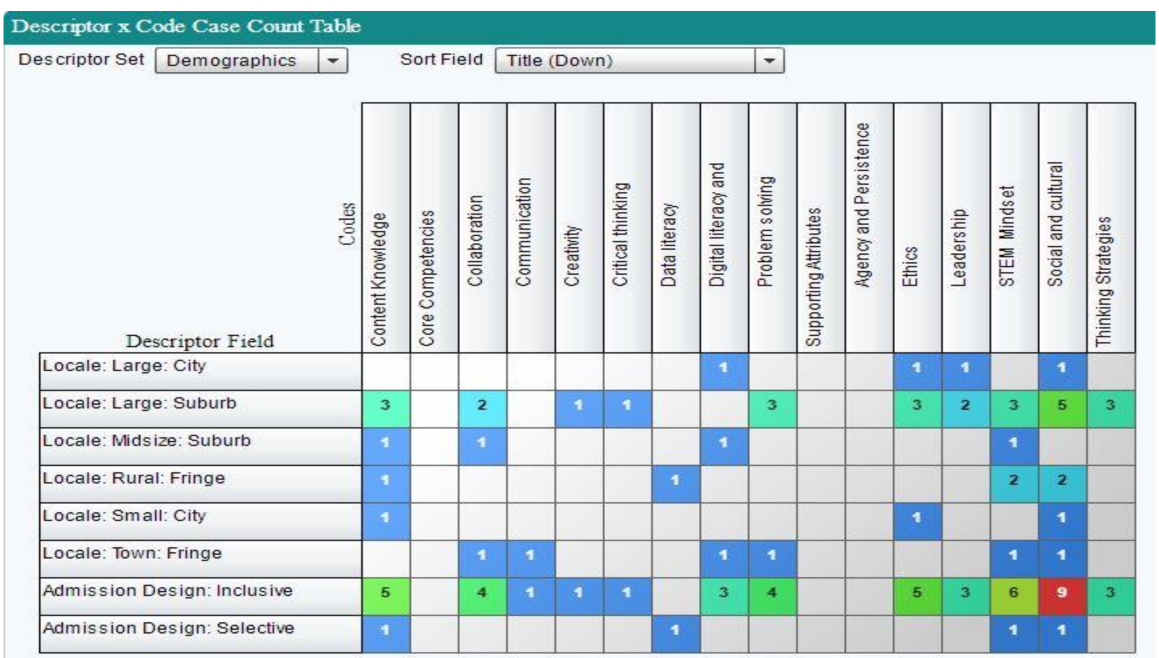


Descriptor x Code Count Table

Descriptor Set: Certifications   Sort Field: Title (Down)

Descriptor Field \ Codes	Content Knowledge	Core Competencies	Collaboration	Communication	Creativity	Critical thinking	Data literacy	Digital literacy and	Problem solving	Supporting Attributes	Agency and Persistence	Ethics	Leadership	STEM Mindset	Social and cultural	Thinking Strategies
STEM Certifications: 1 Certification	2		2	1	1			2	3			1	1	4	3	2
STEM Certifications: 2 or more	4		2			1	1	1	1			4	2	3	7	1

Figure 9 CAQDAS Screen Capture – Program Material Codes Stratified by School Type Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com



Descriptor x Code Case Count Table

Descriptor Set: Demographics   Sort Field: Title (Down)

Descriptor Field \ Codes	Content Knowledge	Core Competencies	Collaboration	Communication	Creativity	Critical thinking	Data literacy	Digital literacy and	Problem solving	Supporting Attributes	Agency and Persistence	Ethics	Leadership	STEM Mindset	Social and cultural	Thinking Strategies
Locale: Large: City								1				1	1		1	
Locale: Large: Suburb	3		2		1	1			3			3	2	3	5	3
Locale: Midsize: Suburb	1		1					1						1		
Locale: Rural: Fringe	1						1							2	2	
Locale: Small: City	1											1			1	
Locale: Town: Fringe			1	1				1	1					1	1	
Admission Design: Inclusive	5		4	1	1	1		3	4			5	3	6	9	3
Admission Design: Selective	1						1							1	1	

Figure 10 CAQDAS Screen Capture – Program Material Codes – Stratified by Certification and Locale. Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

Findings Related to Research Question 2

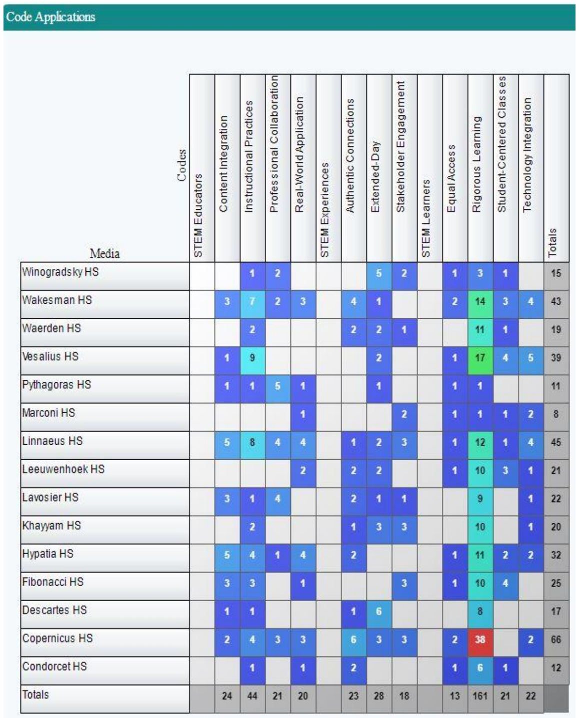
After the examination of the Schools' mission statements, the study next examined the published literature describing each of the STEM Schools' programs. The question posed to examine their program materials was "To what extent does the STEM Schools' program materials include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration?"

The researcher examined program materials for the 15 study Schools and applied 217 codes to 52,093 text characters representing the data sources for STEM Learners. Excerpted program materials by School ranged from 1,756 to 7,168 text characters. All study Schools had multiple occurrences of STEM Learners coding across the sub-categories in the STEM Learning domain except one. Descartes High School mentions of rigorous learning exceeded other schools in the study, however, there was no mention of the sub-categories including equal access, student-centered classes and technology integration. Figure 11 shows the presence of coded items and Figures 12 and 13 shows the frequency of coding application for conceptual framework elements of instructional pedagogy and student learning experiences. The frequency table maps the code frequency to a color spectrum. Red indicates that the codes were more frequent, and blue represents less frequent coded data. The resulting patterns help to visualize how the conceptual framework has been applied to the source data.

Code Presence

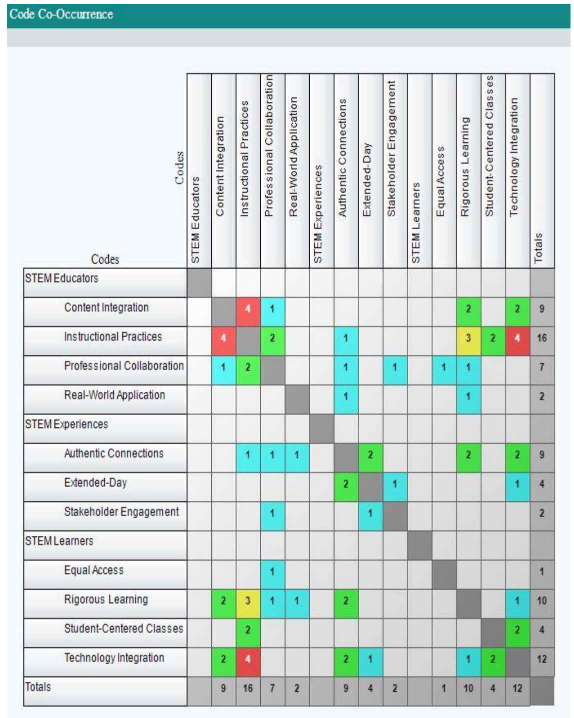
Media \ Codes	STEM Educators	Content Integration	Instructional Practices	Professional Collaboration	Real-World Application	STEM Experiences	Authentic Connections	Extended-Day	Stakeholder Engagement	STEM Learners	Equal Access	Rigorous Learning	Student-Centered Classes	Technology Integration
Condorcet HS			1		1		1				1	1	1	
Copernicus HS		1	1	1	1		1	1	1		1	1		1
Descartes HS		1	1				1	1				1		
Fibonacci HS		1	1		1				1		1	1	1	
Hypatia HS		1	1	1	1		1				1	1	1	1
Khayyam HS			1				1	1	1			1		1
Lavosier HS		1	1	1			1	1	1			1		1
Leeuwenhoek HS					1		1	1			1	1	1	1
Linnaeus HS		1	1	1	1		1	1	1		1	1	1	1
Marconi HS					1				1		1	1	1	1
Pythagoras HS		1	1	1	1			1			1	1		
Vesalius HS		1	1					1			1	1	1	1
Waerden HS			1				1	1	1			1	1	
Wakesman HS		1	1	1	1		1	1			1	1	1	1
Winogradsky HS			1	1				1	1		1	1	1	

Figure 11 CAQDAS Screen Capture –Code Presence
Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com



Code Applications

Media	STEM Educators	Content Integration	Instructional Practices	Professional Collaboration	Real-World Application	STEM Experiences	Authentic Connections	Extended-Day	Stakeholder Engagement	STEM Learners	Equal Access	Rigorous Learning	Student-Centered Classes	Technology Integration	Totals
Winogradsky HS			1	2				5	2		1	3	1		15
Wakesman HS		3	7	2	3		4	1			2	14	3	4	43
Waerden HS			2				2	2	1			11	1		19
Vesalius HS		1	9					2			1	17	4	5	39
Pythagoras HS		1	1	5	1			1			1	1			11
Marconi HS					1				2		1	1	1	2	8
Linnaeus HS		5	8	4	4		1	2	3		1	12	1	4	45
Leeuwenhoek HS					2		2	2			1	10	3	1	21
Lavosier HS		3	1	4			2	1	1			9		1	22
Khayyam HS			2				1	3	3			10		1	20
Hypatia HS		5	4	1	4		2				1	11	2	2	32
Fibonacci HS		3	3		1				3		1	10	4		25
Descartes HS		1	1				1	6				8			17
Copernicus HS		2	4	3	3		6	3	3		2	38		2	66
Condorcet HS			1		1		2				1	6	1		12
Totals		24	44	21	20		23	28	18		13	161	21	22	



Code Co-Occurrence

Codes	STEM Educators	Content Integration	Instructional Practices	Professional Collaboration	Real-World Application	STEM Experiences	Authentic Connections	Extended-Day	Stakeholder Engagement	STEM Learners	Equal Access	Rigorous Learning	Student-Centered Classes	Technology Integration	Totals
STEM Educators															
Content Integration			4	1								2		2	9
Instructional Practices		4		2			1					3	2	4	16
Professional Collaboration		1	2				1		1		1	1			7
Real-World Application							1					1			2
STEM Experiences															
Authentic Connections			1	1	1			2				2		2	9
Extended-Day							2		1					1	4
Stakeholder Engagement				1				1							2
STEM Learners															
Equal Access				1											1
Rigorous Learning		2	3	1	1		2							1	10
Student-Centered Classes			2											2	4
Technology Integration		2	4				2	1				1	2		12
Totals		9	16	7	2		9	4	2		1	10	4	12	

Figures 12 and Figure 13 CAQDAS Screen Capture – Code Frequency and Co-Occurrence
Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

STEM Learning indicators were the most frequently coded across all text. Hypathia, Linnaeus, Versalius and Wakesman high schools all had a high frequency of STEM learning as part of their STEM programs. Evidence of a strong presence of STEM Learning can also be seen in the sub-groups as schools are stratified by number of certifications. Figure 14 details the code frequency by this stratification.

Descriptor Field \ Codes	STEM Educators	Content Integration	Instructional Practices	Professional Collaboration	Real-World Application	STEM Experiences	Authentic Connections	Extended-Day	Stakeholder Engagement	STEM Learners	Equal Access	Rigorous Learning	Student-Centered Classes	Technology Integration
STEM Certifications: 1 Certification		4	6	4	6		5	4	3		7	7	6	4
STEM Certifications: 2 or more		5	7	3	3		5	7	5		4	8	4	5

Figure 14 CAQDAS Screen Capture -Code Frequency Stratified by Certifications Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

Findings Related to Research Question 3

The research question posed was “Is there evidence in the STEM Schools’ program materials to support the conceptual framework indicators for STEM learning experiences including project-based learning, problem-based learning, case-based learning, real-world applications and external learning experiences including mentorships, internships, apprenticeships, job shadowing, and STEM student competitions?” The researcher examined program materials for the 15 study Schools and applied 109 codes to 52,093 text characters representing the data sources for STEM Educators. Excerpted program materials by School ranged from 1,756 to 7,168 text characters. All Schools had mentions of at least one indicator in this domain. There were 44 mentions of “improvement in instructional strategies” for the STEM Educator category. Mentions in this category were nearly double that of all other child codes for STEM Educator. Figure 15 illustrates coded program materials stratified by certifications.

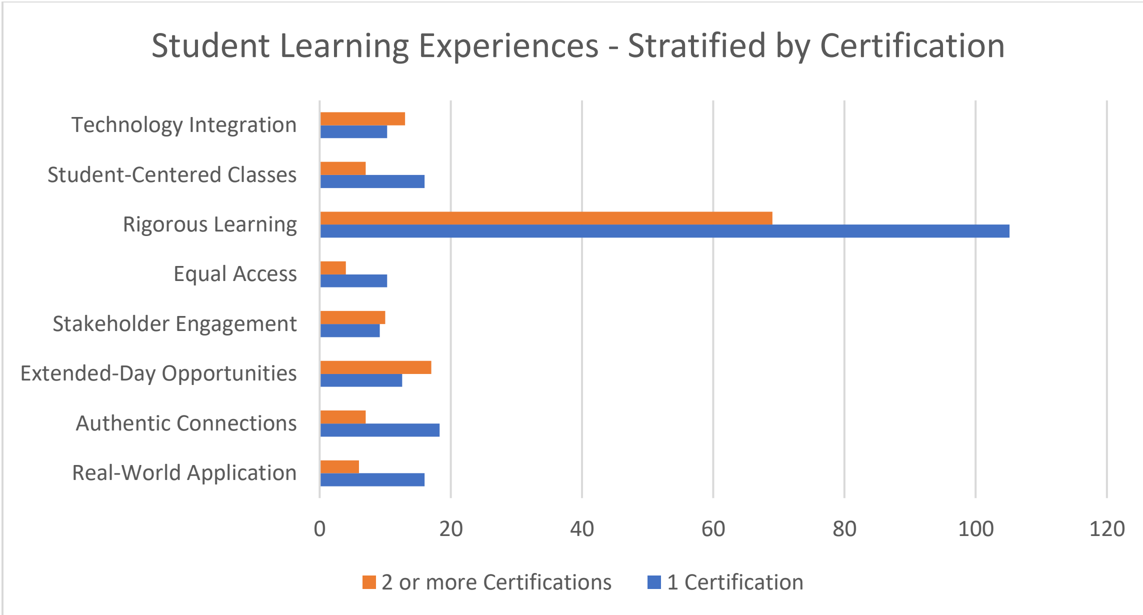


Figure 15 Student Learning Experiences- Stratified by Certification
Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

Findings Related to Research Question 4

The questions posed was "Is there evidence in the STEM Schools' program materials to support the conceptual framework indicators for researched-based instructional pedagogies including project-based learning, problem-based learning, performance-based learning and assessment, technology integration, content integration, and the necessary materials and supports for teacher STEM professional development and collaboration with interdisciplinary team?" The researcher examined program materials for the 15 study Schools and applied 82 codes to 52,093 text characters representing the data sources for STEM Experiences. Excerpted program materials by School ranged from 1,756 to 7,168 text characters. All 15 study Schools included evidence of STEM experiences in their program materials. STEM experiences received the least number of coded occurrences as compared to STEM Learners and STEM Educators. All Schools made mention of evidence in this category.

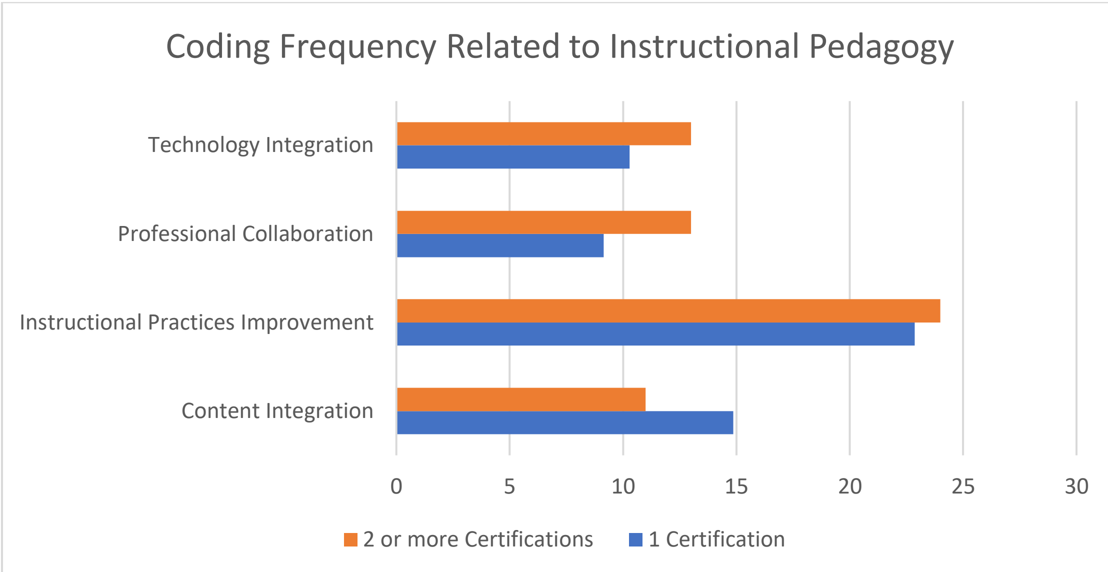


Figure 16 Instructional Pedagogy - Stratified by Certification
Dedoose Version 8.1.8 web application for managing, analyzing, and presenting qualitative and mix method research data (2018). Los Angeles, CA: SocioCultural Research Consultants, LLC www.dedoose.com

CHAPTER V

DISCUSSION OF FINDINGS

The performance of U.S. students on international measures of math and science, the underrepresentation of women and minorities in STEM-related fields, and the demand for STEM-related skills in the workforce all necessitate the continued development and support of STEM education for all students. The collective commitments that multiple universities, businesses, and community organizations are dedicating toward STEM research, innovation and education indicate how integral STEM is and will continue to be for America's success. STEM education reflects the technological age in which we live and provides the knowledge base and skills that will enable us to address some of the most important issues we will face in the world. STEM literacy is required for "personal decision making, participation in civic and cultural affairs, and economic productivity" for all 21st century citizens (NRC, 2011a, p. 5). Some of the competencies strengthened through STEM education include "critical thinking, problem-solving, collaboration, effective communication, motivation, persistence, and learning to learn," as well as "creativity, innovation, and ethics" (Pellegrino & Hilton, 2012, p. 17). Developing STEM education in our schools is not only strategic and important to ensure the inclusion of underrepresented groups of students, but it has become an essential component in education for all children to be able to fully participate and succeed in our modern world.

Study Summary

The data studied were purposefully selected and, by design, published physical documents. The use of published physical documents eliminated the bias that is sometimes associated with primary data collection. Results from the research confirm that many of the study's STEM Schools have aligned their learning experiences, instructional practices and curriculum with national priorities of recruiting students from underrepresented groups, providing rigorous, inquiry-based learning experiences and partnering with business, industry, and communities to create holistic and authentic learning experiences (Holdren et al, 2013). The alignment of research-based instructional pedagogy and student learning experiences facilitated the development of student engagement with STEM learning (Holdren et al, 2013; Means et al, 2008; Office of the Press Secretary, 2010).

Four research questions were used to guide this content analysis study.

1. To what extent does the STEM Schools' mission statements include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration?
2. To what extent does the STEM Schools' program materials include evidence of the STEM competency skills referenced in the conceptual framework including critical thinking and problem-solving, collaboration, communication, creativity and innovation, and technology integration?
3. Is there evidence in the STEM Schools' program materials to support the conceptual framework indicators for STEM learning experiences including

project-based learning, problem-based learning, case-based learning, real-world applications and external learning experiences including mentorships, internships, apprenticeships, job shadowing, and STEM student competitions?

4. Is there evidence in the STEM Schools' program materials to support the conceptual framework indicators for researched-based instructional pedagogies including project-based learning, problem-based learning, performance-based learning and assessment, technology integration, content integration, and the necessary materials and supports for teacher STEM professional development and collaboration with interdisciplinary team?

Discussion of Findings

Research has confirmed that a positive relationship exists between student engagement and student achievement (Connell, et al., 1994; Connell et al., 1995; Marks, 2000; Sirin & Rogers-Sirin, 2004). Research also supports that students are more likely to be engaged in learning if they see a connection to their own world (NYC Department of Education, 2015). Therefore, the creation of schools and programs designed for students to engage in experiences that promote problem-solving or projects connected to the real world can generate student interest and academic achievement within schools (NYC Department of Education, 2015). A total of 14 themes emerged from the content analysis of the STEM Schools -- three specifically related to the mission statements and 11 related to the STEM Schools' program materials.

Content Knowledge, Competency Skills and Thinking Strategies

The underlying hypothesis of the examination of mission statements was that STEM Schools' mission statements would directly align with the core tenets of the AdvancED STEM Standard. Evidence from the research did not support the underlying hypothesis. There was a disconnect between the mission statement, AdvancED STEM Standard and program materials for 80% of the study's Schools. It was expected that the mission statement would articulate the schools' vision and the AdvancED STEM Standard in an actionable way, outlining the goals and objectives of the STEM program (Evans, 2010). Only two schools in the study outlined the goals and objectives of their STEM program in their mission statement. The other 13 schools had generic, broad statements that did not address the STEM program's goals or objectives. One School did not have a school or STEM program mission statement. The inconsistency with mission statements made it difficult to compare the evidence of competency skills. For the STEM Schools in the study it was assumed that the mission statements would go further and speak to ways that students could become productive 21st century citizens and constructive contributors to their communities.

The STEM mission statement should explain the overall purpose of the STEM education program and seamlessly integrate into the existing mission and vision of the school (NYC Department of Education, 2015). A STEM-centric culture is the heart of a good STEM education program and builds upon the STEM mission the school has established (Yager and Brunkhorst, 2014). In this type of culture, students are regularly immersed in addressing real-world challenges, answering complex questions, and applying the use of science, technology, engineering and mathematics to address these challenges. A STEM-centric environment strengthens stakeholder's sense of belonging, as well as supports a pathway to success for students (Habegger, 2008).

What is apparent from the frequency reporting of mission statements themes is that competency skills were reported the most with 36 codes, followed by 6 codes for content knowledge and 3 codes for thinking strategies. The core competencies theme did have more sub-groups associated with it which contributed to the higher frequency counts. In alignment with the Global STEM Alliance STEM education framework, supporting attributes including agency and persistence, ethics, leadership, STEM mindset and social and cultural awareness were listed as additional sub-groups for core competency skills. Normalizing for this inclusion, reduces the reported frequency counts for core competency skills to 15. STEM Schools with two or more STEM certifications had higher mentions of content knowledge and core competencies. Stratifying the results further to look at the variation in STEM School design, the results report higher frequency counts in all three areas (content knowledge, core competencies and thinking strategies), for schools with "inclusive", open-enrollment designs. In fact, the total frequency count for all three areas of "selective" STEM Schools was four, compared to 45 for inclusive STEM Schools.

All STEM schools mentioned the inclusion of competency skills in their program materials. The competency skills included critical thinking and problem-solving, collaboration, communication, creativity and innovation and technology integration The following trend was noted for Schools classified as ISHS -- schools with open enrollment policies: Regardless of the number of certifications or locale, ISHS schools were generally rated higher across the board for mentions of core competency skills and thinking strategies than were Schools identified as selective STEM schools (schools that cater to talented and gifted academic students). The research study revealed that ISHS's overall invest more time developing students' knowledge of STEM as meta-discipline which increases students' core competencies and ability to compete in STEM and non-STEM careers. As a meta-discipline STEM is viewed from an amalgamative perspective, representing only the overlaps between the disciplines which represent the "soft skills" that are common to all four disciplines (Hobbs et al, 2018; Vasquez, 2015). Figure 17 gives a visual description of this concept.

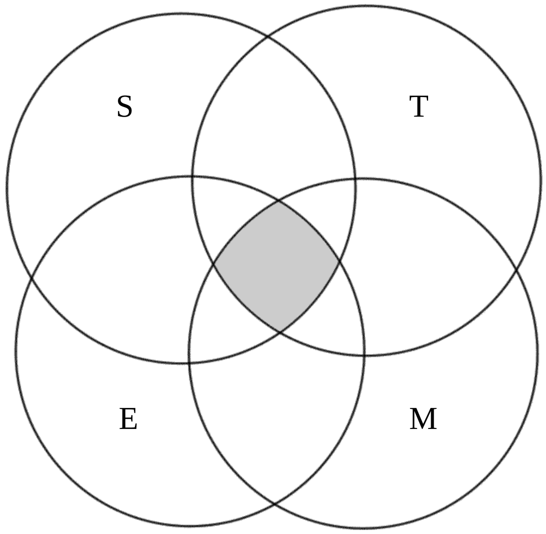


Figure 17 Amalgamated STEM model representing STEM as a meta-discipline. The gray area in the middle shows the overlap of soft skills developed from STEM education.

perspective of STEM allows teachers to use research based instructional practices that extend holistic STEM content learning to include the teaching of soft skills that are important for our country's success in innovation and creativity. Research already report American students score higher on average in critical-thinking and collaborative problem-solving than they do math and science related subjects – ranked 13th and 25th globally, respectively (OECD, 2018). This is an area that requires further study, but provides important insights for STEM education.

Instructional Pedagogy and Student Learning Experiences

The remaining 11 themes that emerged from the content analysis all deal with instructional pedagogy and student learning experiences. Themes related to student learning experiences include rigorous learning, student-centered classes, technology integration, equal access for underrepresented students, authentic connections, stakeholder engagement and extended day opportunities. Themes related to instructional pedagogies include real-world application, content integration, professional collaboration and improvement in STEM instructional practices for teachers.

The themes with the largest reported frequencies were rigorous learning, instructional practices and extended-day opportunities respectively. The frequency reporting for rigorous learning was four times greater than the next most reported theme, instructional practices. These results align with the assumed hypothesis for the study confirming that the presence of student learning experiences and research based pedagogies increase student engagement and students' persistency in STEM for careers and education. It is also interesting to note the high frequency level for extended-day opportunities. Several of the STEM Schools offered multiple ongoing industry and post-secondary partnerships that increased the reported frequency for extended-day opportunities. Evidence suggested that the above stakeholders also engaged regularly with teachers and students in the STEM programs. STEM students participated in formal programs of mentorships, apprenticeships, internships, research and/or job shadowing.

Overall, there was evidence across the STEM Schools to suggest that Schools were implementing time for teacher collaboration, professional development and improvement of instructional practices. There was a strong correlation between STEM instructional pedagogy and student learning experiences for several sub-groups suggesting that the greater the investment in developing quality STEM instructors, the higher the level of student engagement and student learning in the classrooms. Evidence supporting the instructional pedagogy domain included activities that described educator instructional practices and curriculum design that support student STEM learning and engagement. Evidence included curriculum integration across and beyond STEM disciplines. The curriculum was organized around multiple interdisciplinary and authentic problem-based learning experiences. The curriculum provided learning experiences that developed cross-cutting competencies necessary for college and career.

Evidence supported opportunities for STEM educators to stay current on practices in the STEM world through professional learning. STEM educators had access to ongoing opportunities to expand their proficiency in the use of technology. Teachers regularly planned and collaborated to discuss integrated STEM curricular and instructional practices. Evidence also included STEM educators reviewing student work as an interdisciplinary team to develop and review standards of mastery. Even though all schools were coded with evidence of some instructional pedagogy, only 33% of the STEM Schools received coding in all areas for instructional pedagogy including real-world application, content integration, professional collaboration and improvement in instructional practices. The largest coded sub-group under instructional pedagogy was "instructional practices improvement" with a frequency count of 44 codes across all schools. These results indicate that most schools are building the capacity of their teachers to teach using research based pedagogies.

Implications for Practice

The results of the research study revealed many implications for practice. The most important implications for practice include devising a proactive plan that addresses the new STEM culture and the instructional design for the school. The same adage can be used for STEM planning as we use for instructional planning - begin with the end in mind. The initial task of planning requires assembling a team of educators and stakeholders from the community, including local business partners, that will serve as members of a STEM planning team. Next, and most important, the team needs to create a vision for the program/school. A STEM vision needs to be drafted to anchor the planning team's initiatives and help guide the goals, outcomes and the action plan. The vision statement should be inspirational in nature, reflect long-term plans and operate as a compass guiding the work (Evans, 2010). It is also important for the STEM vision and mission to integrate with the existing vision and mission for the school (NYC Department of Education, 2015). Once the STEM vision has been developed, a mission statement should be created that articulates the vision in an actionable way. The mission statement outlines the goals and objectives of the STEM program and is instrumental in setting the stage for the program (NYC Department of Education, 2015).

Preparing staff and students for a shift in curricular programs as well as shifting their siloed mindsets requires a great deal of foresight and planning. A school's STEM vision and mission are critical to building a STEM-centric culture. Developing a culture shift to "STEM mindsets" requires more than just a commitment to add a STEM program or STEM-related activities. A STEM-centric culture includes: stakeholders sharing a common vision and goals toward STEM education, fostering a culture of inquiry and sharing of best practices, shifts instruction from isolated disciplines to interdisciplinary or transdisciplinary practices, and develops relationships based on social respect, personal regard and integrity (NYC Department of Education, 2015).

Planning the instructional design of the STEM program requires identifying the most effective research-based pedagogies for STEM education, deciding if content integration will be interdisciplinary, multidisciplinary or transdisciplinary, determining how real-world applications will be implemented and building the capacity of the teaches to absorb and implement this new way of thinking and delivering education. It will be difficult to implement or grow a STEM program if teachers are not implementing new pedagogical practices appropriate for STEM instruction (NYC Department of Education, 2015). In addition to STEM pedagogical development, educators must also demonstrate strong content knowledge and knowledge of 21st century skills or competencies for effective delivery of STEM instruction (Johnson, Peters-Burton, and Moore, 2016).

Results from this study will be invaluable to the researcher in the design and implementation of a new STEM program in an existing academy. The design of the STEM academy has changed from a stand-alone entity to a program embedded in the school's existing magnet Academy which previously only focused on the integration of business and academic pathways. During its three-year history the magnet academy has boasted many successes for the school including increased student achievement. The Academy students have consistently outperformed other students in the high school on 100% of the statistically-significant state standardized assessments. The school has also seen a 55% increase in student attendance since the Academy's inception (School Internal Reports, 2018).

As a comparative measure the researcher used the AdvancED STEM standard, representative of the study's conceptual framework, to evaluate the current level of the STEM program at the researcher's school. The school was rated on a scale from Beginning, Developing, Proficient to Distinguished. The results follow: The STEM School is at a "Beginning" level for support of non-traditional student participation through outreach to groups often underrepresented in the STEM pipeline. The current outreach plan is limited and only consists of open house recruitment nights each semester. The Academy leaders also visit middle schools in the county to recruit students for the upcoming year. To move further along the continuum, the school needs to create and sponsor STEM nights to showcase the projects of students and educate the community about STEM. Additionally, partnerships with middle and elementary schools should be fostered that allow high school students to work during extended hours with students exposing them to projects related to STEM.

The STEM school is developing in the areas of personalizing and self-directing STEM learning experiences and demonstrating their learning through performance-based assessments. A “developing” rating was given in this category because all STEM students are new to the Academy this school year. Students have not had an opportunity to become immersed in the STEM competitive events or self-direct STEM learning due to a limited staff of highly qualified STEM teaches. The STEM school is proficient with creating an environment that fosters independent and collaborative work in an inquiry-based environment and students’ use of technology resources to conduct research, demonstrate creative and critical thinking, and communicate and work collaboratively. Case methodology is the Academy’s anchor for interdisciplinary pedagogy, relevant connectivity and authentic project-based application. Each grade level receives different case studies every six weeks. Students present solutions to the case problem to company executives at the end of the six weeks during a field trip to the company’s location.

The academy is in its fourth year of existence and has established routines and processes in place for teacher collaboration and professional development. To this end, the STEM program is rated proficient for educators collaborating as an interdisciplinary team and participating in a continuous program of STEM-specific professional learning.

All academy teachers are part of a weekly professional learning community (PLC) with a focus on STEM integration and resources. Individual teachers are also identified to receive professional development training on new STEM initiatives and instructional practices. Teachers then share new learnings with academy team members. The academy is still in the beginning and development stage for mastery of STEM learning outcomes demonstrating students' STEM literacy for college and career and interdisciplinary problem-based curriculum focusing on deeper learner with real-world applications. Again, these categories are specific to STEM learning and new to the academy and not fully implemented. The Academy is currently working to build the capacity of the STEM instructors to work across disciplines to create and embrace interdisciplinary activities and curriculum.

The foundational structure of the academy is sound and operating proficiently relative to community, post-secondary, business/industry partners and families actively support and involvement. The school has partnerships with many of the major businesses and post-secondary institutions in the area. Students are exposed to companies via Case studies, field trips, job shadowing opportunities and senior year internships. STEM students are engaged with the same companies and post-secondary institutions. There is still a need to partner with STEM specific companies as STEM students matriculate through the program and become seniors ready for job placement into STEM specific internships. Additionally, STEM students need more opportunities to learn STEM through extended day activities like involvement with the technology student association, society of black engineers, robotics club and after school STEM programs.

Suggestions for Further Investigation

This research study examined different STEM Schools' instructional pedagogies and student learning experiences. The operative word in the above sentence is "different." The most critical areas still requiring extensive research is the development of a common model and language for STEM Schools as well as an expanded evaluation system capable of measuring student competency outcomes. Answers to the following questions are still varied and unknown: What exactly are inclusive STEM-focused high schools? How do they work? Who seems to benefit from attending such schools and why? What are the critical components that operate in each school, and across schools (Lynch et al, 2013).

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APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL LETTER

UNIVERSITY OF GEORGIA

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Athens, Georgia 30602
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Human Research Protection Program

NOT HUMAN RESEARCH DETERMINATION

October 12, 2018

Dear Joyce Adams:

On 10/12/18, the Human Subjects Office reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Exploring STEM Schools and Student Engagement: An examination of STEM education and Student Learning Experiences
Investigator:	Joyce Adams
Co-Investigator:	Valencia Bradshaw
IRB ID:	STUDY00002253
Funding:	None
Grant ID:	None

We have determined that the proposed activity is not research involving human subjects as defined by DHHS and FDA regulations. The project will analyze publicly available data at the institutional level.

University of Georgia (UGA) IRB review and approval is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities are research involving human subjects, please submit a new request to the IRB for a determination.

Sincerely,

Kimberly Fowler, Director
Human Subjects Office, University of Georgia

APPENDIX B

SNAPSHOST OF PERFORMANCE IN SCIENCE, READING & MATHEMATICS

Snapshot of performance in science, reading and mathematics

Countries/economies with a mean performance/share of top performers **above** the OECD average Countries/economies with a share of low achievers **below** the OECD average
Countries/economies with a mean performance/share of top performers/share of low achievers not significantly different from the OECD average
Countries/economies with a mean performance/share of top performers **below** the OECD average Countries/economies with a share of low achievers **above** the OECD average

	Science		Reading		Mathematics		Science, reading and mathematics	
	Mean score in PISA 2015	Average three-year trend	Mean score in PISA 2015	Average three-year trend	Mean score in PISA 2015	Average three-year trend	Share of top performers in at least one subject (Level 5 or 6)	Share of low achievers in all three subjects (below Level 2)
	Mean	Score dif.	Mean	Score dif.	Mean	Score dif.	%	%
OECD average	493	-1	493	-1	490	-1	15.3	13.0
Singapore	556	**7**	535	**5**	564	1	39.1	4.8
Japan	538	3	516	-2	532	1	25.8	5.6
Estonia	534	2	519	**9**	520	2	20.4	4.7
Chinese Taipei	532	0	497	**1**	542	0	29.9	8.3
Finland	531	**-11**	526	**-5**	511	**-10**	21.4	6.3
Macao (China)	529	**6**	509	**11**	544	**5**	23.9	3.5
Canada	528	-2	527	**1**	516	**-4**	22.7	5.9
Viet Nam	525	-4	487	**-21**	495	**-17**	12.0	4.5
Hong Kong (China)	523	**-5**	527	-3	548	1	29.3	4.5
B-S-J-G (China)	518	m	494	m	531	m	27.7	10.9
Korea	516	-2	517	**-11**	524	-3	25.6	7.7
New Zealand	513	**-7**	509	**-6**	495	**-8**	20.5	10.6
Slovenia	513	-2	505	**11**	510	2	18.1	8.2
Australia	510	**-6**	503	**-6**	494	**-8**	18.4	11.1
United Kingdom	509	-1	498	2	492	-1	16.9	10.1
Germany	509	-2	509	**6**	506	2	19.2	9.8
Netherlands	509	**-5**	503	-3	512	**-6**	20.0	10.9
Switzerland	506	-2	492	-4	521	-1	22.2	10.1
Ireland	503	0	521	**13**	504	0	15.5	6.8
Belgium	502	-3	499	-4	507	**-5**	19.7	12.7
Denmark	502	2	500	3	511	-2	14.9	7.5
Poland	501	3	506	3	504	**5**	15.8	8.3
Portugal	501	**8**	498	4	492	**7**	15.6	10.7
Norway	498	3	513	**5**	502	1	17.6	8.9
United States	496	2	497	**-1**	470	-2	13.3	13.6
Austria	495	**-5**	485	-5	497	-2	16.2	13.5
France	495	0	499	2	493	**-4**	18.4	14.8
Sweden	493	**-4**	500	1	494	**-5**	16.7	11.4
Czech Republic	493	**-5**	487	5	492	**-6**	14.0	13.7
Spain	493	2	496	**7**	486	1	10.9	10.3
Latvia	490	1	488	2	482	0	8.3	10.5
Russia	487	3	495	**17**	494	**6**	13.0	7.7
Luxembourg	483	0	481	**5**	486	-2	14.1	17.0
Italy	481	2	485	0	490	**7**	13.5	12.2
Hungary	477	**-9**	470	**-12**	477	**-4**	10.3	18.5
Lithuania	475	-3	472	2	478	-2	9.5	15.3
Croatia	475	**-5**	487	**5**	464	0	9.3	14.5
CABA (Argentina)	475	**51**	475	**46**	456	**38**	7.5	14.5
Iceland	473	**-7**	482	**-9**	488	**-7**	13.2	13.2
Israel	467	**5**	479	2	470	**10**	13.9	20.2
Malta	465	2	447	3	479	**9**	15.3	21.9
Slovak Republic	461	**-10**	453	**-12**	475	**-6**	9.7	20.1
Greece	455	**-6**	467	**-8**	454	1	6.8	20.7
Chile	447	2	459	5	423	4	3.3	23.3
Bulgaria	446	4	432	**1**	441	**9**	6.9	29.6
United Arab Emirates	437	**-12**	434	-8	427	-7	5.8	31.3
Uruguay	435	1	437	**5**	418	-3	3.6	30.8
Romania	435	6	434	4	444	**10**	4.3	24.3
Cyprus[1]	433	-5	443	-6	437	-3	5.6	26.1
Moldova	428	**9**	416	**17**	420	**13**	2.8	30.1
Albania	427	**18**	405	**10**	413	**18**	2.0	31.1
Turkey	425	2	428	**-18**	420	2	1.6	31.2
Trinidad and Tobago	425	**7**	427	**5**	417	2	4.2	32.9
Thailand	421	2	409	**-6**	415	1	1.7	35.8
Costa Rica	420	-7	427	**-9**	400	-6	0.9	33.0
Qatar	418	**21**	402	**15**	402	**26**	3.4	42.0
Colombia	416	**8**	425	6	390	**5**	1.2	38.2
Mexico	416	2	423	-1	408	**5**	0.6	33.8
Montenegro	411	1	427	**10**	418	**6**	2.5	33.0
Georgia	411	**23**	401	**16**	404	**15**	2.6	36.3
Jordan	409	**-5**	408	2	380	-1	0.6	35.7
Indonesia	403	3	397	-2	386	**4**	0.8	42.3
Brazil	401	3	407	-2	377	**6**	2.2	44.1
Peru	397	**14**	398	**14**	387	**10**	0.6	46.7
Lebanon	386	m	347	m	396	m	2.5	50.7
Tunisia	386	0	361	**-21**	367	**4**	0.6	57.3
FYROM	384	m	352	m	371	m	1.0	52.2
Kosovo	378	m	347	m	362	m	0.0	60.4
Algeria	376	m	350	m	360	m	0.1	61.1
Dominican Republic	332	m	358	m	328	m	0.1	70.7

1. Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Notes: Values that are statistically significant are marked in bold.

The average trend is reported for the longest available period since PISA 2006 for science, PISA 2009 for reading, and PISA 2003 for mathematics.

Countries and economies are ranked in descending order of the mean science score in PISA 2015.

Source: OECD, PISA 2015 Database, Tables I.2.4a, I.2.6, I.2.7, I.4.4a and I.5.4a.

PISA 2015 Results in Focus | 5

SNAPSHOT OF COLLABORATIVE PROBLEM SOLVING

Snapshot of performance in collaborative problem solving and attitudes towards collaboration

- (blue) Countries/economies with a mean performance/relative performance above the OECD average
- (white) Countries/economies with a mean performance/relative performance not significantly different from the OECD average
- (grey) Countries/economies with a mean performance/relative performance below the OECD average

	Collaborative problem solving					Index of valuing relationships	Index of valuing teamwork
	All students	Relative performance[1]	Boys	Girls	Gender difference (boys – girls)		
	Mean score	Score dif.	Mean score	Mean score	Score dif.	Mean index	Mean index
OECD average-32	500	3	486	515	**-29**	0.01	0.00
Singapore	561	16	552	572	**-20**	0.32	0.27
Japan	552	23	539	565	**-26**	-0.22	-0.03
Hong Kong (China)	541	15	523	559	**-36**	-0.04	0.05
Korea	538	20	522	556	**-33**	-0.02	0.14
Canada	535	10	516	555	**-39**	0.11	0.00
Estonia	535	8	522	549	**-27**	0.03	-0.10
Finland	534	7	511	559	**-48**	-0.08	-0.22
Macao (China)	534	11	515	553	**-38**	-0.15	0.01
New Zealand	533	20	513	553	**-41**	0.01	0.07
Australia	531	23	511	552	**-41**	0.09	0.01
Chinese Taipei	527	5	513	541	**-28**	0.22	0.37
Germany	525	14	510	540	**-30**	0.15	0.14
United States	520	22	507	533	**-26**	0.13	0.06
Denmark	520	14	509	530	**-21**	0.01	-0.12
United Kingdom	519	12	503	536	**-34**	-0.04	-0.04
Netherlands	518	8	504	531	**-27**	-0.18	-0.26
Sweden	510	9	489	531	**-42**	0.05	-0.19
Austria	509	13	498	521	**-24**	0.24	0.19
Norway	502	-5	487	518	**-30**	0.11	-0.23
Slovenia	502	-10	484	521	**-36**	-0.04	0.02
Belgium	501	-4	489	514	**-25**	-0.06	-0.11
Iceland	499	15	485	512	**-27**	-0.09	-0.20
Czech Republic	499	3	486	512	**-26**	-0.20	0.00
Portugal	498	-5	489	507	**-19**	0.37	0.32
Spain	496	-1	485	508	**-22**	0.19	0.15
B-S-J-G (China)	496	-17	486	508	**-22**	0.01	0.39
France	494	-7	480	508	**-29**	-0.07	0.11
Luxembourg	491	2	478	504	**-25**	0.03	0.00
Latvia	485	-9	465	505	**-40**	-0.30	-0.14
Italy	478	-11	466	489	**-23**	-0.14	0.02
Russia	473	-22	460	486	**-25**	-0.25	-0.18
Croatia	473	-12	459	486	**-27**	0.01	0.21
Hungary	472	-10	459	485	**-26**	-0.03	-0.02
Israel	469	-11	459	481	**-22**	0.24	-0.03
Lithuania	467	-15	453	482	**-29**	0.16	0.33
Slovak Republic	463	-7	448	478	**-30**	-0.34	-0.12
Greece	459	-10	444	475	**-31**	0.03	0.18
Chile	457	-3	450	464	**-14**	0.08	0.21
Cyprus[2]	444	-6	424	464	**-40**	0.07	0.10
Bulgaria	444	-10	429	461	**-31**	-0.03	-0.07
Uruguay	443	-6	434	451	**-17**	0.11	0.20
Costa Rica	441	4	437	445	**-7**	0.35	0.34
Thailand	436	2	416	451	**-35**	0.10	0.37
United Arab Emirates	435	-14	416	454	**-38**	0.32	0.45
Mexico	433	-1	426	440	**-14**	0.16	0.23
Colombia	429	-4	425	433	**-8**	0.05	0.23
Turkey	422	-19	411	434	**-23**	0.00	-0.04
Peru	418	2	414	421	**-7**	-0.08	0.09
Montenegro	416	-18	403	429	**-26**	-0.05	-0.09
Brazil	412	-9	402	421	**-18**	-0.04	0.20
Tunisia	382	-18	375	387	**-12**	0.12	0.43
Ireland	m	m	m	m	m	0.03	0.04
Poland	m	m	m	m	m	-0.21	-0.06
Switzerland	m	m	m	m	m	0.19	0.22
Dominican Republic	m	m	m	m	m	0.27	0.51
Qatar	m	m	m	m	m	0.12	0.23

1. Relative scores are the residuals obtained from a pooled linear regression, across all participating countries/economies, of the performance in collaborative problem solving over performance in science, reading and mathematics.
2. See note 1 under Figure 1. Snapshot of performance in science, reading and mathematics.
Note: At the country/economy level, values that are statistically significant are marked in bold (see Annex A3).
Countries and economies are ranked in descending order of the mean collaborative problem-solving score.
Source: OECD, PISA 2015 Database, Tables V.3.2, V.3.9a, V.4.3a and V.5.1.

APPENDIX C

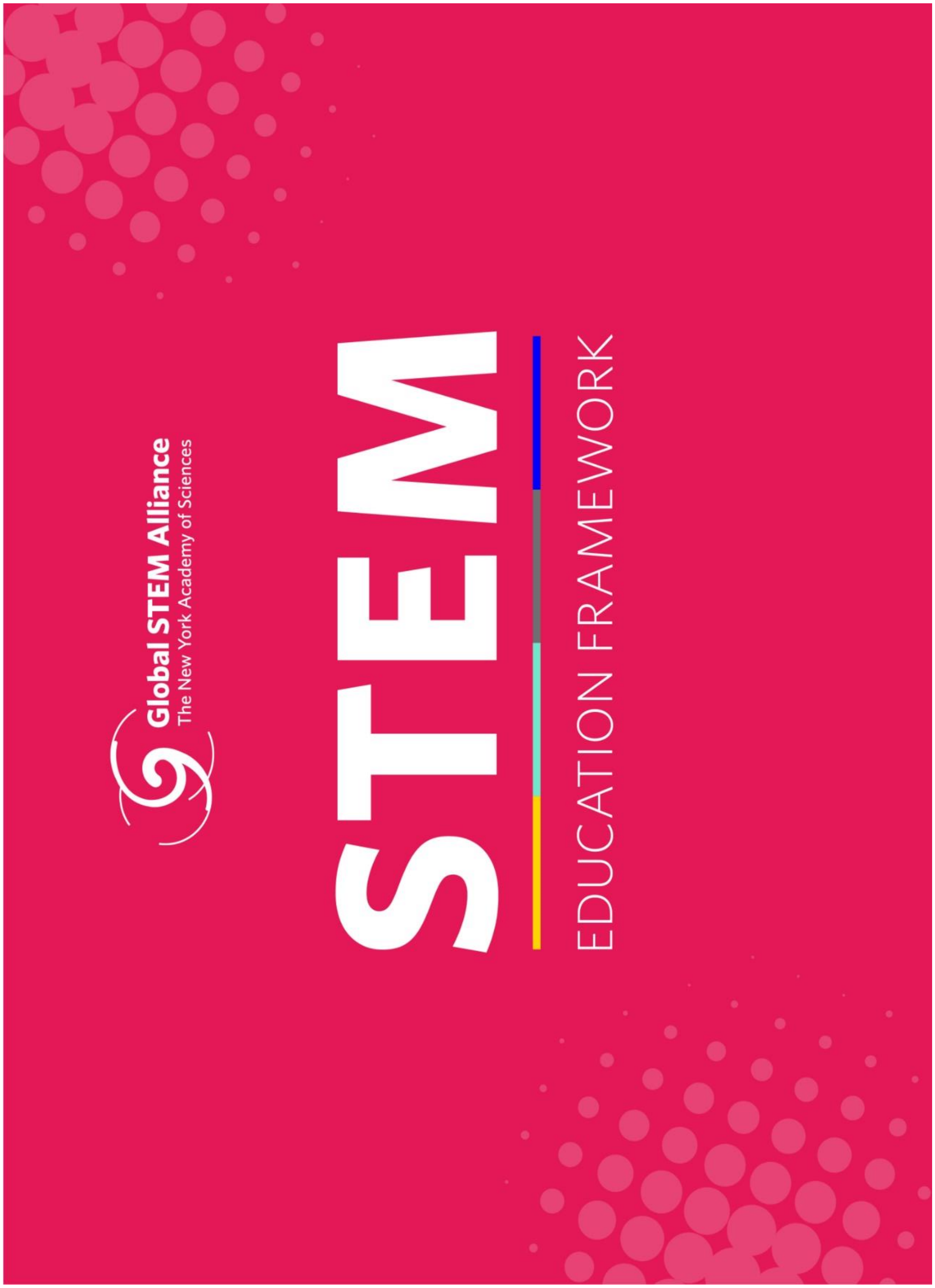
ADVANCED STEM STANDARD AND INDICATORS

AdvancED STEM Certification Standard	
STEM students have the skills, knowledge, and thinking strategies that prepare them to be innovative, creative, and systematic problem-solvers in STEM fields of study and work.	
STEM Learning Indicators	
In accordance with the mission of AdvancED, the student is the most important focus of the STEM Certification. Institutions and programs geared toward providing a strong STEM education should strive to include all learners, paying close attention to those groups often marginalized in STEM fields. Students should regularly engage in activities that meet the diverse needs and styles of learners in ways that foster independent critical thinking as well as transformative collaboration. In keeping with the nature of STEM, students should make regular use of technology throughout the learning process, from enhanced research and data gathering to innovative experiential learning opportunities. Finally, STEM learners should be encouraged to demonstrate their knowledge through both traditional and nontraditional performance-based assessments.	
Indicator	Description
Standard 1.1	The STEM school/program supports non-traditional student participation through outreach to groups often underrepresented in STEM program areas.
Standard 1.2	Students work independently and collaboratively in an inquiry-based learning environment that encourages finding creative solutions to authentic and complex problems.
Standard 1.3	Students are empowered to personalize and self-direct their STEM learning experiences supported by STEM educators who facilitate their learning.
Standard 1.4	Students use technology resources to conduct research, demonstrate creative and critical thinking, and communicate and work collaboratively.
Standard 1.5	Students demonstrate their learning through performance-based assessments and express their conclusions through elaborated explanations of their thinking.
STEM Educator Indicators	
To maximize students' STEM learning, educators should regularly engage in collaborative planning to develop an interdisciplinary curriculum that emphasizes high-quality problem-based instruction. Educators should empower students by providing	

them with learning experiences that prepare them for the types of problem solving skills they will need in order to be successful in their postsecondary endeavors and their future careers. Such high demands on educators can only be met through rigorous, ongoing professional development targeted at continuously improving STEM-based educational practices.	
Indicator	Description
Standard 1.6	The interdisciplinary problem-based curriculum includes a focus on real world applications.
Standard 1.7	STEM educators collaborate as an interdisciplinary team to plan, implement, and improve integrated STEM learning experiences
Standard 1.8	STEM learning outcomes demonstrate students' STEM literacy necessary for the next level of STEM learning and for post- secondary and workforce readiness.
Standard 1.9	STEM teachers and leaders participate in a continuous program of STEM-specific professional learning.
STEM Experience Indicators A key focus of national policy initiatives to improve STEM education has been the need to prepare today's learners for the information and technology economy. In order to educate students who can compete for jobs in a global market, institutions and programs should partner with businesses, post-secondary institutions, and the community at large to provide students with opportunities to engage in STEM learning in real-world settings. Student learning should be further enhanced through involving families and by arranging learning experiences for students that extend beyond the confines of the normal school day and the physical plant of the institution	
Standard 1.10	Community, post-secondary, business/industry partners and/or families actively support and are engaged with teachers and students in the STEM program.
Standard 1.11	Students are supported in their STEM learning through adult-world connections and extended day opportunities.

APPENDIX D

GLOBAL STEM ALLIANCE STEM EDUCATION FRAMEWORK



Global STEM Alliance
The New York Academy of Sciences

Contents

Introduction

The Global STEM Alliance (GSA) STEM Education Framework aims to identify best practices in science, technology, engineering, and mathematics (STEM) education. It reflects current education research and draws on innovative and effective practices employed around the world.

The framework details 26 features of quality STEM education in 3 essential areas:

- **Core Competencies:** To what extent are students provided with opportunities to develop 21st-century skills needed to thrive in the modern workplace?
- **Instructional Design:** To what extent do the materials and/or program design reflect research-based pedagogy and a cohesive system of learning objectives, supports, and assessment resources?
- **Implementation:** To what extent are necessary supports or services available to facilitate distribution and ensure effective implementation?

This framework is intended to be used by anyone engaged in STEM education—curriculum developers, content providers, teachers, students, parents, school leaders, policymakers, and philanthropists—to help guide the development and evaluation of high-quality instructional programs and materials. It was developed by the New York Academy of Sciences in collaboration with SRI International and an advisory board of STEM education experts. For details about the development process and research supporting the framework, see *STEM Education Framework Research Foundations*.

Part A: Core Competencies

Part A has two sections: *Essential Skills* are competencies that, in addition to content knowledge, students must develop to thrive in the modern workplace; *Supporting Attributes* are competencies that facilitate the development of and enhance these essential skills. To be Exemplary in these areas, materials must include explicit guidance for instruction and assessment of a given competency, including rubrics or instructions for interpreting assessment outcomes.

A.1 Essential Skills

A.1.1 Critical Thinking

Exemplary	Developing	Basic	Undeveloped
Students have opportunities to evaluate multiple sources of information, evidence, and primary material; select appropriate material to support arguments; critique the work of others; and differentiate evidence from inference and opinion. Activities include the use of scientific procedures to test students' hypotheses. Students are supported and have opportunities to apply one or more perspectives to reason about problems, experimental procedures, and phenomena (e.g., computational, systems, or design thinking) when developing arguments, critiques, or hypotheses. Supports are provided to facilitate teacher and student discussion and reasoning when evaluating sources and critiquing each other's work.	Students have opportunities to evaluate sources of information, evidence, and primary materials; critique the work of others; and use evidence to build an argument, but not as integral components of instructional activities. Students have opportunities to make predictions based on given information (if X, then Y) and form conclusions or generalizations about phenomena. Students are supported and have opportunities to apply one or more perspectives to reason about problems and phenomena (e.g., computational, systems, or design thinking).	Students have limited opportunities to review primary materials or sources that allow them to evaluate and integrate new knowledge. Students have opportunities to make predictions based on given information (if X, then Y), but are not asked to generalize or test hypotheses.	Students do not have opportunities to evaluate information or evidence presented; information is imparted from a unitary perspective. Materials to do not include or reference outside resources. Students are not asked to make predictions, test hypotheses, or build arguments.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

A.1.2 Problem Solving

Exemplary	Developing	Basic	Undeveloped
Students have opportunities to develop their ability to generate solutions to a range of STEM-based problems and scenarios, including organizing ideas, defining goals and milestones, and executing plans. Materials support the use and evaluation of a range of approaches to problem solving, including the scientific method and design thinking. Students are supported and have opportunities to apply one or more solutions to a range of STEM-based problems and scenarios. Supports are provided to facilitate teacher and student reasoning about challenges that occur during problem solving, with an emphasis on strategy, creativity, collaboration, and persistence.	Students have opportunities to develop their ability to generate solutions to a range of STEM-based problems and scenarios, including organizing ideas, defining goals and milestones, and executing plans. Materials support the use and evaluation of a range of approaches to problem solving, including the scientific method and design thinking.	Students have opportunities to develop their ability to generate a single solution to a range of STEM-based problems and scenarios, including organizing ideas, defining goals and milestones, and executing plans.	Students are led through activities step by step. Teachers may model problem-solving skills, but students do not engage with these skills, and therefore do not have opportunities to develop them.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

A.1.3 Creativity

Exemplary	Developing	Basic	Undeveloped
Students have multiple opportunities to approach problems from many different perspectives, including their own. Novel approaches or solutions are explicitly valued. Activities promote exploration of varied approaches to a task, allowing students to devise their own path. Teacher and/or student supports are included to facilitate synthesis of activity outcomes and reflection upon the value of novel and innovative approaches and solutions. Materials encourage students to develop work products (e.g., explanations, representations, presentations) that express their perspectives or approaches to activities.	Students have opportunities to approach problems from different perspectives and are encouraged to generate and adopt novel, innovative approaches. Teacher and/or student supports are included to facilitate synthesis of activity outcomes and reflection on the value of novel and innovative approaches and solutions. Materials encourage students to develop work products (e.g., explanations, representations, presentations) that express their perspectives or approaches to activities.	Activities do not explicitly present opportunities for students to approach problems from different perspectives; however, materials encourage students to develop work products (e.g., explan-ations, representations, presentations) that express their perspectives or approaches.	Students do not have opportunities to approach problems from different perspectives.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

A.1.4 Communication

Exemplary	Developing	Basic	Undeveloped
Students have frequent and varied opportunities to practice and demonstrate their ability to communicate clearly, accurately, and/or persuasively about STEM topics to multiple audiences, both formal and informal. Students frequently use multi-modal methods, such as drawings, images, visual representations, and models, to convey ideas. Communication is integral to instructional activities and goals. Supports are provided to facilitate teacher and student discussion and reasoning about forms and purposes of communication in STEM, as well as evaluation of their own and others' communication skills.	Students have periodic opportunities to practice and demonstrate their ability to communicate clearly, accurately, and/or persuasively about STEM topics. Activities do not require students to address multiple audiences or use multi-modal methods to convey ideas. Communication is a component of some instructional activities.	Students have occasional opportunities to practice and demonstrate their ability to communicate clearly, accurately, and/or persuasively about STEM topics. Activities do not require students to address multiple audiences or use multi-modal methods to convey ideas. Communication is a component of select instructional activities (e.g., capstone activities only).	Students do not have opportunities to practice or demonstrate their ability to communicate clearly, accurately, and/or persuasively about STEM topics.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

A.1.5 Collaboration

Exemplary	Developing	Basic	Undeveloped
Students have frequent opportunities to engage in group work. Teacher and/or student supports are included to help students work together to plan, organize, and execute activities. Activities are structured to support co-construction of knowledge and work products (e.g., students are assigned roles within groups so that each student can contribute).	Students have periodic opportunities to engage in group work. Teacher and/or student supports are included to help students work together to plan, organize, and execute activities. Activities do not explicitly support co-construction of knowledge or work products (e.g., roles are not defined for students; most subtasks can be completed independently).	Students have occasional opportunities to engage in group work; however, supports to help students work together to plan, organize, and execute activities are not provided. Activities do not explicitly support co-construction of knowledge or work products (e.g., roles are not defined for students; most subtasks can be completed independently).	Students do not have opportunities to engage in group work.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

A.1.6 Data Literacy

Exemplary	Developing	Basic	Undeveloped
Activities require students to engage with qualitative and quantitative data as part of analytical tasks such as problem solving, investigation, and design. Materials provide teacher and student guidance for data-related activities, including technical support for use of necessary tools or technology. Materials support student reasoning about data generation, analysis, representation, and interpretation, as well as appropriate and ethical uses of data and data methods in various contexts.	Activities require students to engage with qualitative and quantitative data as part of analytical tasks such as problem solving, investigation, and design. Materials provide teacher and student guidance for data-related activities, including technical support for use of necessary tools or technology.	Activities provide opportunities for students to engage with qualitative and/or quantitative data.	Activities do not provide opportunities for students to engage with qualitative or quantitative data.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

A.1.7 Digital Literacy & Computer Science

Exemplary	Developing	Basic	Undeveloped
Computer science concepts are integrated into STEM content when appropriate (e.g., as part of problem solving, critical thinking, and logic-based reasoning). When technology tools are used, appropriate teacher and student supports are provided to equip students with the digital literacy skills needed to use the tools.	Computer science concepts are presented, but are not integrated into STEM content. When technology tools are used, appropriate teacher and student supports are provided to equip students with the digital literacy skills needed to use the tools.	When technology tools are used, appropriate teacher and student supports are provided to equip students with the digital literacy skills needed to use the tools.	Digital literacy and computer science concepts are not introduced.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

A.2 Supporting Attributes

A.2.1 STEM Mindset

Exemplary	Developing	Basic	Undeveloped
Students are encouraged to approach problems with an open mind, consider a range of solutions, seek innovation, and express their ideas in a variety of modes. Students are encouraged to investigate questions objectively by generating and testing hypotheses, and by collecting and analyzing evidence to support claims. Activities are designed to promote students' curiosity and flexibility across situations by providing many types of projects and problem scenarios. Supports are provided to facilitate teacher and student discussion and reasoning about STEM epistemologies (e.g., empiricism, design thinking, mathematical proof) and productive STEM dispositions (e.g., curiosity, objectivity, flexibility).	Students are encouraged to approach problems with an open mind, consider a range of solutions, seek innovation, and express their ideas in a variety of modes. Students are encouraged to investigate questions objectively by generating and testing hypotheses, and by collecting and analyzing evidence to support claims. Activities are not explicitly designed to promote curiosity and flexibility.	Students have opportunities to investigate questions objectively by generating and testing hypotheses, and by collecting and analyzing evidence to support claims. Activities are not designed to promote open-minded exploration, innovation, curiosity, and flexibility.	Activities are not designed to promote objectivity, open-minded exploration, innovation, curiosity, and flexibility.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

Global STEM Alliance
The New York Academy of Sciences

A.2.2 Agency & Persistence

Exemplary	Developing	Basic	Undeveloped
Activities are designed to allow adequate time for student-directed exploration of problem-solving approaches, setbacks, and adoption of new approaches as obstacles are encountered. Failure is treated as an opportunity to learn and troubleshoot. Failure to find a complete or satisfactory solution to a problem does not adversely affect students' grades or standing. Supports are included to assist teachers in facilitating student-driven exploration and providing feedback to students when they experience failure or frustration.	Activities are designed to allow adequate time for student-directed exploration of problem-solving approaches, setbacks, and adoption of new approaches as obstacles are encountered. Failure is treated as an opportunity to learn and troubleshoot. Failure to find a complete or satisfactory solution to a problem does not adversely affect students' grades or standing.	Minimal time is allotted for student-directed exploration of problem-solving approaches. Failure is treated as an opportunity to learn and troubleshoot. Failure to find a complete or satisfactory solution to a problem does not adversely affect students' grades or standing.	The value of student setbacks is not explicitly addressed or supported.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

A.2.3 Social & Cultural Awareness

Exemplary	Developing	Basic	Undeveloped
Materials introduce multiple cultural perspectives and address the value of social and cultural awareness, sensitivity, and empathy in STEM professional work and in society, especially as related to global citizenship and global STEM challenges. Materials link directly to the social studies curriculum as appropriate. Supports are provided to help teachers facilitate class discussions about empathy and sensitivity, and identify opportunities to raise issues of social and cultural awareness beyond those in the materials (e.g., selecting a diverse group of STEM experts to interact with students).	Materials introduce multiple cultural perspectives and address the value of social and cultural awareness, sensitivity, and empathy in STEM professional work and in society, especially as related to global citizenship and global STEM challenges. Materials link directly to the social studies curriculum as appropriate.	Materials introduce multiple cultural perspectives and address the value of social and cultural awareness, sensitivity, and empathy in STEM professional work and in society, especially as related to global citizenship and global STEM challenges.	Materials do not introduce multiple cultural perspectives or address the value of social and cultural awareness, sensitivity, and empathy in STEM professional work and society. Materials may express negative attitudes toward other cultures and/or social groups.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

A.2.4 Leadership

Exemplary	Developing	Basic	Undeveloped
Students have opportunities to take leadership roles and practice leadership skills. Skills such as taking initiative, building consensus, and communicating effectively in groups are practiced and evaluated. Materials include guidance for teachers to organize groups, assign leadership roles, offer students feedback about their leadership skills, and facilitate discussions about leadership.	Students have opportunities to take leadership roles and practice leadership skills. Skills such as taking initiative, building consensus, and communicating effectively in groups are practiced and evaluated.	Students have opportunities to take leadership roles and practice leadership skills.	Leadership roles and skills are not explicitly addressed, and students have few or no opportunities to take leadership roles or practice leadership skills.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

A.2.5 Ethics

Exemplary	Developing	Basic	Undeveloped
Materials introduce students to the notion of ethics as part of STEM professional work and its application. Materials prompt students to consider ethics in their approach to their work, and by recognizing diverse perspectives and viewpoints. Supports are provided to help teachers facilitate discussions about ethics in students' work and in STEM professional work.	Materials introduce students to the notion of ethics as part of STEM professional work and its application. Materials prompt students to consider ethics in their approach to their work, and by recognizing diverse perspectives and viewpoints.	Materials introduce students to the notion of ethics as part of STEM professional work and its application.	Ethics are not addressed in materials or activities.

Is this a stated learning outcome? ______ Yes ______ No **Rating:** E / D / B / U

Notes:

Part B: Instructional Design

B.1 Research-based Pedagogy

Exemplary	Developing	Basic	Undeveloped
Materials are well aligned to current research, and alignment is clearly documented. Comprehensive materials, tools, and/or guidance are provided to support identified pedagogical strategies.	Materials leverage known research-based strategies. Though strategies are not explicitly aligned, they are identifiable in the design of activities. Sufficient materials, tools, and/or guidance are provided to support identified pedagogical strategies.	Materials minimally leverage research-based strategies. Though strategies are not explicitly aligned, they are identifi-able in the design of activities.	Materials do not obviously leverage research-based strategies.

Rating: E / D / B / U

Notes:

B.2 STEM Content Integration

Exemplary	Developing	Basic	Undeveloped
To the extent possible and strategic, STEM content is presented in an integrated, multidisciplinary approach in which students have multiple opportunities to apply STEM skills and knowledge in the context of STEM activities, problems, and/or practices (e.g., modeling, argumentation). Alignment of STEM content to relevant policy initiatives (e.g., local or national economic development efforts and workforce needs) and instructional frameworks (e.g., grade-level standards) is clear and documented.	At some opportunities, STEM content is presented in an integrated, multidisciplinary approach. Alignment of STEM content to relevant policy initiatives (e.g., local or national economic development efforts and workforce needs) and instructional frameworks (e.g., grade-level standards) is apparent but not documented.	Primary STEM content is related to other disciplines, but is not presented in an integrated, multidisciplin-ary approach. STEM content is partially aligned to relevant policy initiatives (e.g., local or national economic development efforts and workforce needs) and instructional frameworks (e.g., grade-level standards).	STEM content is not presented in an integrated, multidisciplinary approach. STEM content is not well aligned to relevant policy initiatives (e.g., local or national economic development efforts and workforce needs) or instructional frameworks (e.g., grade-level standards).

Rating: E / D / B / U

Notes:

B.3 Real-world Application

Exemplary	Developing	Basic	Undeveloped
Content is embedded in scenarios that relate to problems or challenges students are likely to encounter outside of school at some time in their lives. Relationships between instructional content and real-world application are made explicit to students. Supports for the identification and use of scenarios related to challenges or activities of local or regional STEM industries are provided to teachers.	Content is embedded in scenarios that relate to problems or challenges students are likely to encounter outside of school at some time in their lives. Relationships between instructional content and real-world application are made explicit to students.	Content is related to real-world scenarios; however, scenarios may not relate to students' experiences, and no rationale for their selection is provided.	Content is not embedded in or related to real-world scenarios.

Rating: E / D / B / U

Notes:

B.4 Project- or Problem-based Learning

Exemplary	Developing	Basic	Undeveloped
Projects or problem-based activities vary in length and complexity, and are used throughout the curriculum. Students have multiple opportunities to work collaboratively to identify a problem, identify and implement one or more solutions, and present their work to various stakeholders. Supports are provided for teachers to help students identify problem contexts that impact their school or community.	Projects or problem-based activities occur regularly throughout the curriculum (e.g., as recurring capstone activities, or as long-term activities coordinated with other instructional activities). Project or problem contexts may be predetermined, but students have opportunities to identify solutions or strategies.	Projects or problem-based activities are presented as special opportunities for students (i.e., not part of typical instruction). Project or problem contexts and solution strategies are predetermined.	Projects or problem-based activities are not provided.

Rating: E / D / B / U

Notes:

B.5 Scaffolding

Exemplary	Developing	Basic	Undeveloped
Materials provide clear guidance for teachers, or embedded student supports, to scaffold instruction and move students progressively toward deeper understanding and greater independence in the learning process. A variety of instructional techniques are presented to support teachers in scaffolding students of varying abilities and backgrounds. There are clear milestones to reach, multiple techniques for achieving the same milestone, and strategies to remove scaffolding as milestones are achieved.	Materials include embedded student supports and/or guidance for teachers to scaffold instruction. Instructional techniques are presented, but they do not include strategies to support students of varying abilities or backgrounds.	Materials include minimal student supports and/or guidance for teachers to scaffold instruction (e.g., only one approach may be suggested). The concept of scaffolding may be inferred, but explicit approaches are not presented.	Materials do not include embedded student supports or guidance for teachers to scaffold instruction.

Rating: E / D / B / U

Notes:

B.6 Assessment

Exemplary	Developing	Basic	Undeveloped
Materials and opportunities for formative and summative assessments are provided. Assessments align to learning objectives, and include a variety of formats as appropriate. Assessments include necessary scoring materials, guidance about using outcomes to make data-driven decisions, and pedagogical strategies to address conceptual challenges identified by assessments.	Materials and opportunities for formative and summative assessments are provided. Assessments align to learning objectives, and include a variety of formats as appropriate. Strategies for interpreting assessment results are limited to scoring rubrics.	Materials and opportunities for formative and/or summative assessments are provided, but are limited in scope and/or format. Assessments align to learning objectives. Strategies for interpreting assessment results are limited to scoring rubrics.	Assessment materials are not provided or do not align to learning objectives.

Rating: E / D / B / U

Notes:

B.7 Cultural Sensitivity & Relevance

Exemplary	Developing	Basic	Undeveloped
Content is situated within a range of diverse historical, cultural, and political contexts, referencing social studies standards as appropriate. The role of historical, cultural, and political context in current and past STEM work is discussed. Activities, teacher materials, and supports consistently value multiple cultural perspectives. Teacher supports include guidance to lead student discussions and activities to acknowledge and value the backgrounds, cultures, and experiences of others.	The role of historical, cultural, and political context in current and past STEM work is discussed. Activities, teacher materials, and supports consistently value multiple cultural perspectives. Teacher supports include guidance to lead student discussions and activities to acknowledge and value the backgrounds, cultures, and experiences of others.	The role of historical, cultural, and political context in current and past STEM work is discussed. Activities, teacher materials, and supports consistently value multiple cultural perspectives.	Materials do not situate content in diverse historical, cultural, or political contexts. Support for recognizing and valuing diverse perspectives and experiences is not provided.

Rating: E / D / B / U

Notes:

B.8 Technology Integration

Exemplary	Developing	Basic	Undeveloped
Students use technology as a tool throughout the curriculum. Technology is used to support student learning, enable a broad range of activities, and enhance collaboration. Activities take advantage of how students use technology outside of school, and encourage teachers and students to use technology in novel ways. Teacher and student supports include guidance and training in the use and benefits of technologies.	Students use technology as a tool through-out the curriculum. Technology is used to support student learning, enable a broad range of activities, and enhance collaboration. Teacher and student supports include guidance and training in the use and benefits of technologies.	Technology is used to support student learning and/or collaboration.	Technology is rarely or never used, and does not enhance the curriculum.

Rating: E / D / B / U

Notes:

Part C: Implementation

C.1 Accessibility

Exemplary	Developing	Basic	Undeveloped
Activities are designed to engage learners with diverse backgrounds, abilities, and experiences. All materials and supports adhere to Universal Design for Learning principles to meet students' and teachers' diverse needs. Teacher supports present a variety of strategies to address students' diverse needs, including use of multiple means of representation, expression, and engagement.	Activities are designed to engage learners with diverse backgrounds, abilities, and experiences. Teacher supports present a variety of strategies to address students' diverse needs, including use of multiple means of representation, expression, and engagement.	Activities are designed to engage learners with diverse backgrounds, abilities, and experiences.	There is no evidence that accessibility issues have been considered in the design of materials.

Rating: E / D / B / U

Notes:

C.2 Alignment to Local Contexts

Exemplary	Developing	Basic	Undeveloped
All materials are designed to be adapted by stakeholders to align to their instructional context (e.g., local or national education policies, assessment goals, and accountability frameworks). Supports for this adaptation are provided (e.g., content is aligned to an instructional framework that is relevant across regions or a set of frameworks that represent a range of approaches internationally). All materials are designed to be adapted by stakeholders to align to their socio-cultural context. Supports for this adaptation are provided (e.g., problem-based scenarios include a range of industry or agricultural contexts that may be selected based on local economies).	Some materials are designed to be adapted by stakeholders to align to their instructional and/or socio-cultural context. Supports for this adaptation are provided.	Materials include examples of adaptations to local instructional and/or socio-cultural contexts, but no supports are provided to stakeholders to facilitate adaptation.	Materials are not designed to be adapted by stakeholders to align to local contexts.

Rating: E / D / B / U

Notes:

C.3 Professional Development & Learning Supports

Exemplary	Developing	Basic	Undeveloped
Supports are provided for both teachers and school leaders, including substantial opportunities to prepare prior to implementation; ongoing, individualized support for planning and reflection; and coaching, mentoring, or collaboration throughout implementation. Professional development interactively engages teachers with lesson content, pedagogy, and sample student discussions and/or student work via opportunities to observe or rehearse future lessons.	Professional development resources address both content and pedagogy. Professional development primarily occurs prior to implementation. During implementation, teachers have occasional access to professional learning communities in their region or online.	Professional development resources address both content and pedagogy. Professional development primarily occurs prior to implementation.	No professional development resources are provided.

Rating: E / D / B / U

Notes:

C.4 Evidence of Effectiveness

Exemplary	Developing	Basic	Undeveloped
Evidence of effectiveness, gathered via rigorous evaluation methods, is made available and accessible to all stakeholders. Supports are available for ongoing data collection and analysis to measure impact and support data-driven decision making.	Evidence of effectiveness in the form of a research study is available.	Positive user reviews are available.	No evidence of effectiveness is available.

Rating: E / D / B / U

Notes:

C.5 Access to Materials & Practitioner Support

Exemplary	Developing	Basic	Undeveloped
There are no significant barriers to stakeholders' engagement with materials as designed. Any localization of materials needed is easy and not cost-prohibitive. Access to user support is not restricted by time of day or stake-holders' location, language, budget, or technology expertise. Limitations on stakeholders' access to technology (e.g., slow Internet speeds) are addressed to the extent possible (e.g., option to download materials as small, individual files). Any technology requirements are well documented and easily accessible.	Although access to materials and support may be constrained (e.g, by time, language, location, or format), resources are sufficient for all stakeholders to participate as intended. Limitations on stakeholders' access to technology (e.g., slow Internet speeds) are addressed to the extent possible (e.g., option to download materials as small, individual files). Any technology requirements are well documented and accessible.	Access to materials and supports may be intermittent or otherwise insuf-ficient for all stakeholders to participate as intended. Technology requirements may not be well documented.	Access to necessary materials and/or supports is significantly constrained.

Rating: E / D / B / U

Notes:

C.6 Scalability

Exemplary	Developing	Basic	Undeveloped
All materials and supports are delivered online, locally, or through a flexible distribution channel. There is a proven mechanism to scale professional development and learning supports (e.g., train-the-trainer model). Content is reviewed and updated regularly to ensure that examples and real-world applications remain relevant.	All materials and supports are delivered online, locally, or through a flexible distribution channel. Content is reviewed and updated regularly to ensure that examples and real-world applications remain relevant.	Scalability is limited by one or more of the following: format of materials; distribution channel; training or professional development mechanisms; dated or static content.	Scalability is significantly constrained by one or more of the following: format of materials; distribution channel; training or professional development mechanisms; dated or static content.

Rating: E / D / B / U

Notes:

APPENDIX E

REPRINT PERMISSIONS

STEM Education Framework

nyas.org/landing/stem-education-framework-materials/

Get Started Today by Downloading the STEM Education Framework

Download

A Framework for 21st-century STEM Learning

The STEM Education Framework establishes a vision for STEM teaching and learning that prepares students to live and work in the modern world.

- Based on the latest learning science and education research
- Developed by the New York Academy of Sciences, a 200 year-old institution dedicated to advancing scientific research, education, and policy, and SRI Education, a division of SRI International and an established leader in STEM education research, instructional design, implementation, and evaluation
- Reviewed by an international advisory board of education experts

An Open Educational Resource

The STEM Education Framework is a freely available resource to be used by anyone engaged in STEM education—curriculum developers, content providers, teachers, students, parents, school leaders, policymakers, and philanthropists—to ensure that their efforts align to sound pedagogy and best practices. The framework outlines 26 features of quality STEM education in three fundamental areas:

- **Core Competencies:** To what extent are students provided with opportunities to develop essential 21st-century skills?
- **Instructional Design:** To what extent do the materials and/or program design reflect research-based pedagogy and a cohesive system of learning objectives, supports, and assessment resources?
- **Implementation:** To what extent are necessary supports or services available to facilitate distribution and ensure effective implementation?

FAQ: Open Educational Resources

What are Open Educational Resources (OER)?

Open educational resources (OER) are educational materials that are distributed at no cost with legal permission for the public to freely use, share, and build upon the content.

The Hewlett Foundation defines OER as "teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use and re-purposing by others. OER include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge"

How do OER help educators and students?

Open educational resources give educators the ability to adapt instructional resources to the individual needs of their students, to ensure that resources are up-to-date, and to ensure that cost is not a barrier to accessing high-quality standards-aligned resources. OER are already being used across America in K-12, higher education, workforce training, informal learning, and more.

What is the difference between 'free' and 'open' resources?

Open educational resources are and always will be free, but not all free resources are OER. Free resources may be temporarily free or may be restricted from use at some time in the future (including by the addition of fees to access those resources). Moreover, free-but-not-open resources may not be modified, adapted or redistributed without obtaining special permission from the copyright holder.

Are all OER digital?

Like most educational resources these days, most OER start as digital files. But like traditional resources, OER can be made available to students in both digital and printed formats. Of course, digital OER are easier to share, modify, and redistribute, but being digital is not what makes something an OER or not. This flexibility is important, because it no longer makes print and digital a choice of one or the other. OER textbooks, for example, can typically be printed for $5-50 (compared to $100-300 for traditional books) while still being available free digitally.

OECD TABLE REPRINT PERMISSION

Terms and Conditions

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