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# How Middle and High School Principals Provide Culturally Responsive Leadership for Underrepresented Students in Stem: a Qualitative Comparative Case Study

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# HOW MIDDLE AND HIGH SCHOOL PRINCIPALS PROVIDE CULTURALLY RESPONSIVE LEADERSHIP FOR UNDERREPRESENTED STUDENTS IN STEM: A QUALITATIVE COMPARATIVE CASE STUDY

KENNETH JEROME SANDERSON

426 Pages

This study explored how principals who have experienced success in working with underrepresented students in STEM have challenged inequitable practices and transformed the culture of their schools so that all students can thrive. A purposeful sampling strategy was used to identify four principals who served as the cases for the study. The research revealed that culturally responsive school leadership (CRSL) behaviors and practices were regularly used by the principals to provide a STEM program that was responsive to the needs of underrepresented students. The principals in the study formed a critical consciousness by engaging in self-reflection about their leadership practices and displaying courageous leadership when confronted by attitudes, behaviors, and mandates that compromised the ability of their schools to provide high quality STEM instruction for all students. The principals engaged marginalized students by fostering positive relationships with students, providing students with voice, maintaining high expectations for all students, and securing a culturally responsive curriculum. The principals empowered community involvement in their schools by developing strategic partnerships, enlisting STEM role models and mentors for minoritized students, and fostering meaningful relationships with parents and community members. The principals developed a culturally responsive teaching staff in their schools by hiring for mission, leveraging professional

development, encouraging teachers to reflect on their attitudes and practices, and promoting an equitable and inclusive school environment. The findings from this study suggest that culturally responsive school leadership (CRSL) is efficacious for increasing the interest, persistence, and success of students who have been minoritized in STEM.

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QUALITATIVE COMPARATIVE CASE STUDY

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*I can do all things through Him who strengthens me.*

Philippians 4:13

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K. J. S.

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CHAPTER I: INTRODUCTION

In a competitive global marketplace which craves technological innovation, the science, technology, engineering, and mathematics (STEM) fields are critical to American economic prosperity (National Science Board [NSB], 2016; Xie & Killewald, 2012). In the United States, STEM employment has grown at six times the rate of non-STEM jobs over the past decade (Noonan, 2017), and above-average growth is expected for the STEM sector in the foreseeable future (Fayer et al., 2017). In addition, continued excellence in the STEM fields is considered essential to national defense (National Academy of Sciences [NAS], 2007; U.S. Commission on National Security/21st Century, 2001). Consequently, STEM education has become a focal point for both funding and reform. There is growing pressure on schools to foster scientific and technical expertise among their students.

**Statement of the Problem**

Females and students of color are historically underrepresented in the STEM fields. Increasing the participation and success of students who have been minoritized in STEM is critically important for enriching our nation's technical talent pool and expanding the diversity of insight, perspectives, and creative ideas necessary for driving innovation and problem-solving in America (Egan, 2011; Kilmartin & Pimentel, 2014). Unfortunately, far too many females and students of color drop out of the STEM pipeline during their middle and high school years (Hayden et al., 2011; Kelly & Zhang, 2016). School leaders have a moral obligation to address this problem and create schools with the capacity to help all students thrive. However, little is known about the salient leadership practices for implementing a STEM program that increases the interest, persistence, and success of minoritized students (Kilmartin & Pimentel, 2014; Sampson, 2018; Winn, 2016). Therefore, the problem under investigation in this study was how

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middle and high school principals can provide leadership that is responsive to the needs of

underrepresented students in STEM.

While STEM is essential to America's economic prosperity and national security,

participation in STEM has been dominated by white males (Ong et al., 2018; Riegle-Crumb &

King, 2010). Women and racial or ethnic minoritized groups such as African Americans,

Latinos, and Native Americans are notably underrepresented in the STEM workforce (Grossman

& Porche, 2014; Holdren et al., 2010; Ong et al., 2018; Tsui, 2007; Xu, 2013). For example, the

number of underrepresented minorities (URMs)[1] in STEM would need to increase threefold to

match their representation in the general population (Schneider et al., 2012). Underrepresented

groups in STEM constitute an "underused resource and a lost opportunity for meeting our

nation's technology needs" (NAS, 2011, p. 2).

Due to America's "ethnoracial diversity, challenging disparities in STEM participation

and completion rates is a critical objective" (Baber, 2015, p. 252). Increasing diversity in STEM

education and careers is imperative for expanding our technical talent pool and enhancing

innovation and research (NAS, 2011). With the average salary for STEM careers being almost

double the national average for all occupations (Fayer et al., 2017), the lack of women and

people of color in the STEM pipeline "perpetuates entrenched economic and social inequities"

(Stearns et al., 2016, p. 87) and limits their access and participation in more highly paid STEM

jobs.

Women are notably underrepresented in the STEM fields (Blickenstaff, 2005; Farinde &

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[1] The term underrepresented minorities (URMs) is offensive to many. It defines people negatively, insinuating that they are lacking something that would place them in the majority. In addition, in many parts of the U.S., people of color are not a numerical minority. Nevertheless, underrepresented minorities (URMs) is the standard term used by contemporary STEM scholars, including scholars of color, to refer to African Americans, Latinos, and Native Americans – groups who have been historically underrepresented in STEM.

Lewis, 2012). Although they make up half of the college-educated labor force, only 28% of

STEM jobs are held by women (NSB, 2018). Women are also underpaid in STEM occupations

compared to their male counterparts (Corbett & Hill, 2015). According to recent science and

engineering occupational data, women comprise 15% of engineers and 24% of those employed

in computer science in the United States (NSB, 2018). "Engineering is the most sex-segregated

nonmilitary profession in the United States" (Cech et al., 2011, p. 643), with women representing

just 8% of all mechanical and electrical engineers and 6% of the nation's petroleum engineers

(Corbett & Hill, 2015).

Despite recent gains in the health sciences, the overall trend for women in STEM has not

been encouraging. Women are substantially underrepresented in computer science and physics

(Halpern et al., 2007; Perez-Felkner et al., 2012; Xie et al., 2015). Corbett & Hill (2015) report

that "women's representation in computing declined from just over a third of workers in 1990 to

just over a quarter in 2013" (p. 8). Koput and Gutek (2010) affirm that "over a relatively short

period of time, a field [information technology] that was once relatively gender integrated has

become solidly male dominated" (p. 103). Although females constitute almost 40% of web

developers, just 7% of computer network architects are women (Corbett & Hill, 2015).

African Americans, Latinos, and Native Americans have also been historically

underrepresented in STEM. URMs make up 11% of workers in the STEM fields despite

representing 27% of the total U.S. population age 21 and above (NSB, 2018). Minoritized groups

are particularly underrepresented in engineering. African American men make up 4% of

America's engineering workforce, Latinos 5%, and Native Americans 0.2% (Corbett & Hill,

2015). Meanwhile, Latinas and African American women comprise just 1% of U.S. engineers

(Corbett & Hill, 2015). URMs also experience higher rates of unemployment in engineering than

their white counterparts and are more likely to hold part-time engineering positions (Fouad & Santana, 2017).

Based on data from the High School Longitudinal Study, when African American and Latino students enter high school, they are as likely to foresee themselves working in a STEM career as their white and Asian classmates (Alvarado & Muniz, 2018). For many of these students, however, their dream of a successful STEM career goes unfulfilled. Just 13.2% of African Americans, 15.9% of Latinos, and 14.9% of Native Americans who aspire to a STEM bachelor's degree earn their credential in four years (Ghosh-Dastidar & Liou-Mark, 2014). Such students are unlikely to be taught by a member of their race or ethnicity, as less than 5% of fulltime professors at research universities who hold a doctorate in a STEM field are members of an underrepresented group (National Science Foundation [NSF], 2015). Native Americans earn 0.63% of STEM bachelor degrees and 0.48% of STEM doctorates, revealing that they are "60% underrepresented at the college level and 67% underrepresented at the doctoral level" (Bang & Medin, 2010, p. 1012).

The obstacles along the STEM pipeline are especially pronounced for women of color due to a phenomenon known as the double bind (Ong et al., 2011). Women of color must "negotiate both race and gender discrimination, as well as bias among school personnel to succeed in school" (Archer-Banks & Behar-Horenstein, 2012, p. 200). A greater percentage of women of color intend to major in science or engineering in college than white females (Malcom & Malcom, 2011). Yet at multiple points along the STEM pathway, women abandon this pursuit. The double bind is painfully evident at the STEM doctoral level. As reported by Ong et al. (2011), white women receive 32.81% of STEM doctoral degrees, a level consistent with their representation in the general population, which is 33.24%. In contrast, African American women

make up 6.01% of the population, but earn 2.61% of STEM doctorates. Hispanic women are 6.86% of the population and receive 2.53% of STEM doctoral degrees. Native American women represent 0.43% of the population and garner 0.14% of STEM doctorates (Ong et al., 2011). Fewer still are employed in STEM, as African American, Latina, and Native American women comprise less than 2% of those employed with STEM doctorates (Johnson, 2007).

The double bind is especially evident in computer science. Women of color make up 20% of the general population, but only 4% of the computing workforce (Scott et al., 2017). Additionally, only 2.1% of doctorates in computer science are awarded to women from minoritized groups (Payton et al., 2015). Participation in computing is particularly problematic for Latinas and Native American women. Although women comprise 25% of computer personnel, Latinas make up just 1% of the computing workforce (Payton et al., 2015). A total of 63 bachelor's degrees in computer science were conferred upon Native American women in 2007 (Hill et al., 2010); the number of Native American women earning bachelor's degrees in computer science fell to 57 by 2014 (NSF, 2017). There are no Native American women among the computer science tenure track faculty at the nation's top 100 research universities, and just 5 Latinas hold tenure track positions in computer science (Towns, 2010).

More than half of students who begin college intending to major in STEM leave for other degree programs (NAS, 2007). Those who leave the STEM pipeline are "disproportionately women and students of color" (NAS, 2007, p. 99). This trend is highly problematic for several reasons. First, it perpetuates economic injustice (Stearns et al., 2016). STEM graduates earn at least $700,000 more over their careers than graduates with degrees in liberal arts or social science (Kim et al., 2015). Consequently, when women and people of color leave the STEM

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pipeline, it maintains the gender wage gap and the cycle of poverty[2]. The underrepresentation of women and URMs in STEM also jeopardizes the future integrity of America's STEM workforce. According to Museus et al. (2011), racial and ethnic minoritized groups are projected to represent over 50% of the U.S. population by 2050. Unless steps are taken now to improve the persistence of women and people of color in STEM, there will be critical shortages of qualified workers in America's STEM labor force in the years ahead. There are already shortages of qualified STEM workers to fill job openings in America's largest metropolitan areas, which have significant minoritized populations (Byars-Winston, 2014). The underrepresentation of women and minoritized groups in STEM also impedes technological advancement. Bell et al. (2017) assert that "if women, minorities, and children from low-income families were to invent at the same rate as white men from high-income families, the rate of innovation in the economy would quadruple" (p. 16).

### Purpose of the Study

The purpose of this study was to look at principals who have experienced success in working with underrepresented students in STEM to learn how they challenge inequitable practices and work to transform the climate and culture of their schools so that all students can thrive. Culturally responsive school leadership (CRSL) served as the theoretical lens to guide the study. All too often, women and people of color do not have access to robust STEM instruction and are shut out of opportunities in the STEM fields (Blickenstaff, 2005; Delaney & Lee, 2016; Flores, 2007; Gándara, 2006; Kuncel & Hezlett, 2007; Reuben et al., 2014; Martin, 2009; Moss-

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[2] The term "cycle of poverty" can be problematic since some people equate it with the myth of a culture of poverty – the belief that poor people share certain behaviors and values which contribute to their poverty, such as a weak work ethic or little interest in their children's education. However, the term "cycle of poverty" as used in this paper refers to the social, political and structural issues that lead to generational poverty including inequitable access to quality schools and workplace discrimination.

Racusin et al., 2012; Museus et al., 2011; NSB, 2010; NSB, 2018). School leaders therefore have a moral obligation "to transform schools from being sorting mechanisms in the larger global market—where people of color, women, and the disenfranchised are prepared to fit a particular role in society" (López, 2003, p. 71).

While leadership is a key attribute in schools that have improved student learning outcomes in STEM (Honey et al., 2014), research regarding how principals provide leadership in specific content areas such as math and science is limited (Lochmiller et al., 2012). Davis (2015) confirms that "although there is a large volume of research literature on effective educational leadership practices in general, there is not a great quantity of research specifically focused on leadership in relation to STEM education" (p. 3). Kilmartin and Pimentel (2014) add that school "leadership can influence minority students and women in STEM career fields and has yet to be investigated in depth to determine best practices" (p. 50). Sampson (2018) attests that little is known about how principals' "leadership styles influence decisions of equity in addressing underrepresentation of women, and specifically women of color, in STEM fields" (p. 14). Winn (2016) posits, "Future research that considers racial and cultural differences within the realm of STEM instructional leadership practices and self-efficacy would contribute substantiality to the field" (p. 124).

Scholarship in the area of STEM leadership is largely silent regarding how principals cultivate institutional commitment to serve the needs of underrepresented groups in STEM and the problems and challenges they face in doing so. What are the salient leadership practices for implementing a STEM program that is responsive to the needs of underrepresented students? Are culturally responsive leadership practices efficacious for developing a school climate and culture that fosters the participation of underrepresented groups? The present study responded to this gap

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in the literature by exploring the behaviors, skills, and practices employed by school administrators to address the needs of females and students of color in STEM. Principals who have been successful in providing STEM leadership to underrepresented students provide valuable insights that can contribute to the leadership capacity of other principals who seek to eliminate barriers for URMs and create schools that are socially just.

<div align="center">

**Research Questions**

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The following research questions were developed to guide the design of the study:

1. What problems or challenges do principals encounter in addressing the needs of underrepresented students in STEM?

2. What are the culturally responsive leadership behaviors and practices principals employ when implementing a STEM program that is responsive to the needs of underrepresented students?

3. What strategies are used by principals to increase the interest and persistence of underrepresented students in STEM?

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**Relationship of the Study to Personal Background and Experiences**

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One of my earliest memories of school is when I started first grade. About a week into the school year, Ms. Cissna introduced two new classmates from Mexico. One of the girls did not speak English (and said nothing at all), while the other student knew only a few words of English, doing her best to translate for her friend. As the weeks went by, it was apparent that my new classmates were not receiving the academic and social supports they needed to be successful. Since I was excelling academically, Ms. Cissna assigned me to help my new Latina friends with reading and math—a role for which I felt helplessly inadequate. Nevertheless, I tried my best to assist them. Then one morning, I came to school and the girls were gone. They were

not at school the next day or the day after as well. When I finally gathered my courage and asked Ms. Cissna how they were doing, she politely informed me that their parents were migrant farm workers and they had moved on to their next job. I asked her when I would see them again, and she told me they would not be back. I still wonder what became of my Latina friends. Did they eventually find a school that was able to meet their learning needs? Did they succeed in school?

I have been a Catholic school educator throughout my professional career, serving first as a classroom teacher, later as a school principal, and now as an assistant superintendent in a central office responsible for more than 40 elementary and high schools. The word "catholic" means universal, so in its fullest sense, a Catholic education is one that strives to meet the needs of all students. Yet my personal and professional experiences have revealed that too many children fall through the cracks of society due to poverty, lack of confidence, prejudice, indifference, stereotypes, and/or a lack of cultural congruence in their education. As a Catholic educator, I have a moral responsibility to address these issues.

God has blessed me with four children—a son and three daughters. My son has a successful career in engineering while none of my daughters have pursued a STEM career. Is this merely a coincidence? Or did their education inadvertently shape their interests and abilities? It is my hope that this study will provide insight and guidance for school leaders who want to fix the leaky pipeline and help girls and students of color realize their God-given aspirations and talents in science, technology, engineering, and mathematics.

**Type of Study**

A qualitative comparative case study design was utilized to examine the leadership practices, behaviors, and strategies employed by principals who have provided exemplary leadership when working with underrepresented students in STEM. A case study is defined as

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"the study of an issue explored through one or more cases within a bounded system (i.e., a setting, a context)" (Creswell, 2007, p. 73). The case study method is commonly employed when the researcher wants to understand "the experiences and perceptions of participants" (Mabry, 2008, p. 215). Data in the present study was collected from multiple sources including semi-structured interviews and documents and artifacts relevant to each case.

Comparative case studies are also known as multisite, cross-case, multicase, or collective case studies (Merriam, 2009). A comparative case study "involves collecting and analyzing data from several cases" (Merriam, 2009, p. 49) in order to identify common themes within each case and across cases (Creswell, 2014). I selected a comparative case study approach for this research because I wanted to explore and compare the leadership practices, experiences, and behaviors of principals who have successfully led schools that are responsive to the needs of underrepresented students. A comparative case study approach helped me identify the common leadership traits and strategies of principals working in a variety of sites—such as public middle schools, high schools, STEM academies and/or magnet schools—to gain insight into effective leadership when working with females and other minoritized students in STEM.

**Significance of the Study**

America's national defense and economic success in the global marketplace is more dependent than ever before upon excellence in STEM (NSB, 2016; NAS, 2007). However, too many female and minoritized students drop out of the STEM pipeline at an early age and are underrepresented in STEM at the postsecondary and career levels (Griffith, 2010; Grossman & Porche, 2014; NAS, 2007; Xu, 2013), often due to bias, discrimination, or stereotype threat (Crasnow, 2004; Lane et al., 2012; Museus et al., 2011). With females comprising half of our nation's student population and students of color projected to represent over 50% of America's

students by 2023 (Linley & George-Jackson, 2013), the disparity of access to STEM knowledge and careers by female students and URMs perpetuates the cycle of poverty and threatens our nation's future prosperity and security. Therefore, it is imperative for schools to prepare all students to experience success and develop confidence in the STEM disciplines.

This study examined the culturally responsive leadership behaviors and practices that principals employ to address the underrepresentation of girls and students of color in STEM. This is particularly important because while leadership is a key attribute in schools that have improved STEM learning outcomes (Honey et al., 2014), little is known about how principals foster an environment that enhances the equity and participation of underrepresented students in STEM (Sampson, 2018; Winn, 2016). This study is significant because it gathered data that contributes to the body of research regarding the leadership attributes of school principals that are responsive to the needs of underrepresented students in STEM. This study provides practical guidance for current principals regarding the specific leadership practices they can employ to promote the participation and success of female students and URMs. The study is also valuable for higher education institutions and professional development providers because it helps identify the culturally responsive practices that should be included in principal preparation and continuing education programs to empower principals to transform the future for girls and students of color in the STEM fields.

## Theoretical Framework

A theoretical lens guides "how things are observed and interpreted . . . because real-world phenomena are simply too rich and complex to study without a huge amount of filtering" (Easterbrook et al., 2008, p. 293). The theoretical lens underlying this study is culturally responsive school leadership (CRSL). CRSL is an outgrowth of earlier research on culturally

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relevant pedagogy (Ladson-Billings, 1995, 2006) and culturally responsive teaching (Gay, 2010). Khalifa et al. (2016) define CRSL as "the ability of school leaders to create school contexts and curriculum that responds effectively to the educational, social, political, and cultural needs of students" (p. 1278). Culturally responsive leaders foster an inclusive school climate for students who have been marginalized due to "their nondominant race, ethnicity, religion, language, or citizenship" (Khalifa et al., 2016, p. 1275). Principals are in the best position to promote a culturally responsive school culture (Khalifa, 2013). Therefore, CRSL provides a compelling lens for researching how principals foster a school culture that supports diversity in general and STEM learning for underrepresented students in particular. Further information about CRSL is presented in Chapter II.

## Definition of Terms

The following terms are used in this study. Brief definitions are provided to assist the reader with clarity of meaning and/or to provide greater context.

*Culturally Relevant Pedagogy:* pedagogical practices that help children "accept and affirm their cultural identity while developing critical perspectives that challenge inequities that schools (and other institutions) perpetuate" (Ladson-Billings, 1995, p. 469).

*Culturally Responsive School Leadership (CRSL):* "the ability of school leaders to create school contexts and curriculum that responds effectively to the educational, social, political, and cultural needs of students" (Khalifa et al., 2016, p. 1278).

*Culturally Responsive Teaching:* the teaching methods, strategies, and resources that make a classroom culturally responsive.

*Double Bind:* the challenges that women from underrepresented minoritized groups experience in STEM as they encounter both gender and racial discrimination.

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*Leaky Pipeline:* the tendency for women and URMs to not choose a career in STEM or to leave STEM academic programs or careers at greater rates than their peers.

*Mentor:* a person with experience in a STEM career or profession who forges a direct and ongoing relationship with a student (or group of students) to provide academic support, guidance, advice, and encouragement.

*Minoritized:* people that have been marginalized and rendered minority status in STEM based on their gender (i.e., females) and/or racial/ethnic background (i.e., African Americans, Latinos, Native Americans).

*Role Model:* a person with a background in STEM that students want to emulate.

*Self-efficacy:* confidence that one can complete rigorous coursework and be successful in a STEM career.

*STEM Education:* "a standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study" (Merrill, 2009, as cited in Brown et al., 2011, p. 6).

*STEM Pipeline:* the pathway for students in STEM, beginning in elementary education and continuing through graduation from college and entering the STEM workforce.

*Stereotype Threat:* anxiety about one's abilities due to negative stereotypes.

*Students of Color:* students who are part of a racial or ethnic group that has been historically subjected to prejudice or discrimination.

*Underrepresented Minorities (URMs):* racial and ethnic groups traditionally underrepresented in the STEM fields—African Americans, Latinos, and Native Americans.

## Limitations

This study was limited by the following:

1. I used a purposeful sampling strategy, working with the nonprofit accrediting body Cognia to identify principals from their pool of STEM-certified public middle and high schools who were in the best position to help answer my research questions. This may have contributed to selection bias, as potential study participants whose schools do not hold STEM certification from Cognia were not included.

2. The structured interview questions used in this qualitative case study may not have elicited from study participants some of the salient leadership behaviors and practices that principals employ when implementing a STEM program that is responsive to the needs of underrepresented students.

3. The perceptions of principals who participated in this study may not present an accurate picture of their actual leadership behaviors and practices.

4. Due to the small sample size of this qualitative case study, there was not an opportunity to meaningfully determine the impact of a number of variables which may influence the way principals address the needs of underrepresented students in STEM, such as the principal's race, ethnicity, educational background, and/or years of experience.

5. As a white male, I am not a member of a minoritized population underrepresented in STEM. Therefore, I might have misunderstood, misinterpreted, and/or misrepresented critical leadership factors when working with these students.

6. The qualitative data collected in this study was limited by the subjectivity of my interpretations—my personal biases, opinions, experiences, and world view.

## Delimitations

This study was confined in the following ways:

1. The study investigated the STEM leadership provided by school principals. The focus on principals may have missed some important aspects of leadership when working with underrepresented students in STEM—knowledge which could be gleaned from other school leaders such as superintendents, assistant principals, curriculum directors, instructional coaches, and/or teachers.

2. Due to Covid-19, direct observations of principals interacting with teachers and students in their natural settings was not collected.

## Summary

This chapter highlighted the problem of underrepresented groups in STEM. While STEM is essential to America's economic prosperity and national security, females and students of color do not have the same access to robust STEM instruction as their white male counterparts and find themselves shut out of opportunities in the STEM fields. Furthermore, the research literature is largely silent regarding the salient leadership practices that are needed for implementing a STEM educational program that is responsive to the needs of underrepresented students. This chapter enumerated the research questions that guided the study and provided a brief overview of the study design. Culturally responsive school leadership was posited as a compelling lens for examining how school administrators can impact societal inequities and promote the successful navigation of women and URMs through the STEM pipeline.

CHAPTER II: LITERATURE REVIEW

This chapter presents an extensive review of the academic research relating to the underrepresentation of women and minoritized racial and ethnic groups in STEM. The literature review is intentionally comprehensive—taking up the daunting task of studying the multifaceted and sometimes puzzling phenomenon known as STEM. In doing so, I establish that STEM is intimately connected to national security, prosperity, and power, and why this matters to groups such as women and underrepresented minorities (URMS) who have been historically marginalized in STEM. Ultimately, this extensive review underscores the importance of principals providing culturally responsive leadership in STEM to females and students of color.

The chapter is divided into four distinct but interrelated parts. Part 1 explores what is known about STEM leadership with underrepresented groups, which is the primary focus of this study. Part 2 analyzes the meaning of the STEM acronym and traces the origins and history of STEM, providing the reader with a context for understanding why effective leadership in STEM is critically important. Part 3 presents research about gender and racial/ethnic gaps in student achievement in the STEM disciplines and the underrepresentation of these groups in STEM careers, assisting the reader in understanding that the present study is rooted in issues of prevailing power structures and inequality. Part 4 presents the academic research on strategies for increasing the interest and persistence of underrepresented groups in STEM, demonstrating that there is real hope for eliminating barriers to the equitable participation of women and marginalized minorities in STEM and affirming that they belong in these fields.

## Part 1: STEM Leadership with Underrepresented Groups

*If you want to build a ship, don't herd people together to collect wood and don't assign them tasks and work, but rather, teach them to long for the endless immensity of the sea.*
Attributed to Antoine de Saint-Exupéry (Pascal, 2009, p. 172)

Research on educational leadership indicates that school principals are "the most critical leadership determinant in educational change" (Rogers, 2007, p. 49). According to Lochmiller et al. (2012), "many of the factors shown to affect student achievement in math and science fall under the principal's influence as an instructional leader" (p. 202). Principals shape classroom practice through their influence on organizational culture, values, curriculum, pedagogical strategies, resources, staff development, and school goals (Hallinger, 2005; Hallinger, 2011; Hollingworth et al., 2018; Sun et al., 2013). Merrill and Daugherty (2010) observe that "a consistent finding in studies about principals is that high performing schools have strong, competent leaders" (p. 29). The leadership of principals is second only to classroom instruction in factors that impact the academic achievement of students (Leithwood et al., 2004; Mendels, 2012).

There are numerous studies that confirm the critical relationship between school leadership and student academic outcomes. For example, Waters et al. (2003) conducted a meta-analysis of leadership studies and found a statistically significant relationship between school leadership and student achievement. A meta-analysis by Robinson et al. (2008) indicated that higher achieving schools have principals who place a strong focus on teaching and learning. Williams et al. (2005) analyzed data from more than 250 elementary schools that primarily served low-income students. They found that despite similar demographics, the schools in the study differed by as much as 250 points in their academic performance index (API) scores. The authors attributed the variation among these schools to the role of leadership. According to Williams et al. (2005), API scores were higher in schools where principals cultivated a strong vision for the school, set high expectations, monitored struggling students, and made extensive

use of achievement data for continuous improvement.

Honey et al. (2014) posit that leadership is also a key attribute in schools that have improved student learning outcomes in STEM. In addition, Waight et al. (2018) stress that "when ethnic and racially marginalised students remain underrepresented in STEM, it is critical that more attention be given to the roles of school leaders" (p. 119). However, research regarding how principals provide leadership in specific content areas such as math and science is limited (Lochmiller et al., 2012). The literature "does little to inform our understanding of the ways in which specific differences across content areas prompt administrators to adapt their leadership to specific content areas" (Lochmiller, 2016, p. 77).

Davis (2015) contends that "there is not a great quantity of research specifically focused on leadership in relation to STEM education" (p. 3). Chisholm et al. (2019) concur, noting that STEM reform efforts have focused on factors such as instructional practices, personnel, and resources, while "a significant but often overlooked variable involves the role of school leadership" (p. 71). Kilmartin and Pimentel (2014) posit that school "leadership can influence minority students and women in STEM career fields and has yet to be investigated in depth to determine best practices" (p. 50). They add that "there is no definitive research in a leadership defined role in the recruitment, support, or retention of underrepresented students in STEM" (Kilmartin & Pimentel, 2014, p. 57). So what is known about STEM leadership in general? In particular, what constitutes effective leadership for serving the needs of students traditionally underrepresented in the STEM fields?

**STEM Leadership in General**

STEM leaders need to understand what STEM education means and the strategies that are needed to ensure its successful implementation in their schools (Honey et al., 2014; Myers &

Berkowicz, 2015). However, the majority of principals "have not learned disciplinary content using STEM contexts, nor have they taught in this manner" (Moore & Smith, 2014, p. 7). Brown et al. (2011) directed a qualitative study to find out if school administrators had a basic understanding of STEM education. All of the administrators in their study had at least one teacher in their school enrolled in a STEM master's degree program. Brown et al. (2011) found that "fewer than one half of the administrators . . . understood the concept and/or could describe it" (p. 8). Consequently, in order to successfully lead the STEM program in their schools, principals need ongoing professional development regarding what constitutes an effective STEM learning environment (Moore & Smith, 2014; National Research Council [NRC], 2015).

Lochmiller et al. (2012) have identified five attributes of effective leadership in STEM education:

1. The principal improves student learning outcomes by continually assessing and supporting STEM instructors with improving their content knowledge and pedagogy.

2. The principal promotes the use of project-based and/or inquiry-based learning.

3. The principal works with teachers to foster collaboration within STEM disciplines and across instructional domains.

4. The principal leverages resources to promote the professional development of teachers and student achievement in the STEM subjects.

5. The principal develops partnerships with area businesses and academia to enrich the STEM learning environment.

Effective STEM leadership also requires principals to have passion and vision. A case study by Scott (2012) found that STEM-focused high schools "were led by visionary principals who were . . . committed to making a difference in the lives of students" (p. 38). Principals must be

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passionate about the promise that STEM holds for children, sharing "words that speak to the heads and hearts of followers and partners" (Myers & Berkowicz, 2015, p. 60). They also need to communicate a vision for STEM education that is "transparent and meaningful" (Myers & Berkowicz, 2015, p. 64).

Buckner and Boyd (2015) offer several ways that principals can actively support teachers to foster a STEM culture in their schools:

- Identify curricular materials that support inquiry-based or student-centered learning.

- Assist teachers in developing STEM lesson plans and units.

- Secure the resources teachers need to implement their STEM units and projects.

- During STEM projects, work with students who may need additional challenge or extra support, whether academic or behavioral.

- Arrange meetings between specific teachers and community members and/or business partners who could help with a STEM project or unit.

Principals must be able "to reach across the traditional boundaries of schools . . . to share information and expertise and identify potential partners, such as informal education institutions, community organizations, and businesses" (NRC, 2015, p. 6). By forging partnerships within the local community, principals can identify mentors, student internship opportunities, tutors, guest speakers, and additional funding to enrich the STEM learning environment in their schools.

**Distributed Leadership**

Distributed leadership is the sharing of leadership tasks among multiple leaders within a school, including the principal, department chairs, curriculum specialists, and classroom teachers (Spillane et al., 2001; Sun et al., 2013). Buckner and Boyd (2015) note that "delegating decisions to those who are best suited to make them is a necessary part of promoting high-quality STEM

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education" (p. 26). Myers and Berkowicz (2015) contend that administrators cannot lead STEM singlehandedly, "regardless of skill or experience or passion" (p. 61). Therefore, a distributed leadership model is valuable for furthering the aims of STEM education (Buckner & Boyd, 2015; Kloser et al., 2018). According to Peters et al. (2018), "the culture necessary to share traditional leadership roles and to empower teacher-leaders must be established and fostered by principals" (p. 33). Angelle and Teague (2014) clarify that distributed leadership "is not an output of principal-delegated tasks but is an outcome of collaboration and relationship building" (p. 741). Merrill and Daugherty (2010) add that when principals share with teachers "the ability to define issues, collect data, construct meaning, and frame actions" (p. 25), it deepens the leadership capacity for the entire school.

Copland (2003) reports that the following conditions must be met for a distributed leadership model to be successful:

- the development of a collaborative school culture built upon relational trust, mutual accountability, and professional learning;

- a collective agreement about the essential issues facing the school;

- a sustained pursuit of teaching and learning expertise among all school professionals who work with children.

The sharing of expertise across the school is especially important "because it establishes credibility with peers, which is critical to school improvement" (Angelle & Teague, 2014, p. 741). Distributed leadership enables a school to capitalize on the talents and expertise of all of its members rather than relying on the strengths of a single administrator (Leithwood & Mascall, 2008).

Mendels (2012) asserts that "the more open a principal is to spreading leadership around,

the better it is for student learning" (p. 56). Peters et al. (2018) affirm that "the expectations of continued, annual student academic performance cannot simply be accomplished in isolation" (p. 34). While most research on the distributed leadership model has focused on the roles, functions, and relationships involved in shared leadership (Leithwood & Mascall, 2008), there has been some research showing its potential for increasing student achievement. A study by Leithwood and Mascall (2008) found that higher achieving school districts had greater degrees of shared leadership than lower performing school districts. Similarly, a longitudinal study by Heck and Hallinger (2009) involving approximately 200 elementary schools validated that there is a direct relationship between growth in the distribution of school leadership and a school's academic capacity. In addition, Heck and Hallinger (2009) found that as the academic capacity of schools improved, it had a significant impact on math achievement.

The distributed leadership model is especially helpful for building the capacity of schools to effectively address student diversity. Beachum and Dentith (2004) observe that school administrators "have to build more collaborative and democratic arrangements with teachers and others to . . . respond to students' diverse needs" (p. 277). Distributed leadership has shown to be especially effective in inclusive STEM high schools, which intentionally enroll students who are historically underrepresented in STEM (Kloser et al., 2018). Spillane et al. (2016) conducted a research study that examined how inclusive STEM high schools create opportunities for underrepresented students in STEM. Among their findings, one of the defining characteristics of the schools in the study was "how leadership was distributed among school administration, teachers, and sometimes students" (Spillane et al., 2016, p. 56). The study found that leadership in these schools was distributed both formally and informally. Distributed leadership "created an environment of trust that encouraged teachers to take risks, try new ideas, and connect with the

community beyond their classrooms" (Spillane et al., 2016, p. 59) to help marginalized students.

**Transformative Leadership**

"The norm in STEM is still the white Euro-American male" (Bystydzienski et al., 2017, p. 2303). As a result, women and students of color often encounter prejudice, discrimination, and a lack of diversity in the STEM classroom (Bystydzienski et al., 2017; Kilmartin & Pimentel, 2014). Transformative leadership, which is focused on social justice and equity for all students, is therefore a promising leadership model for addressing the needs of underrepresented students in STEM (Mason, 2009; Sampson, 2018). Rooted in the critical (or transformative) paradigm (Shields, 2017), transformative leadership "critiques inequitable practices and offers the promise not only of greater individual achievement but of a better life lived in common with others" (Shields, 2010, p. 559).

Shields (2010) observes that William Foster was one of the first scholars to describe transformative leadership. According to Foster (1989), "leadership is and must be oriented toward social change, change which is transformative" (p. 52). Foster (1989) posits that the transformative leader must "be critical of current social arrangements and that this critique be aimed at more emancipatory types of relationships" (p. 49). Such emancipatory relationships will in turn have the capacity to lead the community to freedom from "racial oppression, ethnic domination, the oppression of women and so on" (Foster, 1989, p. 49), injustices that affect contemporary STEM culture (Bystydzienski et al., 2017).

"To be truly transformative, the processes of leadership must be linked to the ends of equity, inclusion, and social justice" (Shields, 2011, p. 5). Nevarez et al. (2013) attest that "transformative leaders are aware of oppressive sociocultural norms and microaggressions (subtle discriminatory practices) which serve to reinforce the marginalization of nondominant

groups" (p. 146). Shields (2011) concurs that transformative leaders are cognizant of "the reality that some groups and individuals within a given organization are advantaged and … that other people are generally excluded, disadvantaged, and often marginalized" (p. 6). Transformative leadership rejects traditional stereotypes of leaders as male, authoritarian, and controlling, aspiring "towards creating contexts that make emergence possible" (Montuori & Donnelly, 2017, p. 22).

Transformative leadership theory is not the same as transformational leadership, although the two terms are often interchanged in the academic literature (Hewitt et al., 2014; Shields, 2010; Shields, 2017). According to Hewitt et al. (2014), "the transformational leader is reform-minded but not a revolutionary, whereas the transformative leader interrogates and seeks to disrupt that which is taken for granted" (p. 229). Transformational leaders are concerned with organizational change—school effectiveness, instructional leadership, and school improvement (Shields, 2011). In contrast, transformative leaders are involved with societal transformation—inclusivity, justice, and equitable change in social conditions (Shields, 2011). Whereas transformational leadership focuses on what occurs within a school, transformative leadership is concerned with how "the inequities and struggles experienced in the wider society affect one's ability both to perform and to succeed" (Shields, 2010, p. 568).

All too frequently, schools inadvertently serve as vehicles that maintain the social and political "inequities inherent in gender, race, and class constructs" (Shields, 2010, p. 569), particularly in the realm of STEM education (Nasir & Vakil, 2017). Transformative leaders recognize that their leadership is a "value-laden endeavor that either hinders or advances equity-oriented aims" (Cooper, 2009, p. 697). They actively identify the inequities that operate within their school communities and work passionately to dismantle the frameworks that support

inequitable programs, practices, and policies (Graham & Nevarez, 2017; Jun, 2011). Through the promotion of equity and inclusion for the advancement of both the individual student and the collective body, transformative leaders stimulate the creation of "socially-just learning environments in which all students thrive" (Shields, 2017, p. 5).

To counter the prevailing academic, civic, and social inequities in their schools and communities, transformative leaders must pursue self-awareness to discover their own prejudices and blind spots (Cooper, 2009). Montuori and Donnelly (2017) state that transformative leaders must be "aware of the extent to which they are steeped in the problematic ways of doing things that have caused the very problems they are attempting to address" (p. 9). Only then will they be ready to progress "through enlightened understanding to action" (Shields, 2010, p. 572), redressing the inequities in their school communities and promoting more socially just outcomes for all students.

In transformative leadership, "excuses for gaps in achievement are not made; instead transformative leaders construct change to meet the needs of the diverse population" (Graham & Nevarez, 2017, p. 70). Rather than focusing on achievement gaps, transformative leaders "talk about an *opportunity gap*, or better still, an *empowerment gap* to emphasize the systemic and structural forces . . . that perpetuate inequity" (Shields, 2020, p. 3). Transformative leaders understand that children need to feel welcomed and respected if they are going to reach their full learning potential (Shields, 2017). One of the ways that transformative leaders promote high achievement for all children is through the creation of learning environments based on "liberation, democracy, equity, and justice" (Shields, 2011, p. 2). Shields (2017) suggests that when transformative leaders foster more inclusive and equitable school environments, "academic achievement soars" (p. 5). While transformative leaders promote more socially just curricula and

culturally relevant teaching in their schools, they also recognize that they must "transform

structures, policies, and mind-sets" (Shields & Hesbol, 2020, p. 18) in order to meet the needs of

minoritized students.

Graham and Nevarez (2017) assert that "it is vital for transformative leaders to

collaborate with the community and students' families" (p. 78) to promote learning for all. In

order to be transformative, Montuori and Donnelly (2017) add that leaders must be able to forge

partnerships with their community that "are democratic rather than authoritarian and involve *the*

*creation of mutual benefit*" (p. 11). Transformative leaders are also called to "be both leaders *and*

followers" (Montuori & Donnelly, 2017, p. 6). Instead of seeing the community as an assortment

of problems that must be dealt with, transformative leaders reject a deficit perspective and view

the community as a source of strength and support (Rodríguez & Villarreal, 2001). They

consider working with the community a win-win rather than a zero-sum game (Montuori &

Donnelly, 2017). And since transformative leadership is situated within a community,

"ultimately leadership resides in the community itself" (Foster, 1989, p. 49).

Scholars have set forth a number of attributes of transformative leaders. Transformative

leaders display moral courage (Shields, 2017). They are clear about the goals that need to be

attained and how to achieve them (Shields, 2011). Transformative leaders possess a "tolerance

for ambiguity" (Montuori & Nevarez, 2017, p. 23). They persevere "despite limited fiscal

resources and frequent community backlash" (Shields & Hesbol, 2020, p. 19). Transformative

leaders serve as bridge builders among school stakeholders in the establishment of emancipatory

spaces (López et al., 2006). Transformative leaders simultaneously "embody and enact the

future" (Montuori & Nevarez, 2017, p. 15).

Rodríguez and Villarreal (2001) delineate nine ways that leaders employ transformative

leadership to engage their school communities for change:

1. Visionary. Transformative leaders articulate a clear vision of how schooling must change in order for marginalized students to be successful, and they partner with their constituents to form the vision for a preferred reality.

2. Community Consciousness. Transformative leaders place the welfare of their families and community at the center of their responsibility. They recognize that culture and language are assets that define the community's attitudes and values, and they realize that it is through the broader community that they can create space for all students and their families to grow.

3. Power. Transformative leaders recognize that unfilled desires within the community can be powerful because they heighten focus, unleash creativity, and bring people together to achieve change. They are aware that power is not something to be acquired in the future through status or position; rather it exists in the present through the evolving thoughts and choices of the community.

4. Life Experiences. Rather than getting bogged down by negative images such as racism and poverty that have dominated the lives of individuals and the community, transformative leaders harness these life experiences to place a renewed focus on where others want to go in achieving a better reality for families and students.

5. Imagination. Transformative leaders understand that imagination has the power to expand thoughts and aspirations beyond the restrictions of the present reality and inspire new possibilities for enhancing the future for students.

6. Reflection. Transformative leaders do not get trapped in an endless circle of victimization. Instead, they reflect on their progress and accomplishments, recognizing

how far they and their community have come. They celebrate the resilience of their

stakeholders and reflect on how everyone can learn from their past and present

circumstances to achieve educational equity and excellence.

7.  Catalysts. Transformative leaders serve as catalysts for change. They encourage students

    and their families to believe in themselves and what they are capable of achieving.

    Transformative leaders sow seeds which will be harvested by others. They understand

    that lasting change takes time, balancing determination with patience.

8.  Valuing perspective. Transformative leaders do not engage in a deficit mentality

    regarding their leadership. Instead, they understand that the more they give their

    leadership away, the more that leadership will emerge in others. They value the

    perspective of others and draw them into leadership through shared accountability and

    responsibility.

9.  Inspiration. Transformative leaders find inspiration in knowing they are forging a better

    reality in the lives of their community. They recognize that their work has a spiritual

    dimension—that they are part of something bigger than themselves in fostering a better

    world for others. Transformative leaders are inspired by their abiding belief in the

    community they serve. They savor the present while finding hope in the future that they

    are helping to create.

Rodríguez and Villarreal (2001) maintain that these traits of transformative leadership transcend

language and culture while remaining grounded in traditional communal values.

Jun (2011) suggests four key characteristics that define transformative leadership in

educational settings:

1.  Notion of Critique. Transformative leaders take a critical perspective in regard to how

school policies and practices "perpetuate the marginalization of students" (p. 239).

2. Empathy. Transformative leaders empathize with the plight of marginalized students and demonstrate "an ethic of caring" (p. 240).

3. Schools as Places of Democracy. Transformative leaders provide opportunities for administrators, teachers, and students to collaborate in decision making, and they foster an environment where stakeholders can feel secure in their democratic participation.

4. Dialogue. Transformative leaders ensure that everyone in their school has a voice and they create safe spaces where all stakeholders have "the courage to have open dialogue and speak out against injustices" (p. 241).

Kose (2009) describes five ways that principals can embody transformative leadership in their schools. A principal can serve as a transformative visionary, fostering and articulating a school vision that is built on values such as social responsibility, affirming diversity, and equitable high achievement. Principals can act as transformative learning leaders, guiding professional learning for social justice to help teachers learn how to teach about diversity and how to construct cultural capital for marginalized students. Principals can take on the role of transformative structural leaders, organizing space, schedules, stakeholder collaboration, and resources to optimize opportunities to achieve social justice goals. Principals can also serve as transformative cultural leaders, cultivating "a culture of shared norms, values, and dispositions" (Kose, 2009, p. 642) that supports all students. Finally, Kose (2009) states that principals can function as transformative political leaders, engendering "political and resource support and buy-in for far-reaching change decisions" (p. 249).

Shields (2017) identifies eight tenets of transformative leadership that lead to a more just and equitable community:

- a mandate for deep and equitable change;

- the need to deconstruct knowledge frameworks that perpetuate inequity and injustice and to reconstruct them in more equitable ways;

- the need to address the inequitable distribution of power;

- an emphasis on both private and public (individual and collective) good;

- a focus on emancipation, democracy, equity, and justice;

- an emphasis on interconnectedness, interdependence, and global awareness;

- the necessity of balancing critique with promise;

- the call to exhibit moral courage.

Shields and Hesbol (2020) posit that "transformative leadership theory is normative" (p. 5) not only for individuals but for the common good. In particular, transformative leaders must "ensure appropriate emphases on global citizenship, on interconnectedness and interdependence, and on the need to respect, welcome, and include the lived experiences of all children, regardless of background" (Shields, 2017, p. 6). Such leadership has the power to transform schools into places that provide constituents with an "inclusive, equitable, and deeply democratic conception of education" (Shields, 2010, p. 559) where students underrepresented in STEM can thrive.

**Culturally Responsive School Leadership**

Culturally responsive school leadership (CRSL) embodies aspects of transformative leadership "but pushes further" (Khalifa et al., 2016, p. 1278). While it shares transformative leadership's emphasis on emancipatory practices that free minoritized students from oppression, CRSL is more expansive in its scope, aiming "to identify and institutionalize practices that affirm Indigenous and authentic cultural practices of students" (Khalifa et al., 2016, p. 1278). Unlike transformative leadership theory and distributed leadership research, CRSL is an

emerging but underresearched concept in the academic literature (Beachum, 2011; Khalifa et al., 2016; Levitan, 2020).

CRSL is an outgrowth of earlier research on culturally relevant pedagogy (Ladson-Billings, 1995, 2006) and culturally responsive teaching (Gay, 2010). Culturally responsive education values the cultural knowledge and skills that underrepresented groups bring to learning and counters a prevailing deficit perspective that persists in many educational circles (Gay, 2010; Ladson-Billings, 1995, 2006). According to Khalifa et al. (2016), CRSL can be defined as "the ability of school leaders to create school contexts and curriculum that responds effectively to the educational, social, political, and cultural needs of students" (p. 1278). It is therefore a promising model for leadership in STEM with minoritized students, since "without meaningful culture change—a shift in underlying assumptions—progressive policies alone will not result in more inclusive practices in academic STEM fields" (Bystydzienski et al., 2017, p. 2304).

Culturally responsive leaders foster an inclusive school climate for students who have been marginalized due to "their nondominant race, ethnicity, religion, language, or citizenship" (Khalifa et al., 2016, p. 1275). Khalifa (2013) asserts that school principals are in the best position to promote a culturally responsive school culture. However, to do so successfully, "they must have a clear understanding of the current needs of the marginalized and underrepresented populations" (Khalifa, 2013, p. 71) in their schools. Therefore, principals who are culturally responsive "understand—and encourage their teachers and staff to understand—the community's ancestral knowledge, experiences, and perceptions" (Khalifa, 2018, p. 192).

Unfortunately, principals often lack both adequate preparation to lead diverse schools and the ability to "articulate meaningful discourses around diversity" (Khalifa et al., 2016, p. 1279). For example, Nelson and Guerra (2014) conducted a qualitative study that included more than 70

educational leaders working in school districts with diverse student populations. Their study revealed that school leaders typically lack cultural competence and engage in deficit thinking about students and families from diverse backgrounds. Nelson and Guerra (2014) noted that the educators in their study gave "little consideration . . . to the social aspects of schooling such as identity, culture, language, and relationships" (p. 67), which are essential aspects of culturally responsive leadership.

Beachum (2011) proposes a three-tiered matrix to describe how a teacher leader or school administrator can develop into a culturally responsive leader:

1. Emancipatory consciousness. Many educators lack awareness of the historical inequities in America's schools and the behaviors and structural flaws that enable them. Emancipatory consciousness focuses on how school leaders become cognizant of such inequities, develop the critical awareness that change is needed, and recognize they have the ability to bring about transformation.

2. Equitable insight. School leaders must help others reject a deficit perspective. Equitable insight focuses on how leaders help change attitudes within their schools to affirm the rich diversity and cultural background of their students.

3. Reflexive practice. Educators must accept that many of their traditional practices are discriminatory. Reflexive practice focuses on how school leaders function as change agents who transform their schools through the use of culturally relevant pedagogy and culturally responsive practices which promote the success of all children.

Beachum (2011) summarizes his three-tiered matrix as a progression that "encompasses change in knowledge, change in feelings, and change in actions" (p. 33).

Lopez (2015) conducted a qualitative study to assess the culturally responsive leadership

practices of six educational leaders serving in a large, diverse school district in Canada. Data was collected through questionnaires and semi-structured interviews. Lopez (2015) found that culturally responsive leaders do the following:

1. Develop a critical consciousness for action. Culturally responsive school leaders critically reflect on their beliefs, attitudes, values, and biases toward marginalized students. Through such critical reflection, they come to a deeper understanding of the giftedness and diverse needs of their students and take deliberate action to bring about positive change in their schools.

2. Adopt attitudes and practices that support equity and diversity. Culturally responsive school leaders maintain an ongoing focus on equity and diversity that goes beyond superficial celebrations (e.g., Black History Month). They continually embrace and celebrate the diversity of their students and ensure that all "students can see themselves in the curriculum and feel fully part of the life of the school" (p. 177).

3. Push back against roadblocks that exist in their schools. Culturally responsive school leaders encounter teachers in their schools who lack sensitivity toward marginalized students, pay lip service to equity, resist necessary changes in curricular and instructional practices, and/or become hostile toward leaders who attempt to address issues of equity and diversity in their schools. Culturally responsive leaders acknowledge these tensions but are not deterred by them, pushing ahead to make their schools more responsive to the needs of marginalized children.

4. Seek support through collegial learning communities. Culturally responsive school leaders can feel isolated and emotionally spent from the resistance they encounter to change. Therefore, they need "to find like-minded colleagues and build a supportive

learning community" (p. 180). This support network can provide culturally responsive

school leaders with a safe space to share their feelings, acknowledge their difficulties, ask

questions, and share best practices.

Lopez (2015) stresses that the practices of culturally responsive school leaders are not accidental,

but are realized "through deep self-reflection, commitment to challenge the status quo,

commitment to engage in new ways of knowing and doing, commitment to actively advocate for

issues of equity and diversity, and commitment to stay the course" (p. 173).

Madhlangobe and Gordon (2012) conducted a case study to comprehend how a culturally

responsive leader advances equity in a school with a linguistically and racially diverse student

population. They identified six characteristics that defined how culturally responsive leadership

was practiced by the administration in a highly diverse school context:

- caring for others;

- building relationships;

- being persistent and persuasive;

- being present and communicating;

- modeling cultural responsiveness;

- fostering cultural responsiveness among others.

Madhlangobe and Gordon (2012) propose that these culturally responsive leadership practices

can "make learning more relevant, increase student engagement, reduce discipline problems, and

improve student achievement" (p. 200) for marginalized students.

A synthesis of research by Khalifa et al. (2016) revealed four primary behaviors

associated with culturally responsive school leaders:

1. They critically self-reflect on their leadership practices. Culturally responsive school

leaders continually engage in self-reflection to uncover the beliefs, assumptions, and biases they hold due to their cultural backgrounds that result in oppressive leadership practices such as color-blind ideology. In turn, they use this self-knowledge to comprehend the context in which they lead and visualize an improved learning climate for marginalized students.

2. They develop teachers who are culturally responsive. Culturally responsive school leaders make it a priority to promote culturally responsive curriculum and instruction. They accomplish this by recruiting teachers who are culturally responsive, providing ongoing professional development on culturally relevant pedagogy, identifying culturally responsive curriculum and resources, and providing mentors to model culturally relevant teaching practices. They challenge any teachers who they observe engaging in exclusionary practices.

3. They promote an inclusive environment within their schools. Culturally responsive school leaders are strong advocates for marginalized students. They foster a welcoming school environment that embraces the cultural diversity of their communities. They take concrete action to root out the inequities that hinder students from learning. Culturally responsive leaders foster a culturally responsive climate by "promoting inclusivity, Indigenous youth identities, and integrating student culture in all aspects of schooling" (pp. 1296-1297).

4. They engage parents, students, and the Indigenous community in culturally appropriate ways. Culturally responsive school leaders create schools that are "caring communities and learning organizations at the same time" (p. 1290). They develop meaningful relationships with parents, students, and community members and invite them to have a

voice in important decisions. They validate Indigenous cultures by engaging in practices

such as speaking and/or honoring native languages and lexicons. They leverage resources

including cultural artifacts, customs, traditions, and partnerships with Indigenous

community members to provide for student needs. They acknowledge the issues and

challenges faced by the local community and advocate on their behalf.

Khalifa et al. (2016) contend that principals who engage in these CRSL practices will establish a

school environment that effectively addresses the needs of marginalized students, enabling them

"to have a safe, affirming, and academically challenging place in school" (p. 1297).

Brown et al. (2019) hold that distributed leadership works best when it is coupled with

culturally responsive leadership:

> The former allows for the sharing of power, which enables a school to respond to rapidly
> changing circumstances and provides a mechanism through which policies and practices
> can move quickly from being high-level rhetoric to implementation down through the
> organisation. The latter is a philosophy of care about social justice that guides every
> aspect of the response of a school to meeting the huge challenge of an increasingly
> diverse pupil population. (p. 470)

While distributed leadership can provide a school with the flexibility it needs to effectively

address diversity, in the absence of culturally responsive leadership, distributed leadership will

not necessarily ensure that all students have an equal opportunity to excel regardless of their

race, ethnicity, or gender (Brown et al., 2019).

Lopez (2015) affirms that culturally responsive leaders "develop agency, take action, and

build school-wide capacity on issues of equity, diversity, and social justice" (p. 173). She adds

that CRSL "challenges cultural norms and institutions that produce and maintain social

inequities" (Lopez, 2015, p. 174). Beachum (2011) asserts that CRSL fosters "educational

excellence combined with equity" (p. 34). Culturally responsive school leaders provide supports

to ensure the academic achievement of all students, affirm the home or native cultures of their students, and work as change agents in their schools and communities (Johnson, 2007). Khalifa (2013) observes that when principals create safe spaces for their students which celebrate cultural diversity, "formerly low-performing students [experience] academic success" (p. 78).

According to Kilmartin and Pimental (2014), "meeting the academic and social needs of underrepresented students is crucial if access and inclusion, and their ultimate success in STEM fields, are to be actualized" (p. 53). Since culturally responsive practices have been demonstrated to have a positive impact on both the social and academic needs of minoritized students (e.g., Dover, 2013; Kern et al., 2015; Wilson-Lopez et al., 2016), CRSL offers a compelling way to examine how school administrators promote the successful navigation of women and minorities through the STEM pipeline. Although CRSL is typically cited as a model of leadership for addressing the needs of students of color, culturally responsive approaches have also been demonstrated to have a positive impact on female students (Dancstep & Sindorf, 2018). Therefore, CRSL offers a constructive schema for assessing how effective school leaders respond to the needs of underrepresented students in STEM.

**Additional Leadership Practices for Promoting Equity in STEM**

All too often, women and people of color do not have access to robust STEM instruction and are shut out of opportunities in the STEM fields. School leaders therefore have a moral obligation "to transform schools from being sorting mechanisms in the larger global market— where people of color, women, and the disenfranchised are prepared to fit a particular role in society" (López, 2003, p. 71). However, there is a perception that educational leadership is more about the "technical matters of school finance, organizational theory, leadership theory, and other staple topics" (López, 2003, p. 70) rather than developing schools that work for all

students. Yet according to the National Policy Board for Educational Administration (NPBEA, 2015), "effective educational leaders strive for equity of educational opportunity and culturally responsive practices to promote each student's academic success" (p. 11). Buckner and Boyd (2015) affirm that administrators who want "to improve STEM education in their schools must start with the notion that all students deserve access to rich and rigorous learning experiences" (p. 5).

Brown (2005) posits that "schools in a racially diverse society will require leaders and models of leadership that will address the racial, cultural, and ethnic makeup of the school community" (p. 585). It is imperative for STEM leaders to consider which students in their schools do not have access to authentic and abundant STEM experiences (Buckner & Boyd, 2015). Lochmiller et al. (2012) attest that the active leadership of principals can alleviate many of the disadvantages that underrepresented students face in STEM. For example, school leaders can ensure that their teachers use culturally responsive instructional practices and that their schools provide bilingual courses in the STEM subjects (Lochmiller et al., 2012). Principals can also work with classroom teachers to provide diverse student populations with early exposure to STEM careers (Lochmiller et al., 2012). Unfortunately, principals often underestimate diverse students' interest in learning STEM subjects (Wang et al., 2016).

Allen-Ramdial & Campbell (2014) report that in higher education, "advances in STEM diversity have benefited greatly from strong and committed institutional leadership" (p. 616). However, Toldson (2013) cautions administrators that "diversity in STEM will not occur through happenstance or 'business-as-usual' practices" (p. 367). It is the ongoing commitment of leadership to expanding the participation of underrepresented students which "signals appropriate actions for others" (NAS, 2011, p. 183) within the institution. To assist leadership in

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achieving campus diversity at the university level, Hurtado et al. (1999) identify 12 steps that administrators can take to foster a school climate which promotes the participation of students from historically marginalized populations:

1. Establish as an institutional priority the development of a learning climate that supports cultural and racial diversity.

2. Conduct a systematic assessment of the institution's climate for diversity, including behavioral patterns, psychological climate, historical legacy, and structural diversity, in order to establish a baseline for improvement efforts.

3. Develop a comprehensive improvement plan that addresses issues identified in the diversity assessment.

4. Create an evaluation process to gauge the effectiveness of improvement efforts in accomplishing change.

5. Adopt proactive goals that eliminate past exclusionary practices and increase opportunities for historically underrepresented students.

6. Involve faculty in diversity efforts by helping them recognize their own perceptions and attitudes toward diverse students and introducing programs that help instructors manage classroom conflict due to misconceptions and stereotypes among students.

7. Help faculty adopt instructional practices that create collaborative learning environments which foster positive relationships and increase interactions among diverse racial and ethnic groups.

8. Enhance faculty/student interaction outside of the classroom by providing opportunities for historically underrepresented students to participate in research projects and similar activities.

9. Implement curricular and extracurricular programs such as peer support groups that enhance diverse students' sense of belonging while bridging interaction and understanding across different racial and ethnic groups.

10. Develop a student-centered orientation that focuses on each student's academic and personal development, validating the experiences and needs of students from differing backgrounds.

11. Increase the involvement of diverse students in campus activities by providing coordinated support services for students of color.

12. Provide cultural sensitivity training for campus administrators, faculty, and staff.

While these steps have been empirically verified to improve the climate for diversity, Hurtado et al. (1999) emphasize that it is a long-term process since "institutions are slow to change" (p. 69).

Strong institutional leadership in higher education not only has the ability to positively impact campus diversity, it can also influence diversity at the K-12 level through teacher education programs. Avendano et al. (2019) recommend that university leaders and policy makers consider the following to address the needs of underrepresented students in STEM:

- confirm that candidates in teacher education programs understand that particular groups of students are underrepresented in STEM;

- provide clinical experiences for teacher candidates in urban settings so that they have opportunities to teach and interact with diverse student populations;

- ensure that teacher candidates have received specialized training in STEM education;

- develop a conduit for the university's STEM undergraduates to enter the teaching profession;

- create a pipeline for underrepresented students to enter college and a support structure for

STEM majors.

By implementing such practices, higher education leaders and policy makers can "increase the number of minorities and women pursuing STEM" (Avendano et al., 2019, p. 79).

At the K-12 level, Bakshi (2014) used a mixed method research design to determine the strategies used by district and school level administrators in the State of California to implement STEM initiatives targeting low income high school students. She gathered quantitative data from administrator surveys and student achievement scores from approximately 100 school districts identified as successful based on their academic performance index (API) scores for socioeconomically disadvantaged students. Qualitative data was obtained from structured interviews with district and school administrators. 109 school and district leaders completed surveys for the study, and 10 leaders participated in the qualitative interviews. More than 70% of the school leaders in the study had no teaching experience in STEM.

Bakshi (2014) found that district and school leaders placed a strong focus on providing regular professional learning opportunities for teachers, especially in math and science. District and school administrators and teachers worked together on aligning curriculum to the Next Generation Science Standards (NGSS). Administrators conducted frequent walk throughs to determine the level of student engagement in their schools and monitor the implementation of NGSS instructional practices. A distributed leadership model was used which enabled teachers to share their STEM expertise with both their peers as well as the district and school administration. Principals encouraged teachers to initiate extracurricular STEM activities such as Tech Bridge, a STEM program for girls. Although the majority of district and school leaders did not have STEM backgrounds, they leveraged grants, partnerships, and other resources to sustain STEM initiatives in their communities.

Ford (2017) examined the leadership factors that contributed to the success of four inclusive STEM-focused high schools (ISHSs) that had been identified by an NSF-funded study, Opportunity Structures for Preparation and Inspiration (OSPrI), as exemplary in addressing the needs of underrepresented students in STEM. Ford (2017) used existing data sets from the OSPrI study for his research, which included detailed case studies, administrator and teacher survey data, classroom observations, transcriptions of interviews with school personnel and community leaders, and narratives of focus group discussions with teachers, parents, and students. The four principals whose leadership was the focus of Ford's study had no previous experience teaching STEM or working in a STEM field.

Ford (2017) found that the principals of the ISHSs in his study relied on a distributed model of leadership which utilized shared expertise, planning, and decision-making among teachers and representatives from state STEM networks and nongovernmental organizations to guide their school's STEM programs. The principals were able to mobilize resources by establishing close relationships with local STEM businesses and industry partners, which they deemed critical to the success of their STEM programs. They also developed partnerships with area colleges and universities to enhance course offerings, enable students to earn college credit, and recruit future STEM instructors. The principals hired teachers whose values aligned with their school's mission and goals, and they expanded the STEM capacity of their staff through continuous professional development. School leaders also encouraged project-based learning linked to real world concerns. Finally, they held high expectations for all students and worked to provide their students with personalized supports to ensure their STEM success.

Sampson (2018) conducted a qualitative study to learn how principals support minority female students in STEM. Using a case study approach, she conducted interviews with two

principals who led high schools which specialized in STEM education and where the majority of students were African American. In addition to semi-structured interviews, research data included the school's standardized science and math scores and observations of the principals engaged in their daily work activities. The principals in the study were African American males with multiple years of administrative experience. One of the principals had a degree in a STEM field, while the other principal in the study did not have a teaching background in STEM.

The principals in Sampson's (2018) study employed both transformative and distributed leadership practices to promote the success of African American female students in STEM. The principals engaged multiple levels of support, including teachers, parents, peer counselors, department heads, mentors, internship supervisors, and community members. Each principal actively pursued partnerships with local and national corporations and nonprofit organizations to obtain needed resources. The principals also encouraged their female students to learn the skill of self-advocacy to ensure their success in STEM beyond high school. Sampson concluded that it did not matter whether a principal had an educational background in STEM, provided they recognized that race and gender were challenges that African American females face in pursuing STEM careers and they were committed to helping them be successful.

**Summary**

The academic literature indicates that leadership is a key attribute regarding positive student learning outcomes. However, there is limited research regarding how school administrators provide leadership in the area of STEM. The majority of principals do not have a STEM background. Nevertheless, they can demonstrate effective leadership by providing their teachers with professional development on STEM content knowledge and pedagogy, promoting the use of project-based learning, fostering collaboration across instructional domains, and

leveraging resources to support STEM, particularly partnerships with universities, businesses, and community nonprofit organizations. Effective STEM leadership also requires principals to have passion and vision. But even passionate and visionary principals cannot lead STEM singlehandedly. Therefore, a distributed leadership model is frequently used in STEM education, with leadership tasks shared among multiple personnel including the principal, department chairs, curriculum specialists, and classroom teachers.

All too often, females and students of color do not have access to robust STEM instruction and are shut out of opportunities in the STEM fields. Principals can help alleviate many of the disadvantages that underrepresented students face in STEM by hiring teachers who share their vision and goals regarding the participation of underrepresented youth in STEM. They can arrange for bilingual courses to be available in the STEM subjects, provide ongoing training for their faculty in culturally relevant pedagogy, and ensure through regular walk throughs and observations that their teachers are utilizing culturally responsive instructional practices. They can work with classroom teachers and STEM mentors to provide diverse student populations with early exposure to STEM careers. School administrators can also demonstrate leadership in this area by communicating a clear commitment to expanding the participation of underrepresented students in STEM.

There is a contemporary interest among educators regarding how schools "can be transformed to accommodate historically underrepresented populations, especially women and people of color" (Bystydzienski et al., 2017, p. 2303) in STEM education. The transformative leadership model, which is centered on the themes of social justice and equity for all, has the capacity to address the needs of underrepresented students in STEM (Mason, 2009; Sampson, 2018). "Transformative leaders are aware of oppressive sociocultural norms and

microaggressions (subtle discriminatory practices) which serve to reinforce the marginalization of nondominant groups" (Nevarez et al., 2013, p. 146), and they work tirelessly to rectify inequities in their school communities and promote socially just outcomes for all. Culturally responsive school leadership (CRSL) builds on transformative leadership theory but is "broader in scope" (Khalifa et al., 2016, p. 1285), identifying and systematizing policies and practices that affirm the cultural traditions and values of minoritized students and their families.

CRSL is a promising framework for examining how school leaders foster a school culture that supports diversity in general and STEM learning for underrepresented students in particular. School leaders who are culturally responsive ensure that academic supports are in place for all students, affirm the home and native cultures of their families, and work as change agents in their schools and communities. Since deep seated prejudices and stereotypes have been demonstrated to hinder underrepresented groups such as female students and students of color in STEM education, CRSL offers a constructive schema for understanding how school administrators impact such societal inequities and promote the successful navigation of women and minorities through the STEM pipeline.

**Gap in the Literature**

Research on effective educational leadership is abundant. However, "there is not a great quantity of research specifically focused on leadership in relation to STEM Education" (Davis, 2015, p. 3). Chisholm et al. (2019) concur, noting that STEM reform efforts have focused on factors such as instructional practices, personnel, and resources, while "a significant but often overlooked variable involves the role of school leadership" (p. 71). Lochmiller (2016) adds that the academic literature does not adequately address how school administrators "adapt their leadership to specific content areas" (p. 77). Kilmartin and Pimentel (2014) posit that school

"leadership can influence minority students and women in STEM career fields and has yet to be investigated in depth to determine best practices" (p. 50). They add that "there is no definitive research in a leadership defined role in the recruitment, support, or retention of underrepresented students in STEM" (Kilmartin & Pimentel, 2014, p. 57). Sampson (2018) agrees that little is known about how principals' "leadership styles influence decisions of equity in addressing underrepresentation of women, and specifically women of color, in STEM fields" (p. 14). Winn (2016) posits that "future research that considers racial and cultural differences within the realm of STEM instructional leadership practices and self-efficacy would contribute substantiality to the field" (p. 124).

Scholarship in the area of STEM leadership is largely silent regarding how principals cultivate institutional commitment to serve the needs of underrepresented groups in STEM and the problems and challenges they face in doing so. What are the salient leadership practices for implementing a STEM program that is responsive to the needs of underrepresented students? Are culturally responsive leadership practices efficacious for developing a school climate and culture that fosters the participation of underrepresented groups in STEM? The present study responds to this gap in the literature by exploring the behaviors and practices employed by school leaders to address the needs of females and students of color in STEM.

### Part 2: Understanding STEM and Its Critical Importance

The 21st century has ushered in a renewed focus on the teaching of science, technology, engineering, and mathematics (STEM). In a competitive global marketplace that demands technological innovation, the STEM fields are considered to be essential to America's economic prosperity (NSB, 2016; Xie & Killewald, 2012). To keep domestic industry competitive (NAS, 2007) and to fill a growing number of STEM-based careers (Langdon et al., 2011), there is

growing pressure on schools to foster scientific and technical expertise among students and reduce the gap between the U.S. and foreign countries in math and science achievement. In recent years, STEM education has become a focal point for educational funding and reform.

This section begins by looking at definitions of STEM, how the term was coined, variations of the acronym in education and industry, and why developing a clear definition of STEM has been problematic. An overview of the history of STEM in academics follows, including its foundation in early classical education, governmental support dating from our nation's inception, and the influence of the Second World War and the launch of Sputnik on the STEM fields. The section concludes by examining the impact that publications such as *A Nation at Risk* (Gardner et al., 1983) and *Rising Above the Gathering Storm* (NAS, 2007) have had on amassing support for STEM funding.

**What is STEM?**

At a fundamental level, "STEM stands for science, technology, engineering, and mathematics" (Drake, 2012, p. 9). Although the acronym represents four academic disciplines, many educators consider STEM to mean science and mathematics (Bybee, 2010; Hoachlander & Yanofsky, 2011; White, 2014). Others argue that STEM is primarily technology and engineering (Roehrig et al., 2012; Starkweather, 2011). Regardless of how it is interpreted, STEM has become "a generic label for any event, policy, program, or practice that involves one or several of the STEM disciplines" (Bybee, 2010, p. 30).

The National Science Foundation formulated the term "SMET" in the early 1990s to refer to the disciplines of science, mathematics, engineering, and technology (Mohr-Schroeder et al., 2015; Sanders, 2008). Judith Ramaley, an assistant director for education and human resources at the National Science Foundation, is generally credited with coining the alternative acronym

"STEM" in 2001 (e.g., Aguilera et al., 2021; Breiner et al., 2012; Zimmerman et al., 2019).

Ramaley felt that the term "SMET" placed too much emphasis on science and mathematics, and

she wanted to emphasize the interconnections among the four disciplines (Daugherty, 2013;

Mohr-Schroeder et al., 2015; Raju & Sankar, 2003; Zollman, 2012). She was also concerned

"that 'SMET' sounded too much like 'smut'" (Sanders, 2008, p. 20).

The origin of the STEM acronym is somewhat disputed, however. Rita Colwell, the first

woman to serve as director of the National Science Foundation, recalls that the acronym STEM

> was decided at one of my executive committee meetings…. Dr. Judith Ramaley and I discussed "SMET." I told Judith I disliked the acronym "SMET," because to me, as a microbiologist, it sounded like the *Mycobacterium smegmatis*, which I did not think reflected well on [the] science engineering enterprise. I suggested we reverse the letters and use "STEM" (science, technology, engineering, and mathematics). Judith agreed and she asked how to proceed. My response was simply henceforth to refer to the science, technology, engineering, and mathematics programs as STEM at NSF. Certainly if NSF adopted the acronym "STEM" the rest of the world would surely follow. As simple as the explanation may seem, it is the origin and evolution of the acronym. (R. Colwell, personal communication, January 13, 2017)

Schenk and Lund (2010) confirm the significant role that Rita Colwell played in creating the

STEM acronym. Nonetheless, there is evidence that the STEM acronym was in use prior to this

time. The University of Massachusetts opened its STEM Education Institute in 1995 (Sternheim,

2012), and Carter (2017) reports that the STEM acronym was being used as early as the 1980s

and 1990s by Sue Dale Tunnicliffe and her colleagues at the University of London's Institute of

Education.

While the STEM acronym apparently predates 2001, Rita Colwell and Judith Ramaley

can be properly credited with leveraging the influence of the National Science Foundation to

make STEM rather than SMET the accepted term in the lexicon of science, technology,

engineering, and mathematics practitioners and educators. The STEM acronym caught on

quickly, with the *Journal of SMET Education* changing its name to the *Journal of STEM Education* in the summer of 2003 (Raju & Sankar, 2003). However, despite the growing popularity of the STEM acronym, the National Science Foundation's Committee on Equal Opportunities in Science and Engineering persisted in using the term "SMET" at least into 2004 (NSF, 2004); and some researchers were still referring to the field as SMET in 2005 and beyond (e.g., Moridis & Economides, 2008; Okogbaa et al., 2006; Weber & Custer, 2005; Zhao et al., 2005). In the spring of 2010, the *Journal of Industrial Teacher Education* rebranded itself the *Journal of STEM Teacher Education*, illustrating the clout the STEM acronym had come to possess in a relatively short period of time (Howell, 2010).

The U.S. Department of Education (2007) defines STEM as programs that are "primarily intended to provide support for, or to strengthen, science, technology, engineering, or mathematics (STEM) education at the elementary and secondary through postgraduate levels" (p. 11). Wang et al. (2011) suggest that STEM education is "a curricular approach that integrates science, technology, engineering, and mathematics" (p. 3). Merrill (2009) defines STEM as "a standards-based, meta-discipline . . . where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study" (as cited in Brown et al., 2011, p. 6). Dugger (2010) also defines STEM education "as the integration of science, technology, engineering, and mathematics into a new cross-disciplinary subject in schools" (p. 2). However, Sanders (2008) cautions that the STEM acronym does not necessarily imply any integration of the four STEM disciplines.

Despite the ubiquitous use of the STEM acronym in education, "there is no common operational definition or conceptualization of STEM" (Breiner et al., 2012, p. 9). Policymakers,

educators, and researchers find it difficult to sift through the often conflicting definitions of what

STEM is and how it should be implemented in a school setting (Barakos et al., 2012; Mitts,

2016). Pitt (2009) posits that:

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

Eric Lander, a professor of biology at MIT and co-chair of the President's Council of Advisors

on Science and Technology, observes that with STEM, "everybody who knows what it means

knows what it means, and everybody else doesn't" (Gerlach, 2012, p. 3).

Basham et al. (2010) note that "as an acronym, STEM has multiple interpretations" (p.

10). Many people believe that it means stem cell research or a plant part (Angier, 2010; Breiner

et al., 2012; Bybee, 2010). Indeed, typing "STEM" into databases such as Academic Search

Complete (EBSCO interface) or search engines such as Google Scholar produces substantially

more articles on stem cells than on science, technology, engineering, and mathematics. Even

educators working at institutions heavily involved in STEM education are vulnerable to

misinterpreting the acronym. Breiner et al. (2012) interviewed over 200 faculty members at a

major research university engaged in several STEM partnerships. More than 25% of the

respondents did not understand what STEM stood for, interpreting the "E" as electronics or

concluding that the "M" stood for medicine or management. A similar study by Brown et al.

(2011) revealed that less than half of math teachers and school administrators could adequately

define STEM, even though they were supervising or had colleagues working towards advanced

degrees in STEM education. Additionally, many of the participants who correctly identified the meaning of STEM acknowledged that they used the Internet to look it up after they were contacted to be part of the study.

Gerlach (2012) finds it troubling that educators and researchers define STEM "by using the same term in the definition" (p. 3). Brown et al. (2011) also observe that "STEM is often defined only by having the terms science, technology, engineering, and mathematics follow in parentheses" (p. 6). The problem of defining STEM by self-reference is frequently encountered in the literature. For example, Beede et al. (2007) state that the meaning of "STEM is fairly specific in nature—referring to science, technology, engineering and math" (p. 2). Gonzalez and Kuenzi (2012) define STEM as "teaching and learning in the fields of science, technology, engineering, and mathematics" (p. 1). Petersen (2014) posits that "STEM (science, technology, engineering, and mathematics) education is an educational initiative . . . designed to provide students with content and skills necessary for success in STEM career fields" (p. 12). The report of the Academic Competitiveness Council (U.S. Department of Education, 2007) notes that "Science, Technology, Engineering, and Mathematics education programs are defined as those primarily intended to provide support for, or to strengthen, science, technology, engineering, or mathematics (STEM) education at the elementary and secondary through postgraduate levels" (p. 11). The tendency to use STEM to define itself might be changing, however, as it has been observed that STEM has begun to "encompass a broader, more integrated and inclusive meaning" (Surr et al., 2016, p. 3), changing from a "content-specific definition . . . to a more epistemic one" (Moon & Singer, 2012, p. 32).

An important distinction when defining STEM is whether one is referring to teaching and learning or STEM-based careers. Sanders (2008) observes that many educators "say 'STEM'

when they should be saying 'STEM education,' overlooking that STEM without education is a reference to the fields in which scientists, engineers, and mathematicians toil" (p. 20). Unfortunately, "there is no universally accepted way to define a STEM occupation or group of STEM occupations" (Oleson et al., 2014, p. 3). The National Science Foundation includes social sciences such as sociology, political science, and psychology in their classification of STEM (Green, 2007), while many researchers do not (e.g., Carnevale et al., 2011; Chen & Weko, 2009; Hill et al., 2010; Kuenzi, 2008). Thomasian (2011) notes that some research includes sales and management jobs in the classification of STEM jobs, while others exclude them. Studies have been inconsistent in classifying positions in medicine and other healthcare professions as STEM careers (Oleson et al., 2014; Sadler et al., 2012; Veenstra et al., 2008). There is also disagreement about whether educators who teach one or more of the STEM disciplines should be considered to be employed in a STEM profession (Chen & Soldner, 2013; Hill et al. 2010; Thomasian, 2011).

Another difficulty in defining STEM is that there is confusion regarding the meaning of technology, one of the four disciplines contained in the acronym. Many educators and policymakers perceive that technology just means the use of computers (Bybee, 2000; Daughtery, 2009; Sanders, 2008; Kelly, 2010; Salinger & Zuga, 2009). The majority of technology educators contend that the "T" in STEM refers to technology education, which should not be confused with educational technology (Kelley, 2010). However, Wicklein (2006) observes that technology educators do not agree on the curriculum or focus of technology education. Also, Barakos et al. (2012) note that that the definition of technology is not well-defined. The *Standards for Technological Literacy* characterize technology as a distinct discipline that produces "knowledge and processes to develop systems that solve problems"

(Bartholomew, 2015, p. 17), whereas technology in the *Next Generation Science Standards* is defined as a byproduct or "application of science" (p. 16). Bybee (2000) argues that the "idea that technology is applied science" (p. 23) is flawed. Regardless of how technology is defined, Rose (2007) found that among STEM leaders at the national level, technology "was not considered to be an equal partner in efforts to build interdisciplinary knowledge" (p. 50) among the STEM disciplines.

Katehi et al. (2009) suggest that "engineering might be called the missing letter in STEM" (p. 20). Engineering education integrates the four STEM disciplines since it necessarily includes the use of mathematics, science, and technology (Katehi et al., 2009; Wicklein, 2006). However, unlike the other STEM disciplines, engineering is relatively new to K-12 education (Carr et al., 2012; Daugherty, 2009; Ostler, 2015). Although Salinger and Zuga (2009) contend that engineering is essential to STEM education, Honey et al. (2014) stress that "there is no formal agreement on what constitutes engineering knowledge and skills at the K-12 level" (p. 19). Bybee (2010) notes that when educators talk about implementing STEM, they rarely mean engineering or technology education. However, if STEM is perceived by students to be engineering, it may substantially reduce the number interested in it (Herschbach, 2011). Mitts (2016) insists that some of the prominent STEM definitions do not mention anything about activity-based learning, which is a key component of engineering education. Rissmann-Joyce and El Nagdi (2013) concur, suggesting that in addition to engineering, the "E" in STEM represents "engagement, or active learning" (p. 3). Williams (2011) asserts that the "E" in STEM should be eliminated "because engineering is actually a sub-set [*sic*] of the broad area of technology" (p. 30).

Some scholars contend that STEM means an integrated approach to education (Asunda,

2011; Brown et al., 2011; Dugger, 2010; Wang et al., 2011). However, there is no consensus that STEM implies an integration of the four disciplines (Roehrig et al., 2012; Sanders, 2008), nor is it commonly integrated in practice (Breiner et al., 2012; Katehi et al., 2009). Nathan et al. (2013) observe that there is a "lack of a theoretical framework for understanding integrated STEM education" (p. 138). Even the use of the term "integration" is problematic. According to Berlin and Lee (2005), "There has been a plethora of terms…used to refer to 'integration;' for example, connections, cooperation, coordinated, correlated, cross-disciplinary, fused, interactions, interdependent, interdisciplinary, interrelated, linked, multidisciplinary, transdisciplinary, and unified" (p. 18). Many of these terms are used interchangeably (Dyer, 2003; Wall & Shankar, 2008). However, the terms have different meanings. For example, if STEM is a multidisciplinary approach, it indicates that distinct academic subjects are taught concurrently (Mobley, 2015). In contrast, an interdisciplinary approach provides "collaboration and interactions between disciplines" (Park & Son, 2010, p. 83).

There is also disagreement about the benefits of an integrated instructional approach. Loepp (1999) holds that integration promotes learning. A meta-analysis of 30 studies also supports the premise that curricular integration results in higher student achievement (Hartzler, 2000). However, Czerniak et al. (1999) insist "there is little research evidence that curriculum integration is a better way to provide instruction than traditional discipline-specific methods" (p. 427). Nathan et al. (2013) agree that there is a lack of empirical support for an integrated approach to STEM education. Also, Lederman and Niess (1997) assert that "integrated . . . approaches ignore the conceptual, procedural, and epistemological differences that exist between the various areas of mathematics and the sciences" (p. 58). Even if an integrated approach to STEM is desirable, it would likely be difficult to achieve due to constraints such as the need to

overhaul existing curricular structures and provide interdisciplinary training for teachers

(Williams, 2011).

A definition of STEM that has been gaining traction in recent years on countless websites

(e.g., www.cde.state.co.us/stem; www.iowastem.gov/about; www.wistem.org/network.html) and

in a number of research articles (e.g., Ejiwale, 2013; Reeve, 2015; Wooten et al., 2013) is the

following attributed to Tsupros et al. (2009):

> STEM education 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.

However, a close reading of Tsupros et al. (2009) indicates that the definition frequently

attributed to them does not appear in the publication. The definition apparently has its origin in

the glossary of a long-range plan published by the Southwest Pennsylvania STEM Network

(Slavit et al., 2016). This is a prime example of just how elusive is a clear definition for the

meaning of STEM within the academic literature.

Adding to the confusion surrounding the meaning of STEM is the ongoing proliferation

of adaptations of the acronym. Some of these adaptations are subtle, such as making the T and E

in STEM lowercase (i.e., SteM) to indicate that the subjects of science and mathematics are

receiving the main emphasis (Dugger, 2010). In other cases, the changes are more evident on the

surface, but their definitions are nebulous. In the literature, pSTEM normally refers to physical

science integrated with technology, engineering, and mathematics (e.g., Lewis et al., 2017;

Miller & Wai, 2015; Stout et al., 2016), but pSTEM can also stand for prospective STEM

educators (Dunlap et al., 2016). Ambiguity also surrounds eSTEM, which can refer to "digital,

technology-focused STEM" (Jaeger, 2013, p. 11), in the same manner as an eBook indicates a

book in digital form, or it can stand for environmental STEM (Dostál & Prachagool, 2016). Langdon et al. (2011) use $E_{STEM}$ to indicate the number of people employed in STEM fields. And to further complicate the meaning of the letter E appearing in front of STEM, ESTEM is regularly used in scientific literature to refer to environmental scanning transmission electron microscopes or microscopy (Martin et al., 2015).

Modifications of the STEM acronym are also ambiguous in the health sciences. The most straightforward adjustment is STEM+H, which refers either to STEM plus health or STEM and the health sciences (Wallace et al., 2015). Aschbacher et al. (2014) refer to students' career options in science, technology, engineering, and the medical fields as STE–M. The acronym STEMM is used to show the integration of the traditional STEM disciplines with medicine (Isaac et al., 2012; Wynn & Walsh, 2013). The second M in STEMM can also refer to the medical sciences, such as epidemiology or pharmaceutical science (Moors et al., 2014). STEM$^2$ is sometimes used in place of STEMM (Tumeo & Kendrick, 2015). However, a double M at the end of the acronym does not necessarily indicate the integration of the STEM disciplines with medicine or the medical sciences. For example, Cornelius (2011) uses STEMM to indicate the integration of STEM and multimedia. STEMM is also used to indicate science, technology, engineering, mathematics, and management (Febbraro & Pickering, 2015).

Adaptations of the STEM acronym become even more complex with the addition of the letter I. There is ISTEM which is used in the literature for integrative STEM (Felix et al., 2010) and iSTEM which stands for integrated STEM (Hodges et al., 2016). Italicizing the "I" and adding a hyphen, one has *i*-STEM, defined as interdisciplinary STEM (Buche, 2014). However, the letter "I" does not necessarily suggest that STEM is either interdisciplinary or integrated. For example, STEM-I denotes STEM plus imagination (Lou et al., 2014). Dickerson et al. (2016) use

iSTEM to represent instrumental STEM, an instructional model where students learn to "design, build, and maintain the tools and instruments they need to do authentic scientific inquiry" (p. 139). ISTEM sometimes means inclusive STEM that targets disadvantaged students (Lynch et al., 2013), and iSTEM has also been used to refer to inclusive STEM for students with special learning needs (Goeke & Ciotoli, 2014). Further distorting definitional clarity, iStem is used in the scientific literature to indicate the Inclusion Stem, an RNA secondary structure that regulates splicing of the exon 4 cluster in pre-mRNA (Kreahling & Graveley, 2005).

STEAM is a common mutation of the STEM acronym. STEAM typically means that the arts are intentionally integrated into science, technology, engineering, and mathematics instruction (Daugherty, 2013, Henriksen, 2014). Yakman (2012) includes the "social, fine, manual, physical, and liberal arts" in her definition of STEAM (p. 15). However, the A in STEAM does not always signify the arts. Some educators use STEAM to represent science, technology, engineering, and applied math (Dostál & Prachagool, 2016). Others have used STEAM to designate instruction that combines the teaching of STEM with agriculture (Mitra et al., 2015). There is STEAM-H, where the A represents agriculture and the H refers to health (Toni, 2014). And for anyone who thinks they have a handle on the definition of STEAM, Balasubramanian (2014) uses it to indicate a blending of science, technology, environment, agriculture, and medicine. Used in this sense, STEAM is about the integration of science and technology with sustainable, environmentally sensitive land use, innovative agricultural practices, and health and nutrition research to provide for a rapidly growing population.

Where there is STEAM there is STREAM!  Some educators and scholars have proposed that more than the arts (or agriculture) should be incorporated into STEM education. For example, reading has been integrated into the curriculum to create STREAM (Harvey, 2010;

Ostler, 2012; Turner, 2013). Root-Bernstein and Root-Berstein (2011) call for the development of STREAM through the incorporation of writing into STEM programs. They argue that the thinking and observational skills needed for success in the writing process are also essential for proficiency in STEM. However, STREAM does not necessarily indicate that reading and/or writing have been infused into STEAM education. The R in STREAM is periodically used to indicate robotics (Johnson, K., 2016; Stubbs & Yanco, 2009). The arts may be dropped to form STREM – science, technology, robotics, engineering, mathematics (Dostál & Prachagool, 2016). Gartrell (2016) defines STREAM as "science, technology, relationships, engineering, arts, and mathematics" (p. 56). At times the R in STREAM denotes research (Delp, 2016). Dhuyvetter (2016) states that the R in STREAM stands for religion to attest that the Catholic school system infuses faith into STEAM education. To top it off, Mitts (2016) uses the tumescent acronym STREAMS to describe the addition of social studies to STREAM education. This is enough to make any educator want to SHTREAM, which is the unpronounceable acronym used to represent the incorporation of history (Doig & Jobling, 2016) or the humanities (Johnson, E. D. M., 2016) into the STREAM fields.

In summary, defining the meaning of STEM is problematic. Originally coined as SMET by the National Science Foundation in the early 1990s, the acronym was changed to STEM a decade later to stress the interconnectedness of the disciplines of science, technology, engineering, and mathematics, and to avoid an overemphasis on math and science. While many scholars define STEM education as the integration of the four academic disciplines, there is no consensus in the literature that STEM education means an integrated approach, nor is it commonly integrated in practice. There are also divergent opinions about what an integrated instructional approach represents, whether an integrated approach is desirable, and if the existing

curricular structures in America's schools make an integrated approach attainable.

STEM is often confused with stem cell research or the part of a plant. There is also no universally accepted definition of what constitutes a STEM job. The plethora of STEM acronyms compound the confusion regarding its meaning (e.g., pSTEM, eSTEM, iSTEM, STEM-I, STE-M, STEMM, STEM2, STEAM, STREAM). For many educators, STEM simply means instruction in math and science. The "T" and "E" in STEM are frequently overlooked, especially due to the ambiguity surrounding what constitutes K-12 technology and engineering instruction. Without a "common operational definition" (Breiner et al., 2012, p. 9), STEM has become "a generic label for any event, policy, program, or practice that involves one or several of the STEM disciplines" (Bybee, 2010, p. 30).

**Origins of the STEM Discipline**

While the STEM acronym has a relatively recent origin, "historical precedents for distinguishing STEM from other disciplines may be considerably older than the 20th Century [*sic*]" (Geldis, 2014, p. 7). Grouping the STEM fields apart from other academic subjects dates back to the Middle Ages with the trivium/quadrivium distinctions of classical education (Abeles, 2014; Contakes, 2015; Veith, 2012). The trivium incorporated the subjects of grammar, logic, and rhetoric (including poetry and literature), whereas the quadrivium was comprised of astronomy, music (harmonics), arithmetic, and geometry (Bugliarello, 2003; Grimenstein, 2012). While the trivium was associated with the liberal arts, the quadrivium "became firmly aligned with the 'hard' (or pure) sciences" (Ziedler, 2016, p. 17). As Muller (2009) notes, "At the heart of the medieval university . . . was the distinction between 'liberal' and 'mechanical', . . . the distinction between the Trivium and the Quadrivium, the foundational distinction between the Humanities and the nascent Sciences" (p. 206).

Classical education continued to be the dominant model in America's colonial period (Cohen, 1998). However, Benjamin Franklin published a tract entitled, "Proposals Relating to the Education of Youth in Pennsylvania" in 1749, which called for the establishment of an academy that would emphasize more practical subjects (Haubenreich, 2012; Mumford, 2002). Salinger and Zuga (2009) assert that interest in STEM education was sparked by this publication, which proposed that "topics such as grafting, planting, inoculating, commerce, manufactures, trade, force and effect of engines and machines, and mechanics . . . be taught" (p. 4). Franklin believed that instruction should be centered upon "experimentation and the deduction of principles from it" (Thorpe, 1893, p. 30). This conviction was heavily influenced by the writings of English philosopher John Locke, who asserted that people acquire knowledge and understanding through sensory experience (Chaplin, 2006; Webb, 2006). Although his academy opened in 1751, unfortunately, "Franklin's vision for the school was not . . . realized" (Webb, 2006, p. 90).

Some scholars trace the federal role in STEM to George Washington and the First Congress (Gonzalez & Kuenzi, 2012). Much like his contemporary, Benjamin Franklin, Washington was influenced by Enlightenment philosophers such as John Locke and George Turnbull, who "sought to use logic, grounded in empirical observation, to expand knowledge" (Cook & Klay, 2014, p. 45). At his home in Mount Vernon, George Washington "promoted improvement by experimenting, kept records of his observations, and shared his findings when possible" (Kindell, 2012, p. 359). Washington was the first to suggest that a national university for engineering should be established at West Point (Grayson, 1980; Seely, 1999). Passionate about an educated citizenry, he advocated for young people to be schooled in moral philosophy, the natural sciences, the branches of mathematics, and history (Cooke & Klay, 2014). It was

during this primordial period of the federal government that the Land Ordinance of 1785 was passed, establishing townships in the Northwest Territories that were divided into lots, with one lot in each township "to be preserved for the maintenance of a public school" (Gonzalez & Kuenzi, 2012, p. 30).

The underpinnings of STEM education were further advanced as a consequence of the American military effort during the American Revolutionary War. Technical assistance for the armed forces was lacking, as exemplified by George Washington's lament, "I sincerely wish this camp could furnish a good engineer" (Cullum, 1879, p. 9). The need to develop better military fortifications and ordnance for the war effort led the Continental Congress to authorize the establishment of the Corps of Engineers. West Point, New York, which served as an army outpost during the Revolutionary War, became the home for the corps in 1794 (Grayson, 1980; Katehi et al., 2009). The corps was initially educated in military subjects at West Point, but a fire closed the school in 1796, and it remained closed until the turn of the century (Forman, 1965; Grayson, 1980).

In 1800, Secretary of War James McHenry called for engineering training at West Point to expand beyond military needs to encompass "public buildings, roads, bridges, canals and all such works of a civil nature" (Grayson, 1980, p. 375). In response, Congress established the United States Military Academy at West Point in 1802 (Forman, 1965); it became "the first and one of the foremost schools of professional engineering in the nation" (Weigley, 1962, p. 27). Butz et al. (2004) and Jolly (2009) identify the founding of the United States Military Academy as the initial federal STEM initiative. However, Reynolds (1992) recounts that at first, the cadets at West Point were taught through methods of apprenticeship rather than a well-defined program of studies. Nevertheless, starting in 1817 under the direction of Sylvanus Thayer, West Point

implemented a formal curriculum that provided its students with a "scientific, mathematical, and engineering education" (Reynolds, 1992, p. 463). Thayer divided the Academy's curriculum over four years, created a grading scale, and delineated the subjects required for graduation, establishing a program that would eventually become the model for engineering education in the United States (Grayson, 1980). Shortly after Colonel Thayer began directing West Point, the American Literacy, Scientific, and Military Academy was established in 1819 at Norwich, Vermont by Alden Partridge, a West Point graduate. Later renamed Norwich University, it became "the first civilian school of engineering in the country" (Grayson, 1980, p. 376).

The first technical schools in America were established in the 1820s to provide students with an "education in the practical applications of science and mathematics" (Wang & King, 2009, p. 52). The Rensselaer School in Troy, New York, later renamed the Rensselaer Polytechnic Institute, is frequently credited as the nation's first technical school (Carlin & Manson, 2007; Salinger & Zuga, 2009; Vincent, 2003; Whitman, 1898). Founded by Steven Rensselaer in 1824, the Rensselaer School was created to train students "in the application of science to the common purposes of life" (Feisel & Rosa, 2005, p. 122). Other scholars assert that the Gardiner Lyceum in Maine was the nation's first technical institute (Reynolds, 1992; Smith, 1951; Wang & King, 2009). However, Lang (2002) and Waterous (1989) characterize the Gardiner Lyceum as the nation's first agricultural school. There is also some debate regarding when the Gardiner Lyceum was established. Wang and King (2009) list the establishment of the Gardiner Lyceum as 1821. Both Gillett (1962) and Grayson (1980) assign the founding to 1822. Reynolds (1992) and Smith (1951) place the start of the Gardiner Lyceum as 1823. Meanwhile, Waterous (1989) states that it was founded either in 1821 or 1823.

In addition to laying claim to Rensselaer, the nation's first technical school, Troy was

also the home of the Troy Female Seminary, the first endowed school in America for the education of women (Flexner & Fitzpatrick, 1996; Torche, 1965). The Troy Female Seminary was founded in 1821 by Emma Hart Willard, who believed that women should learn mathematics and science in addition to the domestic arts such as embroidery, painting, and household management that made up the traditional curriculum for females at the time (Rossiter, 1982; Stevens, 1995). As a young woman, Willard realized that her gender was being "deprived of the study of higher mathematics because their brains were not considered equal to the strain" (Flexner & Fitzgerald, 1996, p. 24). When she was unable to take academic courses at Middlebury College because she was a woman, Willard developed a plan to open an educational institution that could engage young women in a rigorous curriculum (Repousis, 2004; Fowler, 1859). In the plan, which was presented to the state legislature to request financial support, Willard asserted, "Natural philosophy [physics] has not often been taught to our sex. Yet why should we be kept in ignorance of the great machinery of nature?" (Willard, 1819, p. 19). Although the state legislature did not provide any money, the city council of Troy authorized funds for the school (Fowler, 1859; Repousis, 2004, Rossiter, 1982).

Stevens (1995) posits that the Troy Female Seminary "was an attempt to induct American women into the new culture of science and technology" (p. 146) that was powering the Industrial Revolution. At the Troy Female Seminary, women were offered a course of study which "approximated that of contemporary men's colleges" (Repousis, 2004, p. 455). Students had the opportunity to learn subjects such as mechanics, hydrostatics, algebra, geometry, trigonometry, chemistry, botany, physiology, physics, and astronomy (Rossiter, 1982; Stevens, 1995). Innovation was apparent in the Seminary's pedagogy as well. Almira Hart Lincoln, Willard's sister, developed several scientific textbooks known for their practical descriptions and

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illustrations of experiments (Badilescu, 2001; Scott, 1978). Also, Scott (1978) observes that

Lincoln at the Troy Female Seminary together with Amos Easton at the nearby Rensselaer

Polytechnic Institute "may have been the first teachers in the country to permit their students to

carry out their own experiments" (p. 690). Lincoln's description of such experiments exemplifies

the level of technical knowledge required of students at the Seminary:

> The young ladies of the Seminary of Troy N.Y. who are in the habit of performing
> chemical experiments in their daily exercises and at the public examinations, have by
> means of a suitable apparatus, exhibited some splendid experiments, to illustrate the
> burning of hydrogen and carburetted hydrogen. (Badilescu, 2001, p. 118)

Although few of the graduates of the Troy Female Seminary became part of the STEM

workforce, many of them entered the teaching profession, where they could advance a "vision of

scientific and technological progress to new generations" (Stevens, 1995, p. 147).

Engineering and technology instruction became increasingly available to students over

the next several decades. "One strategy was to graft technical education onto existing American

colleges" (Seely, 1999, p. 17) through the use of lectures and partial courses. Charles

Bonnycastle, a mathematics professor at the University of Virginia, inserted "engineering topics

in his science and mathematics courses in the late 1820s" (Reynolds, 1992, p. 470). Columbia

University offered lectures on topics such as machinery and mechanics by 1830, and Princeton

provided "a regular series of lectures in civil engineering outside the regular curriculum"

(Reynolds, 1992, p. 468) as early as 1832. The University of Michigan provided technical

courses for its students beginning in 1837 (Seely, 1999). However, Grayson (1980) has education

in the technical fields commencing at Michigan in 1852. Partial courses in engineering were

introduced at Rutgers in 1841 and Brown in 1845 (Reynolds, 1992). Harvard and Yale initiated

technical training in 1847 (Grayson, 1980; Seely, 1999). Technical education started at

Dartmouth in 1851 and the University of Pennsylvania in 1856 (Seely, 1999).

"An important contribution to the advancement of STEM education was the Morrill Act of 1862" (Bailey et al., 2016, p. 4). White (2014) describes the Morrill Act as the most significant event in the historical evolution of STEM education in America. Sponsored by Senator Justin Morrill of Vermont, the legislation was signed into law by Abraham Lincoln (Chapman, 1940; Schejbal & Wilson, 2008; Scott & Sarkees-Wircenski, 1996; Vincent, 2003). It provided for each state to receive a land grant from the federal government to establish at least one institution of higher education dedicated to "instruction in agriculture and the mechanic arts" (Flemming, 1960, p. 133). According to Chapman (1940), the law led to "the establishment of the most comprehensive system of scientific, technical, and practical" (p. 54) instruction ever known. Although it was mainly intended to improve farming practices and job skills, the Morrill Act "spurred the development of science and engineering programs in every state" (Butz et al., 2004, p. 50). Some notable land-grant institutions that were founded during the 1860s and 1870s under the provisions of the Morrill Act include Cornell University, Virginia Polytechnic Institute (Virginia Tech), the University of Illinois (originally called the Illinois Industrial University), The Ohio State University (first known as the Ohio Agricultural and Mechanical College), and Purdue University (Brunner, 1966; Chapman, 1940; Scott & Sarkees-Wircenski, 1996; Seely, 1999; Smyth, 1922; Zirkle et al., 2006). The curricula that emerged from the land-grant colleges marked the first time that classical subjects such as mathematics and literature were fully incorporated into mechanical and agricultural courses without being regarded as superior to the vocational material, establishing "the concept of integrated academics" (Gordon, 1999, p. 37).

The integration of academic and vocational subjects was not limited to land-grant institutions, however. Merrill (2000) and Sanders (2008) place the first formal attempt to connect

the subjects of science, technology, engineering, and mathematics with the manual training movement developed in the 1870s by Calvin Woodward, a mathematics professor at Washington University in St. Louis. Noting that his pupils struggled to create models to illustrate engineering principles, Woodward began experimenting with the integration of shopwork into his curriculum to help students learn how science and mathematics are applied in technical work and design (Katehi et al., 2009). There is a lack of clarity in the literature regarding when this integrative approach commenced. Woodward instituted the integration of manual training with science and mathematics in either 1870 (Katehi et al., 2009), 1871 (Coates, 1923), 1878 (Scott & Sarkees-Wircenski, 1996), or sometime in the late 1870s (Sanders, 2012). However, Woodward (1887) recounts that he began the work in 1872. Known as the founder of technology education in America, Calvin Woodward was "the first to promote and investigate an integrative approach to STEM instruction as best practice" (Sanders, 2012, p. 3).

Inspired by his early success with manual training, in 1880 Professor Woodward opened the Manual Training School of Washington University (Coates, 1923; Floyd, 2005; Scott & Sarkees-Wircenski, 1996). At this school, Woodward eventually formulated a STEM curriculum based "simultaneously on five parallel lines" (Woodward, 1896, p. 48). His program included the fields of science, mathematics, drawing, literature, "and tool work in woods and metals" (Lewis, 1993, p. 183). Believing that all subject areas were critical to a student's cognitive development, Woodward (1896) specified that in his approach "scholarship . . . is based on success in all the five features of the programme. Shopwork and drawing count equally with mathematics, science, and literature" (p. 130). Holding that other schools were doing a disservice to their students by engaging them only in abstract principles (Scott & Sarkees-Wircenski, 1996), he argued that his students were able to learn more through the integration of the disciplines "than by omitting

manual training" (Woodward, 1896, p. 181). Woodward is consequently acknowledged as pioneering "the idea of integrating praxis—the doing of technological activity—with academic subjects" (Sanders, 2003, p. 65). Korwin and Jones (1990) suggest that Woodward's emphasis on hands-on learning continues to be a focus of technology and engineering education today.

Recognizing there was little agreement at the secondary school level regarding appropriate subject offerings and content, the National Educational Association formed a commission in 1892 that became known as the Committee of Ten. Under the direction of Charles Eliot, the President of Harvard University, the Committee of Ten was charged with developing uniform college admission requirements and high school curricula (Nakhleh et al., 2002; Sheppard et al., 2007). Both Krug (2012) and Ostler (2012) trace the history of STEM education in the United States back to the Committee's work. The Committee of Ten advanced STEM education in several ways. Their report, published in 1894, stressed that mathematics should be part of the core curriculum (Cotti & Schiro, 2004). The Committee of Ten also established a major curricular role for science (Haury & Rillero, 1994; Reed, 2007). The Committee's work was the first attempt at creating national content standards, including standards for mathematics, science, and engineering education (Carr et al., 2012; Farmer et al., 2005; Kirst & Usdan, 2009; Wysession, 2013). Students were to "be taught through active learning" (Kirst & Usdan, 2009, p. 6), which is a hallmark of contemporary STEM pedagogy. Hands-on laboratory work was to be used extensively in science instruction, particularly in biology, chemistry, and physics (Bybee, 2011; Nakhleh et al., 2002; National Educational Association, 1894). The Committee's report called for higher qualifications for science teachers, noting that science instructors should have "a preparation at least as thorough as that of their fellow teachers of mathematics" (National Educational Association, 1894, p. 28). The Committee of Ten (National Educational Association,

1894) also promoted academic preparation for STEM careers by recommending "that both

Physics and Chemistry be required for admission to college" (p. 118) and insisting that "pupils

should have as much mathematical knowledge as possible" (p. 119).

Despite numerous educational reforms in support of STEM education, the Committee of

Ten has been sharply criticized by some STEM scholars for establishing a "siloed" curriculum in

America's schools (Honey et al., 2014; Mohr-Schroeder et al., 2015; Morrison, 2006; Wraga,

2009). Meanwhile, other researchers credit the Committee of Ten with promoting curricular

integration (Kingcha et al., 2017; Nelson, 1992; Ostler, 2012). The Committee's report appears

to support interdisciplinary content and teaching since it emphasizes that "different subjects

should be correlated and associated with one another by the programme and by the actual

teaching" (National Educational Association, 1894, p. 16). But Wraga (2009) contends that the

report does no more than "pay lip service to subject interrelatedness and to application of subject

matter" (p. 89). While a "siloed" curriculum may have been implemented in practice in the

decades following the Committee's report, there should be little doubt, however, that the

Committee of Ten endorsed the concept of content integration. An article published in the *School

Review* in 1894 makes the following observation about the Committee of Ten's

recommendations:

> The traditional curriculum separates each subject from every other; reads in reading-books; writes in writing-books; spells words in spelling-books; studies geography in geography books; grammar in grammar books; literature in literature-books: all without the slightest intimation that one of these abstract and bookish subjects has any relation to another; or that they all together have anything to do with reality and life. Each subject must be acquired by a dead lift. Each piece of information is stowed away in a separate pigeon hole of the memory; whence it can be drawn out for examination and exhibition; but to which the pupil would never think of going for ordinary exercise and use. . . .
>
> On the contrary the Committee recommends "that the different subjects should be correlated and associated one with another by the programme and by the actual teaching,

and that every subject should help every other; and that the teacher of each single subject should feel responsible for the advancement of the pupils in all subjects, and should distinctly contribute to this advancement". [*sic*] (Huling, 1894, pp. 629-630)

There is also a lack of consensus in the literature about the merit of another facet of the Committee's work. The Committee of Ten proposed that curricular content and rigor should be the same for all students regardless of whether they planned to attend college (Kirst & Usdan, 2009; Ravitch, 1983). Lee and Ready (2009) find it problematic that the curriculum outlined by the Committee of Ten "did not differentiate students heading for work from those bound for college" (p. 137). Other scholars who are critical of the Committee's "one size fits all" curriculum include Baines and Stanley (2006) and Tienken and Orlich (2013). Kantor and Lowe (2011), however, contend that a rigorous academic curriculum for all is necessary to ensure that "poor and working-class families" (p. 17) have equal access to professional careers. At the time the Committee of Ten's report was released, Charles DeGarmo, President of Swarthmore College in Pennsylvania, also praised its call for all students to receive the same instruction:

> So long as he chooses to remain in school, the training given to the son of the artisan or the farmer shall not differ, so far as any given study is concerned, from that of the future scientist, statesman or professional man. Not only is the principle to hold good for social classes, but it is to be equally valued for the sexes. (DeGarmo, 1894, p. 275)

However, Nelson (1992) refers to such praise as artificial, since "high school students comprised only a small percentage of the total school population at that time" (p. 247). Also, despite Charles DeGarmo's glowing assessment that the report provided for equality of the sexes and social classes, another tenet of the Committee of Ten has apparently proven detrimental to the advancement of women and minorities in the STEM fields. The Committee set forth that physics should be taught last in the science sequence, a recommendation that has been almost universally followed over the past 125 years. According to Sheppard and Robbins (2002), at the time of the

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Committee's report, almost all students enrolled in high school physics. However, since it is now placed last in the course sequence, today's students are far less likely to enroll in physics than if it had been placed in the freshman year. Consequently, only about 20% of secondary school graduates have ever taken a physics course, including just "15% of females and 10% of black and Hispanic students" (Sheppard & Robbins, 2002, p. 429). Such low participation rates inhibit the ability of women and minorities to pursue a STEM degree in college.

While the Committee of Ten was completing its work at Harvard, another key development in the historical origins of STEM took place in Chicago. In conjunction with the World Columbian Exposition of 1893, a series of international congresses were convened around topics such as commerce, engineering, medicine, education, religion, literature, and the progress of women (Johnson, 1898). In preparation for the Exposition's International Congress on Engineering, Ira O. Baker, an engineering professor at the University of Illinois, persuaded the organizers to include a section on engineering education (Grayson, 1980; Reynolds & Seely, 1993). When educators gathered together at the Congress, it marked "the first major meeting of engineering in which engineering education was recognized as an important subject" (Grayson, 1980, p. 381). It was during this Congress that the Society for the Promotion of Engineering Education (SPEE) was founded, "the first specialized professional society devoted solely to education" (Reynolds & Seely, 1993, p. 136).

Several factors contributed to the founding of the Society for the Promotion of Engineering Education. In the decades following the passage of the Morrill Act, preparation for a career in engineering was transitioning from an apprenticeship model where students learned in shops and factories to university-based classroom instruction. One of the reasons for this shift was that emerging technologies such as the electrical industry required engineers to be well-

versed in science and mathematics (Seely, 2005). There was also a lingering stigma associated with engineering that it was merely a vocational trade rather than an academic field on equal status with other professions. Engineering educators viewed "curricular revision as one means to elevate the social status of engineers" (Kynell, 1999, p. 145). The formation of SPEE at the Columbian Exposition ratified the belief that the university and not the shop floor should be the place for engineering preparation and "that engineering curricula should stress fundamental scientific and mathematical principles" (Reynolds & Seely, 1993, p. 136). Ostler (2015) suggests that since a major goal of SPEE was to formalize the integration of science and mathematics into engineering instruction, the Society's efforts can be considered America's "first recorded efforts in STEM learning" (p. 17).

The Society for the Promotion of Engineering Education "was an early voice pushing for STEM standards" (Carr et al., 2012, p. 541). However, notwithstanding its positive contributions to the field, the Society's actions had a chilling effect on the participation of women and minorities in STEM careers. Frehill (2004) asserts that "SPEE represented a unified effort on the part of academic engineers to establish academic training as a prerequisite for being an engineer" (p. 392). This created a structural barrier that made it difficult for women and minorities to gain access to engineering careers. As Frehill (2004) observes:

> The increasing significance of engineering education and the use of engineering colleges to screen out those people who were not considered fit to be engineers is one important mechanism by which middle-class men maintained control of the engineering profession. Most engineering programs were virtually closed to African Americans and other nonwhite people because of the racially segregated U.S. education system. And . . . educational institutions erected barriers to women's successful completion of engineering degrees. (p. 400)

SPEE also limited the participation of women at its annual meetings. A review of conference proceedings by Frehill (2004) revealed that before the First World War, the only women who

attended the Society's gatherings were the spouses or daughters of SPEE members. During

WWI, a few women were invited to SPEE meetings, but their role was limited to "presentations

about teaching English to engineering students and a 'Ladies Committee' that planned

entertainment for the conference attendees" (Frehill, 2004, p. 393). The membership of SPEE

made it clear that engineering was the province of men.

Shortly after the Columbian Exposition of 1893, John Dewey joined the faculty of the

University of Chicago. Considered the father of the progressive education movement in the

United States (Chenneville et al., 2012; Jayanandhan, 2009; Ravitch, 2000), Dewey believed that

it was critical for children "to develop to a robust understanding of the technology that underpins

their society" (Waddington, 2010a, p. 621). According to Webber and Miller (2016), Dewey

fostered the development of an "interdisciplinary, integrated and inquiry-based curriculum" (p.

1064), a key attribute of contemporary STEM education. Rejecting the didactic teaching methods

that were common at the time, he believed that instruction should be pragmatic and tied to a

child's real-life experiences (Dewey, 1902).

Together with his wife Alice, John Dewey opened a laboratory school at the University

of Chicago in 1896 to test his educational theories (Knoll, 2015; Ravitch, 2000; Sublette, 2013).

The Dewey School, as it came to be known, was the first laboratory school in the country

(Henson, 2003; Smith et al., 2016). To assist with the development of innovative activities for

the students, Dewey enlisted some of the top research scientists of the time including Albert A.

Michelson, John M. Coulter, Jacques Loeb, and Thomas C. Chamberlin (Rudolph, 2005). He

was determined that science should be taught in the laboratory school through a real-world

approach. As Ravitch (2000) observes,

In a traditional school, children might study science by memorizing the technical names

for different plants and their parts. In Dewey's school, children would plant seeds, observe how they grew, and consider the soil and climatic conditions that affected plant life. (p. 58)

Based on his observations of students in the lab school, Dewey concluded that "education rises or falls with our ability to make school life an interesting and absorbing experience to the child" (Dewey, 1913, p. ix).

Before the opening of the Dewey School, science education primarily consisted of "the plodding accumulation of facts" (Rudolph, 2005, p. 352). Science and technical knowledge were considered to be something that the teacher possessed and the student received, with a heavy emphasis on rote memorization. Even hands-on science experiments consisted of "rigidly prescribed laboratory manipulations" (Rudolph, 2005, p. 354). However, Dewey viewed his students "as active investigators, not passive recipients in the learning process, representing radical constructivism in mathematics and science education" (Han et al., 2015, p. 1093). In the Dewey School, students worked in cooperative learning groups on engaging and authentic tasks (Smith et al., 2005; Waddington 2010b). The teacher served as a facilitator of learning rather than a holder of knowledge (Barrow, 2006). Students had a "hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry" (Dewey, 1910, p. 125).

Dewey believed "that schools should be operated as microcosms of their communities" (Anderson, 2016, p. 13), providing authentic experiences based on real life. Mayhew and Edwards (1936), teachers at the Dewey School, affirm that Dewey's "main hypothesis was that life itself, especially those occupations and associations which serve man's chief needs, should furnish the ground experience for the education of children" (p. vi). Dewey, therefore, implemented an 'education through occupations' curriculum at the University of Chicago laboratory school (Castellano et al., 2003; Lacy, 2016; Waddington & Feinstein, 2016). Students

learned science and engineering principles as they studied occupations such as construction, metalworking, and textile manufacturing (Lacy, 2016). Work-related activities included everything from spinning wool to "the smelting of metals such as copper, tin, gold, [and] silver" (Mayhew & Edwards, 1936, p. 265).

Scott & Sarkees-Wircenski (1996) suggest that Dewey was a strong supporter of vocational education. He implemented the project method utilized in some manual training schools of the time, recognizing that his students liked "to construct things, to investigate and create" (Scott & Sarkees-Wircenski, 1996, p. 110). Dewey (1901) insisted that manual training "must be assigned a central position" (p. 197) within a school, connected with other subjects such as math and science (Lewis, 2004). However, he was sharply opposed to "the promotion of concepts like vocationalism" (Lacy, 2016, p. 21). Dewey believed that the purpose of vocational education was to help students comprehend technology and its role in society (Waddington, 2010a), not to teach "a narrow set of skills in preparation for future work" (Lacy, 2016, p. 21). As Frank H. Ball (1900), a teacher at the Dewey School, observed at the time, "Because we teach a child to saw or plane, it does not follow that we expect the child to be a carpenter. What we wish is to make the child think—to question—to wonder" (p. 177).

Many researchers trace curricular integration in the STEM fields back to Dewey and the progressive education movement (Corlu & Aydin, 2016; Corlu et al., 2014; Dowden, 2007; Loepp, 1999; Moore & Smith, 2014; Moore et al., 2014b; Watson & Watson, 2013). Dewey believed that curricula should be "interdisciplinary and multidisciplinary" (Smith et al., 2005, p. 90). As early as 1899, he argued in a lecture to university students that schools should avoid "teaching subjects isolatedly from each other" (Dewey, 1966, p. 189). Dewey posited that academic and vocational content should be integrated, connecting learning to real-world

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experiences (Grubb, 1996; Lewis, 1998; Mayhew & Edwards, 1936; Watson & Watson, 2013).

Reflecting on his observations at the laboratory school, Dewey (1900/1915) noted,

> We do not have a series of stratified earths, one of which is mathematical, another physical, another historical, and so on. We should not be able to live very long in any one taken by itself. We live in a world where all sides are bound together. All studies grow out of relations in the one great common world. . . . Relate the school to life, and all studies are of necessity correlated. (pp. 80-81)

Dewey believed that academic disciplines should not be taught in isolation since they are not segregated in real-world experiences (Dewey, 1938; Dewey, 1966).

One of Dewey's enduring contributions to STEM education was the ubiquitous five-step process of scientific inquiry, which he formulated based on his experiences in his laboratory school. Variously referred to as the scientific method, complete acts of thought, steps for critical or reflective thinking, or simply the method of inquiry, Dewey's process consisted of the following steps: "(i) a felt difficulty; (ii) its location and definition; (iii) suggestion of possible solutions; (iv) development by reasoning of the bearings of the suggestion; [and] (v) further observation and experiment leading to its acceptance or rejection" (Chedid, 2005, p. 83).

The main components of Dewey's method are still common in STEM education today (Cowens, 2006; Ellner, 2015; Gerde et al., 2013; Lakin et al., 2007; McGuire, 2015; Nichols & Stephens, 2013; Proulx, 2004). Crippen and Archambault (2012) posit that Dewey's inquiry process outlines "the acceptable tenets for how best to convey and teach STEM content" (p. 160). Also, Chedid (2005) recognizes that Dewey's model of inquiry represents the basic components of the engineering design process. It also reflects the method of problem-solving taught to engineering students (Mina et al., 2003). Rudolph (2005) states that Dewey's five-step process of inquiry would define "the scientific method for generations of students to come" (p. 367).

Despite the popularity of Dewey's model of inquiry, the method is not without its critics. Windschitl et al. (2008) argue that the five-step process is responsible for "allowing distorted images of science to be passed down through schooling practices" (p. 942). Waddington (2010a) suggests that "Dewey's faith in the scientific method may have been excessive" (p. 621). Bell et al. (2003) argue that teaching the scientific method to students is problematic because "there is no single prescribed set of procedures that all scientists follow when conducting investigations" (p. 497). Anderson (2008) contends that the concept of a step-by-step scientific method is irrelevant in an era when computers can use sophisticated statistical tools to analyze vast amounts of data to produce new understandings about the world.

Rudolph (2005), however, submits that "Dewey did not try to provide a stepwise account of how scientists went about their work" (p. 367). Recognizing that educators were misusing his five-step process as a rigid method for teaching the process of scientific inquiry, Dewey later published a rebuttal in a revised edition of his work, *How We Think*, which clarified the process in a section entitled, "The Sequence of the Five Phases Is Not Fixed" (Rudolph, 2005, p. 375). Nevertheless, the perception of the scientific method as a lockstep process describing how scientists conduct their work had already become firmly embedded in the curricula of America's schools.

Perhaps Dewey's greatest contribution to STEM education was his influence on the education of historically marginalized groups, particularly children from economically poor backgrounds and female students. As a pioneer in the progressive education movement, Dewey fostered the development of inquiry-based learning that connected instruction to students' real-life experiences, which has proven to be an especially powerful approach for teaching STEM to Indigenous populations (Miller et al., 2012). Dewey also recognized that schools could be

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vehicles of social reform (Clark, 2007; DeBoer, 2000; Ravitch, 2000). Rudolph (2003) notes that Dewey believed that science education "was one of the key means society had for ameliorating the social condition in which humanity found itself" (p. 71). He was convinced that technological and social change are closely intertwined (Waddington, 2010a). Dewey (1900/1915) once lamented, "How many of the employed are today mere appendages to the machines which they operate!" (p. 22). The Dewey School's emphasis on STEM learning helped students understand both the technology and social significance of their work, empowering them so that they would not "be marginalized and exploited by others in society" (Waddington, 2010b, p. 78).

Dewey was instrumental in advancing coeducation in his laboratory school, particularly in science and technology. Brickhouse (2001) suggests that Dewey was "committed to a coeducation that challenged gender ideologies of the day" (p. 292). Mayhew and Edwards (1936) affirm that "all the children (boys and girls being treated alike) have cooking, sewing, and carpentry" (p. 29). During shop work, girls constructed tool boxes, tables, and bookracks, and in science, they built a dynamo-motor (Mayhew & Edwards, 1936). Frank H. Ball (1900), who directed manual training at the Dewey School, asserted, "There is no reason why girls should not have this training in the lower grades as well as the boys" (p. 178). In the Dewey School, boys and girls worked together on common projects traditionally associated with boys, such as the construction of a clubhouse (Mayhew & Edwards, 1936). Gamo (2014) notes that Dewey's implementation of coeducational activities not only promoted mutual respect "but also the critical thinking, communication of ideas and intellectual honesty which characterise scientific research" (p. 20).

Dewey's laboratory school ended abruptly in 1904 when a disagreement with the president of the University of Chicago led to his resignation and departure for Columbia

University in New York City (Martin, 2002; Tanner, 1991). Ironically, the same year that Dewey

left Chicago for New York, America's first STEM school, Stuyvesant High School, was founded

in New York City (Gnagey & Lavertu, 2015; Kasza & Slater, 2017; Thomas & Williams, 2009).

Thomas and Williams (2009) assert that Stuyvesant was originally a manual training school,

while others describe it as a trade school (e.g., Judson, 2014; Means et al., 2008) or vocational

school (Tofel-Grehl, 2013). Hellman (2005) states that the school provided manual training not

for the purpose of operating a trade school, but as an essential component of "an extremely rich

environment of academic and intellectual activities" (p. 599). Erdogan and Stuessy (2015)

contend that Stuyvesant was founded to help students develop talent in math, science, and

technology, while Thomas and Williams (2009) claim that its primary purpose was "to prepare a

workforce with specific technical skills" (p. 18).

Congress adopted the Smith-Hughes Act in 1917, which provided federal funding for

vocational education (Scott & Sarkees-Wircenski, 1996). Also known as the Vocational Act of

1917, the Smith-Hughes Act inaugurated the federal government's financial commitment to

career and technical education in America's secondary schools, primarily through teacher

training (Bennett, 2016; Lynch, 2000; Salinger & Zuga, 2009). The influx of federal funds led to

the development of additional secondary schools specializing in math and science, including

Brooklyn Technical High School in 1922 and the Bronx High School of Science in 1938

(Atkinson et al., 2007; Kasza & Slater, 2017). Tofel-Grehl (2013) maintains that "Brooklyn

Technical and other magnet schools and STEM-specific programs of the time embraced a

fundamental ethos of inclusion" (p. 19) since they were committed to educating students who

were not necessarily college-bound. However, this "ethos of inclusion" apparently did not

include women. Erdogan and Stuessy (2015) observe that Stuyvesant began accepting female

students in 1969, while young women were not admitted to Brooklyn Technical High School until 1970.

The bombing of Pearl Harbor, which forced the United States into the Second World War, was a watershed moment for STEM in America. Winning the war would require scientific advances and innovation at a level unparalleled in our nation's history (Wissehr et al., 2011). Professionals from the fields of mathematics, science, and engineering collaborated at an unprecedented level to develop new or enhanced technologies such as radar, antimalarial drugs, penicillin, synthetic rubber, long-range rockets and aircraft, computers, and sophisticated scientific instrumentation (Brooks, 1986; Fortun & Schweber, 1993; Mukhopadhyay, 2008; White, 2014; Wooster, 1987). The Manhattan Project, which developed the world's first atomic bomb, was "the largest single-purpose technological enterprise ever established" (Herzenberg & Howes, 1993, p. 34).

A lack of qualified personnel in the STEM fields to conduct research and product development during World War II indicated "that schools were not meeting the educational needs of an increasingly technical workforce" (Wissehr et al., 2011, p. 369). The military draft and war casualties "depleted America of the young scientists and engineers capable of advancing the country's future technological capabilities" (Mastroianni, 2015, p. 37). Shortages of scientific and technical professionals opened the door for women to have much greater participation in the STEM fields. According to Rossiter (1995), more than 20,000 women engineers and scientists assisted with the war effort. At least 85 female scientists worked on the top-secret Manhattan Project, playing key roles in the development of neutron detection, nuclear reactor design, and methods for separating uranium isotopes (Herzenberg & Howes, 1993). Women also had an expanded role working in academia. Between 1942 and 1946, the number of women serving on

college and university faculties tripled (Rossiter, 1995).

During the war, many of the impediments to women receiving a STEM education were eliminated. Zapoleon (1950) observes that the war "removed almost all sex barriers to professional school admissions" (p. 20). From 1940-1945, 29 all-male engineering schools started admitting women, including Rensselaer Polytechnic Institute, the nation's first technical school (Rossiter, 1995). Countless publications during the war years encouraged "women to pursue careers in science and engineering" (Rossiter, 1995, p. 12). However, the expanded role for women in the STEM fields was muted following the war as male veterans enrolled in college under the GI Bill. Many colleges and universities limited the number of women who could enroll, particularly in the STEM fields, which were considered the proper place for men (Hartmann, 1982; Levine, 1995). For example, Cornell University, an engineering school where women comprised more than 50% of the student population during World War II, had a female enrollment of just 20% a year after the war ended (Hartmann, 1996, Levine, 1995). And while enrollment doubled in the nation's engineering schools during the fall of 1946, half of the programs did not admit women, who represented "fewer than 1,300 of the 200,000 enrolled" (Hartman, 1982, p. 110).

Before the Second World War, the role of the federal government in STEM was relatively limited (Jankowski, 2001). However, unprecedented advances in science and technology in support of the war effort convinced President Franklin D. Roosevelt and members of Congress that an enhanced federal role in STEM education and research might also be advantageous in times of peace. In November 1944, President Roosevelt requested that Vannevar Bush, Director of the Office of Scientific Research and Development (OSRD), "outline how lessons learned from the wartime organization of science and engineering could be applied in

times of peace" (Jankowski, 2001, p. 5). In the summer of 1945, Bush released a report entitled *Science the Endless Frontier*, which "elaborated a rationale for federal support of academic science" (Appel, 2000, p. 19). To support innovation in the public and private sectors, Bush argued that "there must be plenty of men and women trained in science and technology" (Bush, 1945, p. 13). He also called for the creation of an independent organization to be known as the National Research Foundation "for the promotion of scientific research" (Bush, 1945, p. 69). While the proposal advanced by Bush gained traction in Congress, President Truman vetoed legislation that would have established a National Science Foundation because he objected that the proposed agency would be controlled by scientists rather than the federal government (Tanner, 1969).

Despite the veto, like his predecessor, Truman was interested in identifying how the federal government could advance scientific knowledge and achievement. He established the President's Scientific Research Board in 1946 "to study the nation's science programs and to make recommendations for improvement" (Wissehr et al., 2011, p. 369). John R. Steelman was named by the President to serve as the chairman (Getman, 2016). In 1947 the Board released *Science and Public Policy*, commonly known as the *Steelman Report*. Like Vannevar Bush's report two years earlier, *Science and Public Policy* stressed the critical importance for an expanded federal role in STEM:

> The security and prosperity of the United States depend today, as never before, upon the rapid extension of scientific knowledge. So important, in fact, has this extension become to our country that it may reasonably be said to be a major factor in national survival. (Steelman, 1947, p. 3)

The *Steelman Report* called for the creation of a National Science Foundation to support scientific education and research, albeit one with "more limited scientific autonomy" (Holbrook,

2005, p. 438) than the agency proposed by Vannevar Bush. In concert, *Science the Endless Frontier* and *Science and Public Policy* charted the direction for federal science policy for the next half century (Getman, 2016; Jankowski, 2001; Pielke, 2010). Based on the recommendations contained in the two reports, President Truman eventually authorized the establishment of the NSF by signing the National Science Foundation Act of 1950, which addressed his earlier concerns by providing the President with the power to appoint "both a twenty-four member National Science Board and a full-time director" (Tanner, 1969, p. 19). The NSF awarded grants to graduate students seeking degrees in the STEM fields by 1952, and in 1953 it "began supporting teacher institutes as a means of improving STEM education in the lower grades" (Gonzalez & Kuenzi, 2012, p. 32).

In summary, the origins of the STEM discipline can be traced back to the Middle Ages with the trivium/quadrivium distinctions of classical education. Classical education continued to be the dominant model of education into America's colonial period. Benjamin Franklin's 1749 tract, "Proposals Relating to the Education of Youth in Pennsylvania," sparked interest in a hands-on, practical education in STEM topics such as mechanics, agricultural science, and manufacturing. George Washington is credited by some scholars as initiating federal involvement in STEM, due to his advocacy for educating young people in mathematics and the natural sciences, as well as his calling for the establishment of a national university of engineering to provide technical assistance for the armed forces.

The founding of the U.S. Military Academy at West Point in 1802 established America's first engineering school. The nation's first technical schools appeared in the 1820s. The Troy Female Seminary, founded in 1821, is credited with being the first program "to induct American women into the new culture of science and technology" (Stevens, 1995, p. 146). Throughout the

first half of the 19th century, instruction in the STEM fields became more readily available as colleges like Harvard, Yale, Rutgers, and Brown inserted technical instruction into their programming. The passage of the Morrill Act of 1862 encouraged the founding of dozens of land-grant universities and "spurred the development of science and engineering programs in every state" (Butz et al., 2004, p. 50). The manual training movement developed by Calvin Woodward at Washington University in St. Louis in the 1870s integrated drafting and shopwork with the study of math, science, and literature, pioneering the concept "of integrating praxis—the doing of technological activity—with academic subjects" (Sanders, 2003, p. 65).

The 1894 report of the Committee of Ten standardized secondary school curricula, anchoring mathematics and science as part of the core curriculum in America's high schools. The Committee of Ten report was the first attempt at creating national content standards for math, science, and engineering instruction, and it established laboratory work as an essential part of science education. At the dawn of the 20th century, John Dewey ushered in the progressive education movement with his innovative research at the University of Chicago Laboratory School, demonstrating the value of an integrated, inquiry-based curriculum tied to real world experiences, a key attribute of contemporary STEM education. The passage of the Smith-Hughes Act in 1917 marked the first federal financial commitment to career and technical education at the secondary school level. The subsequent influx of federal funding spurred the development of magnet schools specializing in math and science such as Brooklyn Technical High School.

The entry of the United States into the Second World War was a watershed moment for STEM, as winning the war required unprecedented collaboration among professionals in the fields of mathematics, engineering, and science. This coordinated effort across the technical fields led to the development of computers, synthetic rubber, penicillin, long-range aircraft, and

the atomic bomb, advances that proved essential in ending the war. Shortages of qualified professionals for technological research and development during the war effort confirmed that STEM education was imperative for national security and opened new opportunities in STEM for women. In the aftermath of WWII, Congress recognized that an enhanced federal role in STEM research and education would be strategically advantageous, leading to the creation of the National Science Foundation in 1950.

**What Started the Emphasis on STEM?**

With the Cold War underway in the early 1950s, critics charged that America's educational system had become lax, particularly in preparing students for success in mathematics and science. Fred McMillan, a professor of electrical engineering at Oregon State, reported that over half of the students who applied for admission to the engineering program at his school in the fall of 1951 had failed the school's mathematics entrance exam (McMillan, 1951). He blamed this on a secondary school curriculum which was not designed to prepare students for college-level work. Maynard Boring (1952), who worked in personnel services for General Electric, also complained that high schools frequently did not provide students with the foundation in math and science necessary for pursuing a technical degree at the college level. He noted that "there is much to be desired in fundamentals, even in the primary schools" (p. 139). Chief among the period's critics was Arthur Bestor, a history professor at the University of Illinois (Bybee, 2013; Feinberg & Odeshoo, 2000; Rudolph, 2002). He published two influential books, *Educational Wastelands: The Retreat from Learning in Public Schools* in 1953 and *The Restoration of Learning* in 1955 (Feinberg & Odeshoo, 2000). In these works, Bestor "blasted the low academic standards" (Cuban, p. 331) of America's public schools and called for a renewed emphasis on math and science (Feinberg & Odeshoo, 2000; Rudolph, 2002).

Criticism of public school curricula led to several reform efforts. Max Beberman inaugurated the New Math era in 1951 with the formation of the University of Illinois Committee on School Mathematics (UICSM) to begin an overhaul of high school mathematics curriculum (Bybee, 2013). This project marked the first time that "mathematicians were actively involved in contributing to K-12 school mathematics curricula" (Klein, 2003, p. 183). The UICSM project included unprecedented collaboration from the university's engineering, education, and liberal arts and sciences departments (Herrera & Owens, 2001). In 1955, the College Entrance Examination Board created a Commission on Mathematics to research the "mathematics needs of today's American youth" (Klein, 2003, p. 184). And in the science arena, Jerrold Zacharias started the Physical Science Study Committee (PSSC) in 1956, motivated by a desire to reform science education so that that it would be taught as it was "known and practiced by scientists" (Akcay & Yager, 2010, p. 603). However, Klein (2003) asserts that the curriculum reform efforts of such groups "received little attention until the U.S.S.R. launched *Sputnik*" (p. 184).

On October 4, 1957, the Soviet Union propelled Sputnik, a 184-pound metallic sphere the size of a beach ball, into outer space just hours before the CBS network showed the premiere episode of *Leave It to Beaver* (Dickson, 2001). This was the first time humans had successfully sent an artificial object into orbit around the Earth. Life for 'the Beaver' and millions of American schoolchildren would never be the same. The contemporary STEM education movement in the United States can be traced to this defining moment in American history (Bybee, 2013; Carter, 2013; Chedid, 2005; Chikoore, 2008; Sanders, 2008; Thomas & Williams, 2009). The media painted the Sputnik launch as a major disgrace for America, placing the blame on "the low quality of math and science instruction in the public schools" (Klein, 2003, p. 184).

Sputnik caused Americans to view the nation "as scientifically, technologically, militarily, and economically weak" (Bybee, 2013, p. 14). Flemming (1960) documents that Sputnik led to a "rigorous self-examination of our total education system" (p. 134). The panic that followed Sputnik's launch led to major investments in STEM education (Baber, 2015; Beach et al., 2012). Educational reform efforts, particularly in math and science, were rapidly accelerated (Bybee, 2013; Sanders, 2008).

A month following the Sputnik launch, President Eisenhower addressed the nation on November 7th, asserting that "one of our greatest and most glaring deficiencies is the failure of us in this country to give high enough priority to scientific education" (Dethloff, 1993, p. 4). A week later, an article in *U.S. News and World Report* noted that Russian students received far more rigorous instruction in science and mathematics than their American peers ("The 3 R's in Russia," 1957). The perception that the Soviet Union's educational system was superior in the STEM fields led Congress to pass the National Defense Education Act of 1958 (Jolly, 2009; Maguth, 2012). The NDEA is acknowledged as "the origin of modern STEM-specialized education in the United States" (Geldis, 2014, p. 9). It provided $1 billion in federal funding for a variety of programs aimed at empowering students with the technical knowledge and skills required for successful entry into the STEM workforce (Flemming, 1960). For example, Title III of the NDEA allocated matching funds to states to bolster math and science instruction through professional development and improved materials (Flemming, 1960; Jolly, 2009). Title V dedicated funding for the identification, assessment, and counseling of talented students (Flemming, 1960). Jolly (2009) contends that "passage of the NDEA catapulted gifted education into relevancy" (p. 51). However, Urban (2010) cautions that NDEA's emphasis on the intellectually gifted implied "a de-emphasis on expanding opportunity" (p. 5) for others.

The Sputnik launch placed increased pressure on educators to emphasize mathematics and science in the curriculum. Donald Maley, a professor of industrial arts (technology) education at the University of Maryland, recognized that the Sputnik reaction opened a door for the industrial arts discipline "to be more integrative" (Sanders, 2008, p. 24). As Maley (1959) observed,

> Where else in the school is there the possibility for the integration and application of the mathematical, scientific, creative, and manipulative abilities of youngsters to be applied in an atmosphere of references, resources, materials, tools, and equipment so closely resembling the society outside the school? (p. 12)

In a collaborative effort between the University of Maryland and the Montgomery County school district, Maley developed a new industrial arts course for junior high students that utilized an integrative approach (Love, 2015; Sanders, 2008). At a time when the STEM subjects were firmly standalone disciplines, Maley's 'Research and Experimentation' course "purposefully situated mathematics and science in the context of technological activity" (Sanders, 2012, p. 4).

The instructional model incorporated into Maley's course was comparable to the approach used today for technology and engineering education (Love, 2015). In his design, the teacher served as a facilitator of learning rather than the holder of knowledge. Students had the freedom to work on projects of their "own choice and design" (Maley, 1959, p. 14). The course was piloted with a group of ninth grade students at Montgomery Hills Junior High in Maryland. Based on his observations and interviews with students, Maley (1959) asserted that the 'Research and Experimentation' course was far more appealing to students than more traditional approaches. Students in the class designed a number of engaging investigations, such as the effect of varying temperatures on adhesives, the heat conductivity of different metals, and the creation of an induction heater. While his course included many facets of best practice in STEM

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instructional design, it fell short in one major area. Although the class included students across the spectrum of intelligence test scores, Maley (1959) reported that all students in the experimental class were male.

In a special address to Congress on May 25, 1961, President John F. Kennedy raised the stakes of the space race when he declared that the United States "should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth" (Kennedy, 1961, p. 908). According to DeJarnette (2012), the race to the moon "sparked a tremendous increase in spending for education" (p. 83). Frances Keppel, who served as U.S. Commissioner of Education under Kennedy, observed that "more time, talent, and money than ever before in history have been invested in pushing outward the frontiers of educational knowledge" (Keppel, 1963, p. 1005). The Apollo program also led to unprecedented levels of investment in technical research and design, fueling demand for highly qualified scientists and engineers (Asunda, 2011; Sobhan et al., 2006). Throughout the 1960s, the space race heightened student interest in science and technology, boosting university enrollments in the STEM fields (Hummel & Cheetham, 2012).

Asunda (2011) attests that Kennedy's speech "was a turning point for science, technology, math, and engineering initiatives in the school curriculum" (p. 8). Hugh Dryden, Deputy Administrator of NASA during Kennedy's administration, envisioned that space exploration would lead to "a demand for revision of the course material by scientists and educators working in collaboration" (Dryden, 1961, p. 8). His prognosis proved accurate. STEM curriculum reform in the 1960s included the Science Curriculum Improvement Study (SCIS), Time, Space, and Matter (TSM), Science: A Process Approach (SAPA), Earth Science Curriculum Project (ESCP), and the Elementary Science Study (ESS) (DeBoer, 1991; Wissehr et

al., 2011). According to Bybee (2013), "curriculum reform led by the scientific and mathematics communities" (p. 17) was one of the significant outcomes of Kennedy's lunar quest.

STEM curriculum reforms spawned by the space race gained moderate traction in America's schools. However, the political and social agenda of the 1960s and 1970s gradually changed the nation's attention from preparing a highly qualified corps of scientists and engineers to equality for the disadvantaged. Books by Freire, Kozal, Kohl, and Holt were critical of the prevailing educational structure (Bybee, 2013; Schubert, 1993). Bybee (2013) observes that as new STEM curricular materials were released, they were criticized "regarding their elitism, the lack of relevancy, and a lack of accommodation for the diverse range of students" (p. 18). President Johnson's War on Poverty included the passage of the Elementary and Secondary Education Act that placed a broad emphasis on equal educational opportunity (Iorio & Yeager, 2011). ESEA targeted equitable access, especially for low-income students and children with exceptional learning needs. Bybee (2013) posits that the political and social upheaval caused by the Vietnam War and the civil rights movement "acted as countervailing forces to the pursuits of excellence, high academic standards, and an understanding of the conceptual and methodological basis of the science, technology, engineering, and mathematics disciplines" (p. 18).

The economies of nations such as Germany and Japan had overcome the ravages of war by the 1970s, challenging the United States in the global marketplace (Getman, 2012). The increased competition fueled growing concerns that America's educational system was failing its citizens. The 1983 report by the National Commission on Excellence in Education (NCEE), entitled *A Nation at Risk: The Imperative for Educational Reform*, punctuated this fear in its opening lines: "Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the

world" (Gardner et al., 1983, p. 5). "If the Cold War ignited the science and technology frenzy, *A Nation at Risk . . .* fanned the flames" (Gleason, 2016, p. 32). The report disclosed that students in the United States were failing to keep pace with students from other nations in mathematics and science (Koehler et al., 2016), and asserted that excellence in the areas of mathematics, science, and technology was critical to America's prosperity (Basham et al., 2010). Mahoney (2010) maintains that *A Nation at Risk* ignited a "resurgence for the science, technology, engineering, and mathematics (STEM) movement in education" (p. 24). Wells (2008) submits that in the aftermath of *A Nation at Risk*, educational reform efforts specifically targeted the STEM disciplines, based on the presumption that excellence in STEM would enable America to successfully compete on a global level.

  *A Nation at Risk* led the American Association for the Advancement of Science (AAAS) in 1985 to establish an initiative called Project 2061 to help U.S. students achieve literacy in the STEM disciplines (Breiner et al., 2012). In 1989, Project 2061 published a landmark report, *Science for All Americans*, which plotted a blueprint for future STEM educational reform (Gleason, 2016; LaPorte & Sanders, 1993). Gleason (2016) contends that prior to the publication of *Science for All Americans*, equity "was not an explicit goal" (p. 36) of STEM education. *Science for All Americans*, however, was unambiguous in asserting the importance of quality STEM for all:

> Race, language, sex, or economic circumstances must no longer be permitted to be factors in determining who does and who does not receive a good education in science, mathematics, and technology. To neglect the science education of any (as has happened too often to girls and minority students) is to deprive them of a basic education, handicap them for life, and deprive the nation of talented workers and informed citizens—a loss the nation can ill afford. (Rutherford & Ahlgren, 1989, pp. 156-157)

*Science for All Americans* also called for the integration of the STEM disciplines, asserting that

"it is the union of science, mathematics, and technology that forms the scientific endeavor" (p. 25). A Project 2061 companion publication, *Benchmarks for Science Literacy*, went further, proclaiming: "The ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others" (AAAS, 1993, pp. 321-322). Wells (2008) concludes that "the unmistakable intent behind these AAAS publications was for curricular reformers to envision the teaching of these content areas as an integrative endeavor" (p. 3). *Science for All Americans* and *Benchmarks for Science Literacy* provided the underlying framework that guided the subsequent development of educational standards in STEM such as the Next Generation Science Standards and Common Core (Gleason, 2016).

At the dawn of the 21st century, policy makers and scholars continued to critique America's competiveness in the global marketplace and insist that the nation's defense depended upon renewed excellence in the STEM fields. For example, the United States Commission on National Security/21st Century (2001), also known as the Hart-Rudman Commission, issued a report entitled *Road Map for National Security: Imperative for Change*, which warned:

> The scale and nature of the ongoing revolution in science and technology, and what this implies for the quality of human capital in the 21st century, pose critical national security challenges for the United States. Second only to a weapon of mass destruction detonating in an American city, we can think of nothing more dangerous than a failure to manage properly science, technology, and education for the common good. (p. 30)

The Commission cited several problems with the American educational system, including a decline in the performance of U.S. students in math and science and a shortage of qualified teachers in the STEM fields. Logsdon (2006) observes that the Hart-Rudman report underscored "the importance of [a] high-technology workforce" (p. 243). And according to Kay (2009), the report "provided a foundation on which to recapitalize America's strategic investment in

education" (p. 3).

Thomas Friedman's (2005) bestseller, *The World is Flat*, created a sense of urgency regarding STEM's role in the economic prosperity of America (Nichols & Berliner, 2008; Duderstadt, 2008). In *The World is Flat*, Friedman delineated the technological changes that were flattening the world, such as the development of the Internet and the personal computer, enabling everyone to be a player in the global economy (Sullivan, 2007). Sanders (2008) indicates that Friedman's book cemented public perception that "China and India were on course to bypass America in the global economy by outSTEMming us" (p. 20). Friedman (2005) believed that educational reform was essential if Americans were going "to compete against the cream of the global crop" (p. 303). To be successful in a global marketplace demanding technological innovation, Friedman (2005) argued: "We should be embarking on an all-hands-on-deck, no-holds-barred, no-budget-too-large crash program for science and engineering education immediately. The fact that we are not doing so is our quiet crisis" (p. 275). *The World is Flat* was particularly influential in the government and business community, leveraging the flow of funding "toward all things STEM" (Sanders, 2008, p. 20).

Pierce (2012) observes that Friedman's work provided the theoretical basis for *Rising Above the Gathering Storm* (NAS, 2007). Published by the National Academy of Sciences, *Rising Above the Gathering Storm* (*RAGS*) warned that globalization threatened "the economic and strategic leadership that the United States [had] enjoyed since World War II" (NAS, 2007, p. 1). The report cited an insufficient number of students journeying through the STEM pipeline and declining academic performance in math and science as factors placing the United States at a disadvantage in the global arena. *RAGS* asserted that meeting this challenge to American supremacy depended on the nation's ability to develop a highly trained STEM workforce

(Logsdon, 2006; Moore et al., 2014a; Salzman, 2013). Calling for a comprehensive

governmental effort to remedy the crisis, the *RAGS* report recommended additional training for

STEM teachers, recruiting more STEM educators, enhancing K-12 STEM curricula, and

increasing the number of students obtaining postsecondary degrees in STEM fields (Kuenzi et

al., 2006; Roehrig et al., 2012).

　　　*Rising Above the Gathering Storm* has been criticized as an "iteration of a neo-Sputnik

fervor . . . placing intense pressure on educational institutions to develop subjects who are

capable of competing in a high stakes global economy" (Pierce, 2012, p. 723). Lowell and

Salzman (2007) present evidence that directly challenges the core assumptions in *RAGS*, such as

the claim that U.S. math and science performance was declining. Catledge (2015) contends that

the recommendations in *RAGS* were built upon a faulty premise "that STEM-credentialed

personnel are the source of technology and that a decline in technical competency translates into

a decline in progress" (p. 22). Despite these criticisms, Kuenzi (2008) validates that *Rising

Above the Gathering Storm* "has been of particular influence" (p. 28) in securing federal support

for STEM education. Reich (2013) confirms that its "conclusions were roundly welcomed by

academic leaders, whose institutions would benefit from the increased funding" (p. 421).

　　　*Rising Above the Gathering Storm* led to the passage of the 2007 America COMPETES

(Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and

Science) Act (Gonzalez & Kuenzi, 2012; Stevenson, 2014; Thomas & Williams, 2009). The

America COMPETES Act was enacted with strong bipartisan support to counter growing

apprehension about the ability of the United States to economically compete with developing

nations such as China and India (Hira, 2010; Stine, 2008). The act addressed such concerns by

targeting K-12 and postsecondary STEM education and investing in scientific and technical

research (Land, 2013; Stine, 2008). To augment the STEM workforce, the act funded programs to encourage greater student participation in STEM, improve the skills of teachers in the STEM fields, and recruit additional STEM instructors (Stine, 2008; Thomas & Williams, 2009). The act specifically targeted the education of underrepresented groups in the STEM workforce, such as women and minorities (Navruz et al., 2014; Stine, 2008). Koehler et al. (2016) posit that "STEM funding has been plentiful" (p. 17) since the passage of the America COMPETES Act.

The rhetoric of *Rising Above the Gathering Storm* has continued to influence federal policy in recent years. Just three months after assuming the presidency, Barack Obama (2009) emphasized the strategic importance of STEM in an address to the National Academy of Sciences: "Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before" (p. 24). In announcing the Educate to Innovate campaign later that year, he stated, "I am committed to making the improvement of STEM education over the next decade a national priority" (White House, 2009, para. 3). In addition to the Educate to Innovate campaign, key federal initiatives supporting STEM efforts during the Obama Administration included the America COMPETES Reauthorization Act of 2010, Race to the Top, the Investing in Innovation (i3) Fund, the STEM Education Act of 2015, and the American Innovation and Competitiveness Act (Assefa & Rorissa, 2013; Bishop, 2015; Gonzalez & Kuenzi, 2012; Nekuda Malik, 2017a; Smith & Hall, 2017). Under President Obama, an unparalleled number of federal departments and agencies supported STEM efforts including the Department of Education, the Department of Defense, the Department of Agriculture, the Department of Energy, the Department of the Interior, the National Aeronautics and Space Administration, the National Science Foundation, and the Environmental Protection Agency (Assefa & Rorissa, 2013). The pivotal role played by science and technology in meeting

America's economic, environmental, and security challenges pervaded the agenda of the Obama Administration (Gwynne, 2017).

Many scientists, educators, and policymakers expressed concern that the federal government's longstanding commitment to STEM would suffer under the Trump Administration (Dempsey, 2017; Devlin & Chiu, 2017; Simmons, 2017). However, despite campaign threats to reduce federal investment in research and education, there are indications that the government's commitment to all things STEM will not be abated anytime soon. Due to advocacy efforts from groups like the National Women's Business Council (NWBC, 2017), on February 28, 2017, President Trump enacted two laws aimed at expanding the participation of women in STEM careers—Inspiring the Next Space Pioneers, Innovators, Researchers, and Explorers (INSPIRE) Women Act and Promoting Women in Entrepreneurship Act (Stanton & Kirby, 2017). In September 2017, President Trump directed the Department of Education to award "at least $200 million in grant funds per year to the promotion of high-quality STEM education" (Trump, 2017, p. 45418). According to Trump (2017), to ensure "economic growth and prosperity, it is critical that we educate and train our future workforce to compete and excel in . . . STEM fields." (p. 45417). The assessment of physicist John Holden, who served as science advisor to Barack Obama, that "STEM education initiatives are likely to survive" (Gwynne, 2017, p. 11) under President Trump, bears due consideration given that the political advocacy efforts of STEM professionals are well established and systematized (Nekuda Malik, 2017b).

In summary, the emphasis on STEM began with the launch of Sputnik in October, 1957. The Sputnik crisis led to a "rigorous self-examination" (Flemming, 1960, p. 134) of the American school system. Public perception that the Soviet educational system was superior in the STEM subjects led Congress to enact the National Defense Education Act (NDEA) of 1958.

Considered to be "the origin of modern STEM-specialized education" (Geldis, 2014, p. 9), the NDEA provided $1 billion in federal funding for a variety of programs to give students the technical knowledge required for entry into the STEM workforce. At a time when STEM subjects were firmly standalone disciplines, the Sputnik reaction inspired Donald Maley at the University of Maryland to develop a junior high course in the late 1950s "which purposefully situated mathematics and science in the context of technological activity" (Sanders, 2012, p. 4), establishing integrative STEM instruction as best practice.

Kennedy's (1961) challenge to the nation "of landing a man on the moon" (p. 908) by the end of the 1960s accelerated the space race and heightened student interest in STEM careers, expanded federal funding for STEM, and fostered reform of STEM curricula "led by the scientific and mathematics communities" (Bybee, 2013, p. 17). However, the political and social upheaval spawned by the Vietnam War, the civil rights movement, and the War on Poverty shifted the nation's attention away from preparing a highly qualified corps of scientists and engineers to providing equal educational opportunity for all students. As new STEM curricular materials were released during this period, they were frequently criticized for "their elitism, the lack of relevancy, and a lack of accommodation" (Bybee, 2013, p. 18) for diversity.

In the 1970s, economic challenges to America's domination of the global marketplace from Germany and Japan fueled concerns that the nation's educational system was failing. The 1983 report, *A Nation at Risk*, asserted that excellence in mathematics, science, and technology was critical to American prosperity. It also claimed that U.S. students were failing to keep pace in the STEM subjects with their foreign counterparts. This ignited a "resurgence for the science, technology, engineering, and mathematics (STEM) movement in education" (Mahoney, 2010, p. 24). *Science for All Americans*, published in 1989, outlined a blueprint for future STEM

education reform efforts. It also emphasized the fundamental importance of providing quality STEM for all, particularly underrepresented groups such as females and minority students.

Thomas Friedman's 2005 bestseller, *The World is Flat*, detailed how technological advances were flattening the global marketplace, enabling workers in developing nations to challenge America's economic supremacy. *The World is Flat* declared that the United States needed "an all-hands-on-deck, no-holds-barred, no-budget-too-large crash program for science and engineering education" (Friedman, 2005, p. 275). Friedman's work provided the theoretical basis for *Rising Above the Gathering Storm* (*RAGS*), which warned that globalization threatened America's national security and economic growth. *RAGS* asserted that meeting this challenge depended on the nation's ability to prepare a highly trained STEM workforce. *RAGS* led to the passage of the 2007 America COMPETES Act, which funded programs to encourage greater student participation in STEM activities and recruit and train STEM educators.

Funding for STEM education flourished under Barack Obama, who began his presidency with the summons of "making the improvement of STEM education over the next decade a national priority" (White House, 2009, para. 3). Under President Obama, an unparalleled number of federal departments and agencies actively supported STEM efforts. Federal initiatives such as Race to the Top, the Investing in Innovation (i3) Fund, and the STEM Education Act of 2015 sealed the nation's longstanding commitment to STEM, a commitment that is not likely to be abated anytime soon.

## Part 3:  Underrepresented Groups in STEM

STEM is increasingly critical to America's economic prosperity and national security (NAS, 2007). However, "participation in STEM has traditionally been the domain of White males" (Riegle-Crumb & King, 2010, p. 656). Women and racial or ethnic minorities such as

African Americans, Latinos, and Native Americans are notably underrepresented in the STEM workforce (Grossman & Porche, 2014; Holdren et al., 2010; Tsui, 2007; Xu, 2013). For example, the number of underrepresented minorities in STEM would need to increase threefold to match their representation in the general population (Schneider, Judy, & Mazuca, 2012). Underrepresented groups in STEM constitute an "underused resource and a lost opportunity for meeting our nation's technology needs" (NAS, 2011, p. 2).

Due to America's "greater ethnoracial diversity, challenging disparities in STEM participation and completion rates is a critical objective" (Baber, 2015, p. 252). Increasing diversity in STEM postsecondary education and STEM careers is essential for expanding our technical talent pool and enhancing technical innovation and research (NAS, 2011). Additionally, the lack of women and minorities in the STEM pipeline "perpetuates entrenched economic and social inequities" (Stearns et al., 2016, p. 87), limiting their access and participation in more highly paid STEM careers. For all of these reasons, "researchers have long been interested in the topic of equity in STEM" (Riegle-Crumb & King, 2010, p. 656). Consequently, this section of the literature review examines what is known about the underrepresentation of women and people of color in STEM and explores some of the reasons these inequities continue to exist.

**Underrepresentation of Women**

Despite gains in the health sciences, women continue to be underrepresented in the STEM career fields (Blickenstaff, 2005; Farinde & Lewis, 2012; Ong et al., 2018). Although they make up half of the college-educated labor force, only 28% of STEM jobs are held by women (NSB, 2018). Women are also underpaid in STEM occupations compared to their male counterparts (Corbett & Hill, 2015). Although women are adequately represented in the

biological sciences, they are substantially underrepresented in computer science, engineering, and physics (Halpern et al., 2007; Perez-Felkner et al., 2012; Xie et al., 2015). According to recent science and engineering occupational data, women comprise 15% of engineers and 24% of those employed in computer science in the United States (NSB, 2018). "Engineering is the most sex-segregated nonmilitary profession in the United States" (Cech et al., 2011, p. 643), with women representing just 8% of all mechanical and electrical engineers and 6% of the nation's petroleum engineers (Corbett & Hill, 2015). Corbett & Hill (2015) also observe that "women's representation in computing declined from just over a third of workers in 1990 to just over a quarter in 2013" (p. 8). Koput and Gutek (2010) affirm that "over a relatively short period of time, a field [information technology] that was once relatively gender integrated has become solidly male dominated" (p. 103). Although females constitute almost 40% of web developers, just 7% of computer network architects are women (Corbett & Hill, 2015).

As educational researchers and policymakers look for ways to reduce the underrepresentation of females in STEM fields such as engineering, "gender differences in mathematics performance and ability remain a concern" (Hyde et al., 2008, p. 494). In analyzing results from the Early Childhood Longitudinal Study, Penner and Paret (2008) identified a performance gap between boys and girls at the top of the distribution in mathematics as early as kindergarten, with boys outperforming girls throughout the distribution by third grade. However, Hill et al. (2010) note that "historically, boys have outperformed girls in math, but in the past few decades the gender gap has narrowed" (p. 3). Results from the 2015 National Assessment of Educational Progress (NAEP) confirm that 8th grade males and females are achieving at identical levels in math (Snyder et al., 2018). Math achievement results from the 2015 TIMSS (Trends in International Mathematics and Science Study) also found no difference between 8th

grade boys and girls in 29 out of 39 countries tested, with girls achieving higher than boys in 7 countries (Mullis et al., 2016).

Robelen (2012) asserts that there are "continued achievement gaps between boys and girls in STEM fields, especially science" (p. 17). The evidence is mixed nonetheless. The 2015 TIMSS found there was no difference between 8th grade boys and girls in science achievement in 20 out of 39 countries assessed, with girls outperforming boys in science in 14 countries (Martin et al., 2016). However, 8th grade boys in the United States outperformed girls in science, one of just 5 countries participating in the 2015 TIMSS where males had higher achievement (Martin et al., 2016). U.S. males also outscored females in science at all grade levels tested on the 2015 NAEP (Snyder et al., 2018). According to summary data compiled from the TIMSS 2015 Advanced, 12th grade males performed better than females in advanced mathematics and physics (Provasnik et al., 2016). College admission test results also reveal a gender gap. For example, on average males had higher scores in math on the 2015-2016 SAT, and higher math and science scores on the 2016 ACT (Snyder et al., 2018). Males have also performed better than females on Advanced Placement (AP) exams in both math and science (Hill et al., 2010).

Ceci et al. (2009) contend that there is "no direct evidence [of bias] in the math-intensive fields where women are most underrepresented" (p. 246). However, since at least the time of Francis Bacon, many of the STEM disciplines have been considered the exclusive sphere of men (Fedigan, 2001; Nelson, 1993). There is a prevailing masculine bias in the sciences that frequently goes unchallenged (Crasnow, 2004; Kerr, 2001). Fennema et al. (1990) observe that first grade teachers tend to overrate the math ability of boys and are more likely to attribute the math achievement of girls to effort rather than ability. In a study of 6th grade teachers, Jussim and Eccles (1992) found that teachers in the middle grades believed that boys have higher math

abilities than girls, even when the girls received higher grades. Riegle-Crumb and Humphries (2012) document that high school teachers perceive that math is easier for males than females, even when controlling for differences in test scores and math grades. Some scholars assert that STEM curriculum is biased against women (Blickenstaff, 2005; Sadker et al., 2009; Verhage, 1990). Kuncel and Hezlett (2007) cite evidence that college admission tests often "underpredict the performance of women in college settings" (p. 1081). In a randomized study, Moss-Racusin et al. (2012) demonstrated that science faculty members from research universities are biased against females. While Ceci and Williams (2010) maintain that the underrepresentation of women in the STEM fields cannot be attributed to discrimination, an experimental study conducted by Reuben et al. (2014) "revealed a strong bias among subjects to hire male candidates" (p. 4404) for STEM work.

Many scholars attribute the underrepresentation of women in STEM to stereotype threat, which is defined as anxiety about one's abilities due to negative stereotypes (Shapiro & Williams, 2012). In Western culture, women are stereotyped as being inferior to men in subjects such as math and science (Hill et al., 2010; Lane et al., 2012; Nosek & Smyth, 2011). Both men and women accept prevailing STEM stereotypes (Lane et al., 2012; Ramsey & Sekaquaptewa, 2011). Girls are often socialized by their parents and teachers to associate the STEM disciplines with men (Cheryan, 2012; Gunderson et al., 2012), and they identify STEM courses as being unfeminine as early as sixth grade (Betz & Sekaquaptewa, 2012). Stereotype threat impacts both the academic performance of females and their interest in pursuing STEM careers (Good et al., 2008; Hill et al., 2010). Stereotype threat also contributes to lower performance for female students on standardized achievement and cognitive ability tests in the STEM domains (Appel et al., 2011; Niederle & Vesterlund, 2010; Nosek et al., 2009). Female students perform better in

math when they are not aware of STEM stereotypes (Modi et al., 2012).

Spatial thinking, the ability of a person to manipulate objects mentally, is critical to success in the STEM disciplines (Newcombe, 2010, 2016; Wai et al., 2009). Numerous studies have confirmed that males perform better on spatial ability tests than women, particularly in the area of three-dimensional mental rotations (e.g., Lauer et al., 2015; Maeda & Yoon, 2013; Silverman et al., 2007; Voyer et al., 1995), which could explain why men are more interested in STEM careers and outperform women in the STEM subjects. Two studies conducted by Ganley et al. (2014) validated that disparities between male and female science test performance are largely due to differences in mental rotation spatial skills. Koscik et al. (2009) assert that gender differences in spatial ability with mental rotations are attributable to structural differences between men and women in the parietal lobe of the brain. However, Hyde (2014) proposes that the male superiority in three-dimensional mental rotations is due to "the absence of spatial training in the schools combined with major gender gaps in relevant out-of-school experiences" (p. 382), such as playing video games. Jirout and Newcombe (2015) suggest that gender differences in spatial ability might be due to young boys playing with blocks and similar spatial activities more than girls do. Ceci et al. (2009) assert that the underrepresentation of women in STEM is primarily due to sociocultural factors rather than differences in brain structure or innate spatial abilities.

Self-efficacy may be another factor contributing to the underrepresentation of women in STEM. Many studies have evaluated gender differences in STEM self-efficacy (e.g., Britner & Pajares, 2006; Carberry et al., 2010; MacPhee et al., 2013; Pajares, 2005). According to Kanny et al. (2014), self-confidence "is by far the most oft-cited explanation for the STEM gender gap" (pp. 138-139). Research has shown that females are less likely to pursue or persist in the fields of

engineering, physics, and computer science due to the lower self-efficacy of women in math and science (Austin, 2009; Beyer, 2014; Sawtelle et al., 2012; Stout et al., 2011). However, Sax et al. (2015), while acknowledging that the lower confidence of women in their mathematical ability can impact their pursuit of a STEM career, contend that it "has become a less powerful explanation for their underrepresentation in STEM" (p. 813).

Male students tend to have higher perceptions of their math performance than female students, even when their actual achievement is similar (Correll, 2001; McGraw et al., 2006; Perez-Felkner et al., 2017). A study by Reuben et al. (2014) found that males overestimated their future performance on a math task while female students underestimated their performance. While girls are confident in math at the elementary school level, this confidence begins to erode in the middle school grades (Streitmatter, 1997). Kelly and Zhang (2016) found that boys and girls have similar levels of engagement in STEM when they begin high school, but boys have higher levels of efficacy in both math and science. Robnett (2016) contends that the low STEM self-efficacy among women is due to gender bias. An experimental study by Correll (2004) validates that the self-efficacy of women decreases when they are led to believe that men are better at a particular task.

Competition is another reason cited in the literature as a contributing factor for the gender gap in STEM. A study by Niederle and Vesterlund (2007) indicated that women shun competitive environments while men embrace them. Bönte (2015) examined data from 36 countries and concluded that "women have, on average, a substantially lower self-reported preference to enter competitive situations than men" (p. 74). Rosser (1993) asserts that math and science classes are more attractive for female students "when cooperative rather than competitive pedagogical methods are used" (p. 205). A meta-analysis by Qin et al. (1995) documents that

cooperative techniques improve problem solving performance, especially for nonlinguistic problems in math. Research by Gneezy et al. (2003) suggests that competition increases the performance of men but not the performance of women. However, Sax (2017) rejects the argument that competition has a negative impact on women, stating that the participation of females in competitive activities increases their self-efficacy and helps them "feel that they are more in charge of their own destiny" (p. 154).

Niederle & Vesterlund (2010) posit that differences in response to competition between males and females "may cause test scores to magnify and potentially distort underlying gender differences in [math] skills" (p. 140). A study by Buser et al. (2014) found evidence that the gender gap between men and women in the selection of a rigorous math and science curricular track in high school was due to the greater levels of competiveness among men. Alon and DiPrete (2015) observed that the heightened competiveness for admission to degree programs such as electrical engineering and computer science had a greater deterring effect on women than men in selecting a STEM major. Goodman et al. (2002) found that competition was cited by a third of women as a reason for dropping out of college engineering programs. In their research, women who dropped out of engineering degrees complained about the competitive nature of classes, such as grading on the curve. However, Buser et al. (2014) note that "women who drop out of science and engineering may search for explanations such as the negative aspect of a competitive environment" (p. 1411) rather than cite reasons such as different career interests.

One of the reasons cited for the underrepresentation of women is that they are less likely to persist in STEM. The tendency for women to leave STEM at greater rates than men is known in the literature as the leaky pipeline (Hernandez et al., 2013; Watt et al., 2006). Women have been shown to have higher attrition rates than men in careers such as engineering and technology

(Hewlett et al., 2008). Women are also less likely than men to remain in a STEM degree program during college (Griffith, 2010; Shaw & Barbuti, 2010). Price (2010) analyzed longitudinal data from 13 public universities in Ohio and found that males persist in STEM majors at a rate of 53% while females persist in STEM degree programs at a rate of 40%. This gap in persistence remained when controlling for scores on college entrance exams. Blickenstaff (2005) suggests that "even when women are equally or better prepared than men for scientific or technical majors, they still drop out of the programs at greater rates" (p. 374).

However, the "leaky pipeline" metaphor has been increasingly questioned by scholars as a viable explanation for the underrepresentation of women in STEM. Lord et al. (2009) examined the undergraduate student records at nine public universities in the southeastern U.S. and found that women persist in college engineering programs at the same rates as their male counterparts. They assert that "what has been framed as a problem of persistence is actually a problem of recruitment" (Lord et al., 2009, p. 185). Analyses of U.S. Department of Education datasets such as the Beginning Postsecondary Students Longitudinal Study and the Education Longitudinal Study confirm that men are twice as likely as women to select a STEM major when initially enrolling in college (Chen & Weko, 2009; Morgan et al., 2013). Miller and Wai (2015) argue that stopping leaks in the STEM pipeline from the start of college until the conferral of a bachelor's degree would have little impact on the number of women earning degrees in pSTEM (physical science, technology, engineering, mathematics), increasing their representation in these fields by just 2%.

Social isolation can have a negative effect on the participation of women in STEM. Rosser (2004) maintains that "isolation and lack of camaraderie/mentoring are particularly acute problems for women in fields such as engineering, physics, and computer science" (p. xxii). In a

survey of 2,500 women working in STEM careers, Servon and Visser (2011) found that a third

of women holding management positions in STEM felt "extremely isolated at work" (p. 278).

Hewlett et al. (2008) record that 44% of women in engineering report feelings of severe

isolation. Servon and Visser (2011) contend that social isolation can lead women to drop out of

STEM careers, "as women who feel isolated are 25 per cent [*sic*] more likely to be stalled in

their career than are their counterparts" (p. 278). Female scientists are often excluded from

collaboration with their male peers on research projects and left out of social gatherings

(Etzkowitz et al., 2000; Hill et al., 2010). The lack of female mentors and role models in STEM

fields such as information technology can contribute to feelings of isolation and restrict access to

informal networks in the workplace (Ahuja, 2002). Females often experience social isolation in

high school computer science courses, which may be a contributing factor to their

underrepresentation in the field of information technology (Goode et al., 2006). Kulturel-Konak

et al. (2011) contend that traditional STEM pedagogy at the postsecondary level, with its

emphasis on competition, can isolate female students "who are people oriented and prefer to be a

part of a team" (p. 16). Experiencing isolation might also lower academic performance in STEM

areas. For example, an experimental research study by Sekaquaptewa and Thompson (2003)

found that social isolation caused women to have lower performance on a math test.

　　　Course selection may also keep women out of the STEM pipeline. Boys and girls take

approximately the same number of math and science courses during high school (Reuben et al.,

2014). However, female students are less likely to take rigorous STEM classes (Blickenstaff,

2005; Farinde & Lewis, 2012; Riegle-Crumb & Moore, 2014; Tyson et al., 2007). In a study

involving more than 18,000 students, Conklin (2000) found that males had a far greater interest

than females in taking STEM classes such as robotics, electronics, computer programming and

networking during high school. A research study conducted by Rudasill and Callahan (2010) found that female students planned to take fewer math courses in high school even though there was no difference between female and male students in the self-perception of their math abilities. Moore and Slate (2008) found that women are more likely to take Advanced Placement (AP) courses in high school than men. However, male students are more likely to take AP courses in math and science (College Board, 2017; Robelen, 2012). Perez-Felkner et al. (2012) assert that female students with the highest mathematical ability often do not enroll in the more advanced math courses in high school because "other fields are much more attractive to women with higher ability scores in mathematics" (p. 1669).

The underrepresentation of women in STEM is frequently attributed to a shortage of female role models (Beede et al., 2011; Chen & Soldner, 2013; Kahn & Ginther, 2017; Sonnert & Fox, 2012). Wang and Degol (2017) affirm that "broader exposure to successful female role models in STEM might encourage girls to reject the stereotype that math and science careers are for men" (p. 132). However, research on the effectiveness of female role models in STEM has been mixed. Two studies by Lockwood (2006) suggest that female role models are more effective than males with inspiring women in their self-concept and future career choice. Marx and Roman (2002) conducted several experimental studies and found evidence that female role models have a positive impact on the math performance of women. Three studies by Stout et al. (2011) indicated that female role models can help women to have more positive attitudes about STEM and greater confidence in their STEM abilities. Carrell et al. (2010) found that having a female professor had a positive impact on the performance of women in math and science classes, particularly for women who ranked in the upper quartile. In analyzing a longitudinal dataset of 54,000 college students, Bettinger and Long (2005) found that women who had female

instructors in math were more likely to take additional courses in mathematics. However, women professors did not have a statistically significant impact on future course selection for female students in physics, engineering and computer science.

Research conducted by Hazari et al. (2010) revealed that the use of female scientists as guest speakers did not have a significant impact on the identification of high school females with physics. In a study of primary grade teachers and students, Beilock et al. (2010) determined that female teachers with math anxiety had a negative effect on the math achievement of girls, but not boys, suggesting that female teachers with math anxiety reinforce stereotypes that girls are not good at math. Antecol et al. (2015) also found that female teachers had a negative effect on girls' math achievement in the primary grades. The negative impact was mitigated, however, if girls were taught by female teachers that had a strong background in math. Griffith (2010) asserts that the presence of female faculty role models does not impact the persistence of women in STEM at the college level, but higher percentages of women graduate students in STEM does have a positive impact on the persistence of female undergraduates. Research by Betz and Sekaquaptewa (2012) indicated that feminine STEM role models detract from STEM interest among middle school girls, due to "the perceived unlikelihood of combining femininity and STEM success" (p. 743). A study by Cheryan et al. (2011) found that stereotypical female role models in STEM lowered women's beliefs that they could be successful. The mixed evidence in the literature regarding the effectiveness of female role models in STEM might be partially attributable to the low number of women working in many STEM fields, reducing the diversity of role models available with which female students can readily identify.

Some researchers posit that males are more interested than females in STEM topics (e.g., Jones et al., 2000; LeGrand, 2013), which could account for the underrepresentation of women in

STEM careers. Female students are less interested in STEM than male students by early adolescence (Halpern et al., 2007). National Assessment of Educational Progress (NAEP) data indicates that while STEM interest is similar for boys and girls in fourth grade, girls' interest in math and science declines during the middle school grades (Hayden et al., 2011). Among students between the ages of 8 to 17, 24% of male students and 5% of female students report an interest in engineering (Ceci & Williams, 2010). In a survey of middle and high school students, Kitts (2009) found that an equal number of boys and girls believe that science is interesting, but that this attitude does not transfer into a desire to pursue a scientific career. An analysis of Trends in International Mathematics and Science Study (TIMSS) data by Riegle-Crumb et al. (2011) indicated that females report a lower enjoyment of STEM subjects than males. Sadler et al. (2012) found that female interest in STEM declined during high school, while the interest of male students in STEM remained steady. Women also drift away from STEM during college due to a lack of interest (Thoman et al., 2014). Women with high mathematical ability have a lower interest in math or science careers than men with a comparable aptitude (Lubinski & Benbow, 2006). Su et al. (2009) conducted a meta-analysis of data from more than 40 interest inventories to evaluate gender differences in vocational interests, which indicated "that the relatively low numbers of women in some fields of science and engineering may result from women's preference for people-oriented careers over things-oriented careers" (p. 880). A meta-analysis of 15 studies by Woodcock et al. (2013) confirmed that women have a stronger orientation for people while males are more inclined toward things, and that such orientations are strong predictors regarding whether a person will select and remain in a STEM major in college.

In summary, women are underrepresented in the STEM fields, especially in computer science, engineering, and physics. Researchers have advanced many explanations for the

shortage of women in STEM, including gender differences in mathematical ability and science achievement. Others have proposed that the STEM gender gap is due to a prevailing masculine bias in the sciences, curricular bias, college admission tests which underestimate the academic performance of women, and/or bias in hiring practices. Some scholars attribute the shortage of women in STEM to stereotype threat—anxiety about one's abilities due to negative stereotypes. Other researchers posit that the STEM gender gap is the result of male superiority in spatial abilities such as three-dimensional mental rotations, giving men an advantage in the STEM disciplines.

Other explanations for the underrepresentation of women found in the research literature include gender differences in STEM self-efficacy, the social isolation that women experience in STEM, and the shortage of female role models in STEM. Some researchers attribute the underrepresentation of women in STEM to a lack of interest in STEM subjects. Other scholars assert that women are less likely than men to take rigorous STEM courses, that women are less persistent in pursuing STEM degrees, or that women are less competitive than men, placing them at a disadvantage in the highly competitive world of STEM education and careers. Despite a plethora of possible explanations tendered in the literature, one fact is painfully clear — although they make up half of the college-educated workforce, only 28% of STEM jobs are held by women (NSB, 2018).

**Underrepresentation of Minoritized Racial and Ethnic Groups**

Based on data from the High School Longitudinal Study, when they enter high school, African American and Latino students are as likely to foresee themselves working in a STEM career as their white and Asian classmates (Alvarado & Muniz, 2018). But for many minorities, their dreams of a successful STEM career go unfulfilled. Just 13.2% of African Americans,

15.9% of Latinos, and 14.9% of Native Americans who aspire to a STEM bachelor's degree earn their credential in four years (Ghosh-Dastidar & Liou-Mark, 2014). Such students are unlikely to be taught by a member of their race or ethnicity, as less than 5% of fulltime professors at research universities who hold a doctorate in a STEM field are members of an underrepresented minority group (NSF, 2015). Native Americans earn 0.63% of STEM bachelor degrees and 0.48% of STEM doctorates, revealing that they are "60% underrepresented at the college level and 67% underrepresented at the doctoral level" (Bang & Medin, 2010, p. 1012). Underrepresented minorities make up 11% of workers in the STEM fields despite representing 27% of the total U.S. population age 21 and above (NSB, 2018). Minority groups are particularly underrepresented in engineering. African American men make up 4% of America's engineering workforce, Latinos 5%, and Native Americans 0.2% (Corbett & Hill, 2015). Meanwhile, Latinas and African American women comprise just 1% of U.S. engineers (Corbett & Hill, 2015).

In order for students to advance through the STEM pipeline, they must demonstrate aptitude in math and science. "Assessments of student achievement increasingly play a vital role in determining college-going options for graduating seniors" (Contreras, 2005 p. 212), often to the detriment of racial and ethnic minorities with an interest in STEM. There is a notable achievement gap in math and science performance between African American and Latino students, on the one hand, and their white counterparts. Using data from the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), Wang (2008) found that there is an achievement gap in math performance as early as prekindergarten between white children and underrepresented groups in STEM such as African Americans and Latinos. An achievement gap in mathematics also exists at the kindergarten level between African American and white children, even when both groups are low income (Wang, 2010). Data from the National

Assessment of Educational Progress (NAEP) indicates that African American and Latino students score lower in mathematics than their white peers at the 4th, 8th, and 12th grade levels (Kena et al., 2015; National Center for Education Statistics [NCES], 2011; NCES, 2017). NAEP data also shows a persistent achievement gap in science at the 4th, 8th, and 12th grade levels (NCES, 2012; NCES, 2015). A study by Else-Quest et al. (2013) documented that 10th grade white and Asian students had higher math and science achievement, based on their end-of-year course grades, than African American and Latino students. White students have higher SAT scores in math than Latinos and African Americans (College Board, 2015; Contreras, 2005). Unfortunately, data attesting to achievement gaps in math and science can lead to "blanket statements about the low performance of certain groups of students in our schools without mentioning the underlying causes [and] may reinforce prejudices and stereotypical images" (Flores, 2007, p. 30).

Indeed, racial and ethnic prejudices and stereotypes may be a contributing factor to the underrepresentation of people of color in STEM. Museus et al. (2011) posit that "the racial inequalities that exist throughout the STEM education circuit and the nature of those disparities cannot be understood fully without acknowledging that race and racism play a critical role in the experiences of minority students" (p. 24). Some of this bias is overt. For example, James Watson, who won the Nobel prize for discovering the structure of DNA, has suggested that people of African descent have less intellectual capacity than whites (Gillborn, 2010; Magnet, 2011). There is evidence that stereotypes about people of color is present in schools, as black and Latino students are often placed in lower track math courses even when standardized achievement data indicates they belong in accelerated classes (Flores, 2007; Gándara, 2006). Sometimes racial and ethnic bias in STEM is less conspicuous. For example, Carlone and

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Johnson (2007) conducted a study of successful women in STEM and concluded that a "subtle racism was at work" (p. 1211) that disrupted the science identities of minority students. A study conducted by Aschbacher et al. (2010) found that students of color perceived that their STEM teachers had lower expectations for them than for white and Asian students. Martin (2009) asserts that there is

> a widely accepted, and largely uncontested, racial hierarchy of mathematical ability: Students who are identified as Asian and White are placed at the top, and students identified as African American, Native American, and Latino are assigned to the bottom. The uncontested nature of this hierarchy has contributed to the social construction of African American, Latino, and Native American students as less than ideal learners; that is, to be African American or Latino or Native American is to be mathematically illiterate. (p. 315)

Since students of color have lower math test scores than their white and Asian counterparts, Riegle-Crumb and Humphries (2012) caution that the perception that such students have less ability in mathematics may not indicate the presence of bias, provided that "teachers' evaluations of ability … are consistent with this [achievement] gap" (p. 296). Nevertheless, to the extent that racial and ethnic stereotypes, real or perceived, steer students away from rigorous coursework in math and science, students of color are less likely to advance through the educational pipeline to a successful STEM career.

Self-efficacy, or confidence that one can complete rigorous coursework and be successful in a STEM career, may play a role in the underrepresentation of minority groups in STEM. Higher self-efficacy has been linked to an increased likelihood of entering STEM fields, better achievement in math and science, and greater persistence with STEM, especially for minority students (Gerardi, 2005; Hernandez & Lopez, 2004; Navarro et al., 2007; Torres & Solberg, 2001). Mau (2003) contends that academic performance "is less predictive than math self-efficacy" (p. 240) for student persistence in the STEM pipeline. Self-efficacy has also been

demonstrated to be a predictor of student interest in technical careers (Lent et al., 2003).

A number of studies have indicated that minority students have lower self-efficacy than white students. For example, a study of high school students conducted by Pajares and Kranzler (1995) indicated that black students have lower self-efficacy in math than white students. Stevens et al. (2004) found a significant gap in math self-efficacy between white and Hispanic students enrolled in 9th and 10th grade. In a comparison of high ability ninth graders, Andersen and Ward (2014) observed that white students had greater self-efficacy in math and science than black or Latino students. Analyzing data sets from the Cooperative Institutional Research Program (CIRP) and the National Longitudinal Survey of Youth (NLSY), which included information collected from high school through college and graduate school, Leslie et al. (1998) determined that minority students have lower self-efficacy in both math and science. A study of undergraduate engineering students by Jordan et al. (2011) revealed that minority students have a lower level of self-efficacy in engineering and white students have higher outcome expectations in mathematics. A longitudinal study of STEM majors conducted by MacPhee et al. (2013) found that minority students from low income backgrounds have significantly lower academic self-efficacy and less confidence in their test-taking abilities. Lin et al. (2018), in a study of the math self-efficacy of students enrolled at a large research university, reported that Native American students are two-and-a-half times as likely as white students to be categorized as unconfident. Flowers and Banda (2016) affirm that self-efficacy is "a critical and underexamined component of the STEM success puzzle for underrepresented students" (p. 406).

A lack of role models may contribute to the underrepresentation of minority students in STEM. Gándara and Maxwell-Jolly (1999) attest to the importance of teachers of color serving as role models for underrepresented minority students because such students "find few models of

high academic achievement in their own communities" (p. 14). Since less than 5% of teachers in the United States are African American, Ladson-Billings (2013) asserts that minority students can "go through 13 years of public schooling—from kindergarten to 12th grade—and never have a Black teacher" (p. 109). A longitudinal study of 12- to 14-year-olds by Zirkel (2002) revealed that students with at least one role model who shared their race and gender performed better academically than those who did not. Griffith (2010) maintains that when minority students pursue a STEM major, they are at a disadvantage because people of color are underrepresented on the faculty of university STEM departments. The shortage of minority role models in the STEM fields can lead to feelings of isolation and contribute to STEM attrition during college (Chen & Soldner, 2013).

Perseverance in a rigorous math trajectory throughout high school is essential for students to advance through the STEM pipeline. Analyzing data from the Texas Schools Microdata Panel (TSMP) on more than 100,000 public school students enrolled in geometry, Klopfenstein (2005) found that having a black math teacher for geometry had a significant, positive impact on the percentage of black students who went on to enroll in algebra II. Lent et al. (2005) conducted a study of students enrolled in introductory level engineering courses at two HBCUs (historically black colleges and universities) and one predominantly white university. Minority students enrolled at the HBCUs had greater academic self-efficacy, higher technical interests, and increased outcome expectations in engineering compared to students attending the predominantly white university. Lent et al. (2005) suggest that one of the reasons for the HBCU advantage was the fact that they "offer strong same-race mentoring and (faculty and peer) role-modeling experiences" (p. 90). It should be noted that Tan (1995), in a study that included a random sample of students attending a large research university, found that the presence of a role model

was not correlated with the academic performance of African American students. However, only a quarter of the African American students in the study had a role model who shared their race. Tan (1995) clarified that it would therefore be "premature to conclude that role models have minimal impact on student satisfaction and academic performance" (p. 50) for minority students.

Minority students are just as likely as white students to enroll in STEM programs when they begin undergraduate studies (Anderson & Kim, 2006; Riegle-Crumb & King, 2010). However, many researchers have documented that minority students have lower STEM persistence rates than white students (Anderson & Kim, 2006; Chen & Soldner, 2013; Griffith, 2010). Analyzing data from the Beginning Postsecondary Students Longitudinal Study, Chen and Weko (2009) found that although STEM degree entrance was comparable among white, African American, and Latino students, white students had a higher STEM degree completion rate. An analysis of statistics from the SAT Validity Study by Shaw and Barbuti (2010) indicated that black and Hispanic students were more likely than white students to switch out of a STEM major during their undergraduate years. Wilson et al. (2012) report that data from 200 colleges and universities collected by the Consortium for Student Retention Data Exchange reveals that the attrition rate in the STEM disciplines for minority students is about 75%. Lord et al. (2009) caution that "persistence issues may not be related to majoring in STEM disciplines alone. Rather, low minority persistence in STEM is a microcosm of low persistence in higher education" (p. 171). Some researchers posit that the persistence of African Americans and Latinos in undergraduate STEM is correlated to academic preparation in high school (Arcidiacono et al., 2016; Cole & Espinoza, 2008). Elliott et al. (1996) affirm that "equally developed ability among students interested in science predicts equal persistence, regardless of ethnic or racial affiliation" (pp. 683-684).

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Many researchers posit that racial and ethnic minorities are underrepresented in the STEM fields due to unqualified teachers (e.g., Delaney & Lee, 2016; Museus et al., 2011; Perna et al., 2009). Ladson-Billings (1997) maintains that one of the reasons African American students have lower math achievement than white students is that they do not have access to highly qualified math teachers. African American and Latino students are less likely than white students to be taught mathematics by a teacher with an advanced degree (NSB, 2010). Minority students are also less likely to be instructed in STEM by a teacher with full certification (NSB, 2018). Adamson and Darling-Hammond (2011) submit that minority students are up to 10 times more likely to have unqualified teachers than students attending schools that are primarily white.

Flores (2007) reports that African American and Latino students attending schools which serve predominantly racial and ethnic minorities are twice as likely to be educated by teachers with three or fewer years of experience compared to students attending majority white schools. Barton (2004) asserts that the rate of teacher absenteeism in schools serving minority students is more than twice the rate of schools serving mainly white students, meaning that minority students are far more likely to be taught by a substitute teacher. Less than half of students who attend schools that are predominantly minority have a math or science teacher who has an endorsement in that area (Barton, 2004; Darling-Hammond, 2010). A study by Wolf (2015) showed that students enrolled in low poverty districts in the State of California are three times as likely to be taught math or science by teachers with full STEM subject-matter credentials compared to students attending school in high poverty districts. Darling-Hammond (2010) affirms that "by every measure of qualifications—certification, subject-matter background, pedagogical training, selectivity of college attended, test scores, or experience—less-qualified teachers are found in schools serving greater numbers of low-income and minority students (p.

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43).

The underrepresentation of racial and ethnic minorities in STEM may be due to cultural

incongruence. African Americans, Latinos, and Native Americans have a cultural orientation that

values community rather than the individual ingenuity and achievement typically emphasized in

STEM fields (Estrada et al., 2016). A study of minority students enrolled in a STEM-based

Multicultural Scholars Program at Oregon State University found that for half of them, "culture

was a challenge as it was perceived to be incongruent with STEM-based educational

experiences" (McKim et al., 2017, p. 321). In Native American cultures, the well-being of the

tribe is placed above individual accomplishments. This cultural orientation is illustrated in a

study conducted by Smith et al. (2014) which documented that Native Americans majoring in

STEM are significantly more likely than their white male peers to value communal work goals.

This creates cultural incongruence with STEM, since Native Americans "perceive STEM fields

as affording individualistic opportunities (e.g., providing money and prestige), and as potentially

antithetical to communal work goals" (Smith et al., 2014, p. 415). Smith et al. (2014) illustrate

this incongruence by quoting one of the Native American participants in their study:

> I know engineering, like a lot of it is working toward getting the solution, and especially
> if you're working for like a corporation or something you kind of want to do it cost-
> effectively. But . . . sometimes the money factor can overlook the safety of how some
> things are worked out. But I would like to focus more on helping people rather than like
> more money I guess. (p. 413)

Latino culture also emphasizes communal familial relationships—Latino students are expected to

care for older relatives and younger children (Ruiz, 2013). Consequently, they are more likely to

attend 2-year community colleges close to home rather than 4-year institutions where they can

earn a bachelor's degree in STEM (Villegas & Vincent, 2005).

STEM curricula can also be incongruent with the cultures of underrepresented groups.

Jett (2013) posits that the math curricula and textbooks used in secondary and postsecondary schools "frame mathematics as a White male enterprise" (p. 102). Ruiz (2013) validates that educators "need to provide more culturally competent curricula in college and university classrooms that eliminate cultural barriers to understanding the language of mathematics" (p. 40). And contemporary science, grounded in Western white male culture, does not recognize and respect Indigenous knowledge and traditions about the natural world, often at the expense of environmental stewardship (Lee & Buxton, 2008; Snively & Corsiglia, 2001).

Some researchers attribute the underrepresentation of minorities in STEM to stereotype threat (e.g., Jordt et al., 2017; Woodcock et al., 2016). "Stereotype threat is being at risk of confirming, as self-characteristic, a negative stereotype about one's group" (Steele & Aronson, 1995, p. 797). Negative stereotypes associated with both Latino and African American students include lack of ability, lack of interest, and laziness (Oyserman et al., 2007). Such stereotypes can lead to performance anxiety and cause minority students to leave the STEM pipeline. More than 300 research studies have validated that minority students and women in STEM perform more poorly on academic tasks "when stereotypes about their group are made salient" (Harackiewicz et al., 2014, p. 376).

In a study comparing African American college students enrolled at a predominantly white institution (PWI) and a predominantly black institution, Chavous et al. (2004) found that perceptions of negative stereotypes were higher at the PWI, and negative stereotypes had an adverse impact on academic performance for African American students, especially males. In addition, students in technical majors such as engineering perceived more racial stereotypes than nontechnical majors. Interviews with 23 African American mathematics and engineering students by McGee and Martin (2011) revealed that despite their past academic success, all of

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them had encountered the stereotype that African Americans do not have the innate ability to perform at high levels in mathematics. Walton and Spencer (2009) conducted two meta-analyses which combined data gathered from approximately 19,000 students. They found that stereotype threat reduced the academic performance of minorities and women in quantitative fields by one-fifth of a standard deviation, a variation "large enough to account for a meaningful proportion of group differences on high-stakes tests" (Walton & Spencer, 2009, p. 1137).

Woodcock et al. (2012) conducted a study using three academic years of data from The Science Study, which was gathered from a panel of 1,420 predominantly African American and Latino science students. They found that both African American and Latino students experienced stereotype threat, and that stereotype threat was associated with attrition from STEM for Latino students, but not African Americans. Woodcock et al. (2012) speculate that this discrepancy was due to the fact that the majority of African American students included in the study attended predominantly black institutions, which may have buffered the impact of negative stereotypes. Beasley and Fischer (2012) conducted a study using data from the National Longitudinal Survey of Freshmen (NLSF). Asian students were used as the comparison group since they are commonly associated with positive stereotypes in STEM. They found that African Americans and Latinos had a higher level of group performance anxiety from stereotype threat than Asian students. Their research also found that 47% of black men and 32% of Hispanic men left STEM during college, compared to just 14% of Asian men. Beasley and Fischer (2012) concluded that the higher rates of STEM attrition for African Americans and Latinos were the result of stereotype threat.

Limited access to rigorous courses in mathematics and science may contribute to the underrepresentation of minority groups in STEM. A study utilizing the Florida Longitudinal

Education and Employment Dataset by Tyson et al. (2007) found that when African American and Hispanic students take high level math and science courses in high school, they are actually more likely than white students to later obtain a STEM baccalaureate degree. A study by Griffith (2010) indicated that taking more AP courses in STEM subjects in high school is positively related to later persistence in STEM for minority students. Unfortunately,

> students from historically disadvantaged groups such as African American and Hispanic students, both female and male, are less likely to have access to advanced courses in math and science in high school, which negatively affects their ability to enter and successfully complete STEM majors in college." (Hill et al., 2010, p. 5)

Latinos and African Americans are less likely than white or Asian students to attend a high school that provides courses in trigonometry, statistics, and calculus (Adelman, 2006). In a study analyzing 11 years of data for all public high schools in Texas, Fowler et al. (2014) found that Asian students were two to three times more likely to complete an advanced course (defined as dual enrollment, Advanced Placement, or International Baccalaureate) than African-American or Hispanic students. Data compiled by the National Science Board (NSB, 2018) affirms that 50.3% of Asian students complete calculus or higher in high school, compared to 14.6% of Hispanic students and 9.0% of black students. In addition, 51.5% of Asian students complete AP or IB advanced science during high school, compared to 15.9% of Hispanic students and 14.4% of black students (NSB, 2018). An ethnographic research study of school counselors working in low-resourced schools by West-Olatunji et al. (2010) found that African American students are often encouraged to take lower track courses and pursue low level career paths in math and science. Toldson (2014) observes that 60 years after the historic Brown v. Board of Education decision, black students make up a disproportionate number of students in special education classes and are noticeably absent from honors courses.

The obstacles along the STEM pipeline are especially pronounced for women of color due to a phenomenon known as the double bind. Double bind is "the way in which race/ethnicity and gender function simultaneously to produce distinct experiences for women of color in STEM" (Ong et al., 2011, p. 176). Women of color face a double bind in navigating the STEM pipeline due to biases about their gender and race/ethnicity in a landscape dominated by white males. According to Archer-Banks and Behar-Horenstein (2012), women of color must "negotiate both race and gender discrimination, as well as bias among school personnel to succeed in school" (p. 200).

A greater percentage of women of color intend to major in science or engineering in college than white females (Malcom & Malcom, 2011). Yet at multiple points along the STEM pathway, women of color abandon this pursuit. The double bind is painfully evident at the STEM doctoral level. As reported by Ong et al. (2011), white women receive 32.81% of STEM doctoral degrees, a level consistent with their representation in the general population, which is 33.24%. In contrast, African American women make up 6.01% of the population, but earn 2.61% of STEM doctorates. Hispanic women are 6.86% of the population and receive 2.53% of STEM doctoral degrees. Native American women represent 0.43% of the population and garner 0.14% of STEM doctorates (Ong et al. 2011). Fewer still are employed in STEM, as African American, Latina, and Native American women comprise less than 2% of those employed with STEM doctorates (Johnson, 2007).

Johnson (2007) conducted an ethnographic study of 16 women of color who were majoring in STEM at a predominantly white university. During her observations of the participants, she noticed that women of color never asked questions in their large lecture classes. She attributed this to the multiple emotions that women of color must negotiate in a white male

culture:

> As women, they have been socialized not to draw attention to themselves. Some, particularly the darker students, reported feeling conspicuous enough already; others felt anomalous. Finally, they almost universally reported a secret fear that they alone—out of 250 students—were confused. Thus, an institutional practice that was ostensibly open to all students, regardless of personal characteristics, actually functioned as a means for more assertive individuals to gain status as science students at the expense of people who, like my informants, were less comfortable having 200 pairs of eyes turned on them. (p. 812)

Johnson (2007) also documented that white students avoided sitting in the same row or at the same table as women of color. One of the Latina students in the study remarked, "I feel at times I have a double stereotype, a woman of color" (p. 814).

The double bind is especially evident in computer science. Women of color make up 20% of the general population, but only 4% of the computing workforce (Scott et al., 2017). Additionally, only 2.1% of doctorates in computer science are awarded to minority women (Payton et al., 2015). In phenomenological research conducted by Charleston et al. (2014a) that studied African American women enrolled in computer science, the participants "expressed how the computer science culture in their respective departments was clearly unwelcoming to women, and even more ostracizing to African American women" (pp. 281-282). Charleston et al. (2014a) noted that many of the participants in the study wondered if they were being mistreated because of their race or due to their gender.

Participation in computing is particularly problematic for Latinas and Native American women. Although women comprise 25% of computer personnel, Latinas make up just 1% of the computing workforce (Payton et al., 2015). 63 bachelor's degrees in computer science were conferred upon Native American women in 2007 (Hill et al., 2010); the number of Native American women earning bachelor's degrees in computer science fell to 57 by 2014 (NSF,

2017). There are no Native American women among the computer science tenure track faculty at the nation's top 100 research universities, and just 5 Latinas hold tenure track positions in computer science (Towns, 2010). The underrepresentation of Latinas and Native American women in computing may be partially attributable to patriarchal cultural roles within these groups (Varma & Galindo-Sanchez, 2006).

In summary, minoritized racial and ethnic groups such as African Americans, Latinos, and Native Americans are underrepresented in STEM, making up 11% of the STEM labor force despite representing 27% of the U.S. population age 21 and over (NSB, 2018). The underrepresentation of minority groups in STEM may be due to achievement gaps in math and science performance. Some scholars posit that stereotypes and racial/ethnic prejudice are major contributing factors to the underrepresentation of people of color in STEM. Others cite reasons such as minority students' lower self-efficacy in the STEM subjects, a lack of minority STEM role models, lower persistence rates of people of color in STEM, a lack of qualified teachers in schools with a predominant minority enrollment, cultural incongruence, stereotype threat, and limited access to rigorous STEM courses. Women of color are especially at risk due to a phenomenon known in the literature as the double bind, as they must "negotiate both race and gender discrimination" (Archer-Banks & Behar-Horenstein, 2012, p. 200) to succeed in STEM.

**Part 4:  Strategies that Promote Success of Underrepresented Groups in STEM**

Expanding the size of America's STEM workforce is critically important to the security and economic prosperity of our nation (NAS, 2007). However, more than half of students who begin college intending to major in STEM leave for other degree programs (NAS, 2007). Those who leave the STEM pipeline are "disproportionately women and students of color" (NAS, 2007, p. 99). This trend is highly problematic for several reasons. It perpetuates economic

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injustice, since STEM graduates earn at least $700,000 more over their careers than graduates with degrees in liberal arts or social science (Kim et al., 2015). Consequently, when women and people of color leave the STEM pipeline, it maintains the prevailing gender wage gap and the cycle of poverty. The underrepresentation of women and minorities in STEM also jeopardizes the future integrity of America's STEM workforce. According to Museus et al. (2011), racial and ethnic minorities are projected to represent over 50% of the U.S. population by 2050. Unless steps are taken now to improve the persistence of women and people of color in STEM, there will be critical shortages of qualified workers in America's STEM labor force in the years ahead. The underrepresentation of women and minorities in STEM also impedes technological advancement. Bell et al. (2017) assert that "if women, minorities, and children from low-income families were to invent at the same rate as white men from high-income families, the rate of innovation in the economy would quadruple" (p. 16). The inclusion of underrepresented groups in STEM expands the diversity of insight, perspectives, and creative ideas which drive innovation and problem-solving (Egan, 2011; Kilmartin & Pimentel, 2014).

Fortunately, scholars have identified a variety of strategies for attracting and retaining women and people of color in STEM. This section of the literature review explores methodologies, programming, and experiences that have proven effective for enhancing the interest and persistence of underrepresented groups in STEM. Strategies such as the use of culturally relevant pedagogy, mentoring, out-of-school time programs, and spatial training can help schools expand their capacity for meeting the specific pedagogical, social, and emotional needs of females and students of color in STEM.

**Culturally Relevant Pedagogy**

There is a growing body of research which shows that culturally relevant education is critically important for engaging underrepresented students by making STEM instruction pertinent to their lived experiences (Museus et al., 2011). According to Johnson (2011), most STEM teachers do not know how to appropriately address the diversity of students found in their classes. Many educators view the STEM disciplines as culturally neutral subjects which should be taught with the same methods to all students. However, Tsui (2007) warns that "it is dangerous to assume that what is recommended for the general STEM student body is necessarily what works best for those who are underrepresented in that population" (p. 555). Furthermore, Farinde and Lewis (2012) assert that the STEM subjects "are not culture free" (p. 426).

Women and people of color have a rich heritage to draw upon in STEM, as their forerunners have a long history of important advances in science and technology. For example, ancient Mayan hieroglyphics detail "in mathematical notations the path of Venus in relation to the sun" (Kidwell, 2002, p. 93). The Haya people of Tanzania began forging steel 2,000 years ago, centuries ahead of European metallurgists (Schmidt & Avery, 1978). The Hohokam started construction of a complex irrigation system in Southwest Arizona more than 1,000 years ago, demonstrating "advanced knowledge and skill in water conservation and management" (Woodson et al., 2015, p. 275). In more recent times, people of color such as Lewis Latimer and his development of a long-lasting carbon filament for the light bulb have made an enduring impact on everyday life (Johnson & Watson, 2005). However, the technological achievements of underrepresented groups in STEM "have been largely obscured, ignored, or diminished in importance" (Johnson & Watson, 2005, p. 89). For example, other than "Marie Curie, few people

can name a single other female scientist" (Helmreich et al., 2017, p. 2427). STEM subjects are taught in America's schools from a Eurocentric, white male point of view, which can lead underrepresented populations to view science "as a hegemonic icon of cultural imperialism" (Aikenhead, 1997, p. 220).

Culturally relevant (or responsive) education was established to value the cultural knowledge and skills that underrepresented groups bring to learning, and to counter a prevailing deficit perspective that persists in many educational circles, the misguided "belief that [some] individuals lack the ability to achieve because of their cultural background" (Brown & Crippen, 2016, p. 127). Culturally relevant education consists of two main strands—culturally relevant pedagogy and culturally responsive teaching. "Although many researchers use these terms interchangeably" (Aronson & Laughter, 2016, p. 167), each strand has a different emphasis. Culturally responsive teaching, developed by Gay (2010), focuses on the teaching methods, strategies, and resources that make a classroom culturally responsive. Culturally relevant pedagogy, conceptualized by Ladson-Billings (1995, 2006), is more concerned with the attitudes and dispositions of teachers:

> Teachers who I term culturally relevant assume that an asymmetrical (even antagonistic) relationship exists between poor students of color and society. Thus, their vision of their work is one of preparing students to combat inequity by being highly competent and critically conscious. While the teachers are concerned with the students who sit in their classrooms each day, they see them in relation to a continuum of struggle. (Ladson-Billings, 2006, p. 30)

Dover (2013) observes that culturally relevant education is concerned not only with culturally responsive techniques, but also "students' out of school lives, family structures, interests, beliefs about schooling, and prior experiences with subject matter, and the demographic, religious, and sociopolitical context of the community in which they teach" (pp. 5-6).

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Culturally relevant approaches have been successfully employed for engaging underrepresented groups in all STEM subjects, especially in science. For example, when teachers use hip-hop culture with urban students in science classes, the students display markers of engagement such as head nods that were not visible previously (Emdin, 2010; Emdin & Lee, 2012). A case study by Dimick (2012) at a diverse inner city high school revealed that students were more engaged in science when they were empowered to analyze social injustices in their neighborhood such as corporate water pollution. Grimberg and Gummer (2013) conducted a study of teachers working with Native American students to investigate the effect of creating points of intersection between the students' culture and school science. Teachers implemented a variety of culturally relevant strategies, such as a unit on accelerated motion that included a presentation from a tribal elder on the craft of constructing and shooting arrows. Results from the study showed that the increased use of cultural connections was a significant factor in gains in the students' science test scores. Strachan (2017) sets forth that educators can create culturally relevant environments in science classes by setting high expectations, getting to know the cultural beliefs and practices of their students, using real-life references from students' communities, and planning activities that students can relate with.

Cultural connections are also important in mathematics learning for underrepresented groups. Bonner and Adams (2012) stress the importance of math teachers learning about the cultural background of their students, noting that "this knowledge will provide support for situating mathematics in real-life contexts that are meaningful to students" (p. 35). To evaluate the effectiveness of cultural connections in mathematics, Ensign (2003) conducted research in the second, third, and fifth grade classrooms in two urban schools where fewer than 20% of the students met state math benchmarks. Teachers in these schools implemented a culturally

connected approach where math problems were based on the daily experiences of their students. For example, "when a student wrote about using money to buy milk for his family, the teacher used the problem during a lesson on counting money" (Ensign, 2003, p. 418). Results showed that students stayed on task more frequently, showed a greater interest in math, and improved their performance on math tests. Gutstein (2003) conducted a study in an urban Latino classroom where mathematics was taught from a social justice perspective. Students used math to analyze social inequities in their community, such as racial profiling during traffic stops. As students came to recognize that math was a tool that could help them examine the discrimination they faced in society, they displayed increased confidence in math and "became demonstrably more adept at explaining their mathematical reasoning and problem-solving strategies" (Gutstein, 2003, p. 54).

Many underrepresented students in engineering feel out of place because they believe that "their cultural practices and identities do not comport with those of engineering cultures" (Wilson-Lopez et al., 2016, p. 279). To counter this perception, Kern et al. (2015) created an engineering activity for Native American students where they were asked to design, construct, and test a fish weir—an ancient technology used by Native Americans to catch fish. By drawing on their cultural history, the students were able to see how engineering principles are "accessible and necessary contributors to the growth and heritage of their community" (Kern et al., 2015, p. 46). A study by Samuelson and Litzler (2016) confirmed that students of color who persist in undergraduate engineering programs draw upon the cultural wealth of their communities to succeed.

Wilson-Lopez et al. (2016) conducted an ethnographic study with a group of Latino adolescents to explore how their cultural knowledge could be connected with the study of

engineering and technology. Over the course of a year, the students were asked to work in small groups to engage in projects where they applied engineering skills to solve problems within their communities. The researchers observed that throughout the study, students drew upon their cultural knowledge to solve problems. For example, a group of students, developing an improved shower chair headrest for children who are unable to hold up their heads, made use of the sewing skills that one of the students had learned in repairing her siblings' clothing in order to construct a prototype out of marine vinyl with an airtight seam. Wilson-Lopez et al. (2016) concluded that the participants in the study "held funds of knowledge that were relevant to engineering design processes" (p. 300) that could be used by educators to connect students with formal principles in the field.

Although culturally relevant approaches are often viewed as strategies for engaging students of color, they can also be successfully employed to bridge the gender gap in STEM (Dancstep & Sindorf, 2018; Williams et al., 2017). Subotnik et al. (2010) suggest that women are drawn to people-oriented careers, and Koppel et al. (2002) posit that "women are more inclined to study subjects they find socially relevant" (p. F1C-4). Unfortunately, "women often do not perceive STEM as a vehicle for improving the human condition (Shapiro & Sax, 2011, p. 9). It is therefore imperative that educators develop projects and assignments that emphasize how the STEM fields can be used to foster environmental stewardship and improve the lives of others (Blickenstaff, 2005; Corbett & Hill, 2015).

Dancstep and Sindorf (2018) explain that in order to identify "effective ways of reaching females, CRP [culturally relevant pedagogy] explores commonalities that women and girls may share in the ways they experience and prefer to participate in STEM learning" (p. 471). Dancstep and Sindorf (2018) specify four powerful ways that culturally responsive approaches can

increase the interest and participation of females in STEM:

1. Represent females and their interests. Girls can be turned off by STEM's masculine, techie topics and environment. They are more engaged with STEM when the subject matter and program aesthetics are connected to their unique interests.

2. Enable social interaction and collaboration. Research shows that girls achieve at higher levels in STEM when learning is social, cooperative, and active.

3. Create a low-pressure setting. Research suggests that girls do not perform as well academically when they are immersed in competitive environments (e.g., Bönte, 2015; Niederle & Vesterlund, 2007; Taylor, 2005). STEM activities are more likely to engage females when they are comfortable, non-threatening, and open-ended.

4. Provide meaningful connections. Girls are more interested in STEM when the subject matter includes applications such as addressing environmental issues, exploring social concerns, or bettering the lives of people or animals.

Franklin et al. (2011) conducted a study with a group of middle school girls that illustrates how culturally relevant strategies such as those enumerated by Dancstep and Sindorf (2018) can be harnessed to engage girls in STEM activities. A computer science unit was developed around the topic of the conservation of endangered animals. "The theme of endangered species was chosen to tap into two interests of young females—having a positive impact on the world and working with animals" (Franklin et al., 2011, p. 2). Caring for animals was considered an especially powerful motivator, as research has shown that females are strongly drawn to this topic (e.g., Irvine & Vermilya, 2010). Students worked together in collaborative pairs, and each group was assigned an endangered animal to research. Throughout the project, the students were given increasingly complex computer tasks as they engaged in

their research, beginning with writing about their animal and advancing to computer animation as they learned major programming concepts. Pre- and post-surveys showed that the students had an increased interest in pursuing careers in computer science. In addition, several students changed their stereotypical views that females do not have the requisite skills to succeed in the field of computer science.

**Role Models and Mentoring**

*In order to teach, it is enough to know something. But to educate, one must be something. True education consists of giving oneself as a living model, an authentic lesson.*
                    Attributed to St. Alberto Hurtado (Delfra & Berends, 2014, p. 7)

STEM role models serve two primary functions—they help students picture themselves in STEM careers, and they give witness to how an individual can overcome barriers to success (Kim et al., 2009). STEM teachers often have limited knowledge about STEM occupations such as engineering and information technology (Brown & Borrego, 2013). Therefore, schools need to provide "early contact between students and [STEM] professionals" (Corbett & Hill, 2015, p. 89). STEM role models can help "students understand the breadth of skills that they will need to be successful" (Corbett & Hill, 2015, p. 89). Ruiz (2013) contends that students need "to see and meet others like themselves succeeding in STEM fields" (p. 40), especially for underrepresented groups like women and people of color.

To address the needs of underrepresented groups in STEM, in addition to providing women and minorities with positive role models, "mentoring programs have become prevalent" (Tsui, 2007, p. 558). Stoeger et al. (2013) assert that mentoring programs provide "an excellent opportunity for improving the situation of girls and women in STEM" (p. 409). Mentoring is also a proven success factor for students of color (MacLachlan, 2006; McBride, 2003; Tsui, 2007). Mentoring underrepresented students in STEM heightens their engagement, increases

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motivation, and boosts retention rates in the STEM pipeline (Ghosh-Dastidar & Liou-Mark, 2014).

Role modeling can sometimes be mistaken with mentoring, but it is not the same thing. Barker and Cohoon (2007) explain that since role modeling is frequently a component of mentoring, "this connection often leads to confusing role modeling with mentoring" (p. 1). Role models are people that others want to emulate. However, STEM role models may not have any direct interaction with students or even know them (Downing et al., 2005; Kim et al., 2009; Shumow & Schmidt, 2014). In contrast, mentoring involves an ongoing relationship between the mentor and mentee (Barker & Cohoon, 2007). "Mentoring is a collaborative process" (Trujillo et al., 2015, p. 1) that engages both the mentor and the student(s) they are mentoring. STEM role modeling might involve a one-time talk or demonstration before a group of students, whereas mentoring is a sustained relationship with student(s) over time.

Many studies have demonstrated the positive impact of female STEM role models for girls and women. Marx and Roman (2002) conducted several experimental studies and found that female role models improved the math performance of women. They concluded that female role models were important for girls "because they represent stereotype-disconfirming evidence about women's inferior math ability" (p. 1183). Plant et al. (2009) ran an experimental study where students were assigned to either a virtual computer role model (male or female) or none at all. The virtual role model delivered a presentation about female engineers. Results showed that girls who had the female computer role model had a significantly greater increase in their interest in engineering compared to the other groups. Female participants in the study also reported higher self-efficacy regarding engineering.

An experimental study by Rosenthal et al. (2013) indicated that female undergraduates

who were exposed to successful female role models had a greater sense of belonging and interest in a STEM career than students in a control group. Stearns et al. (2016) examined longitudinal data to analyze the impact of high school faculty demographics on college major and graduation. They found "a positive and significant association between the proportion of female math and science teachers in high school and young women's probability of declaring a STEM major" (p. 99). Dasgupta and Asgari (2004) conducted two studies which indicated that women's stereotypical beliefs about STEM were mitigated by having female teachers in their math and science courses.

In addition to reducing stereotype threat, one of the ways that female role models benefit girls and women in STEM is by showing how they "balanced work and life/family" (Kim et al., 2009, p. 13). Concerns about their ability to combine a STEM career with raising a family emerge with girls as early as their adolescent years (Bamberger, 2014). A study by Hartman and Hartman (2008) revealed that the potential conflict between a STEM career and raising a family is considered a significant barrier by the majority of female engineering students. Similarly, Goulden et al. (2009) found that female postdoctoral students in STEM were twice as likely as men to cite family issues as a reason for changing their career objectives. Xu (2015) contends that "in order to increase the presence of women in STEM occupations, it is critical to encourage a more accommodative attitude towards the traditional family role of women" (p. 515).

A study by DeWelde and Laursen (2011) found that young women want female role models who demonstrate that it is possible to balance work responsibilities with family obligations. For example, a female aerospace engineering student in the study stated:

> One of the female professors in my department—even though I don't talk to her that much, I did TA for her a semester—and she seems to have it all, from an outside perspective. She's got two young kids, she's tenured, and is one of the leaders in her

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field, and seems to not have a lot of grey hair and huge bags underneath her eyes. So, to look—and even if I don't talk to her that much—to be able to say, 'Well, there's somebody who did it. You know, I might be able to do it too,' is great. (p. 584)

Female undergraduate students participating in a study conducted by Tan-Wilson and Stamp (2015) initially expressed "concerns that research-based careers in STEM following graduate study would not be compatible with raising families" (p. 3). The students were then exposed to role models who discussed how they raised children while engaged in a STEM career. Results of the study confirmed that role models can have a positive influence on changing women's attitudes about their ability to balance a STEM career with family life.

In addition to girls and women, underrepresented minorities also benefit from having STEM role models they can identify with and/or who share their cultural background. African Americans score higher on academic tests when exposed to a role model from their race that serves as a counterstereotype (Marx et al., 2009). Grandy (1998) found that African American, Latino, and Native American college students who had minority role models were more likely to persist in STEM. A study by Karunanayake and Nauta (2004) revealed that African American students prefer to have career role models who share their race. Lent et al. (2005) observe that exposing students of color to same-race role models helps retain them in engineering programs at HBCUs.

Klopfenstein (2005) analyzed longitudinal data from the Texas Schools Microdata Panel (TSMP) and documented that African American students were more likely to continue in a rigorous math course trajectory if they had been taught mathematics by faculty role models who were African American. A study by Thompson and Lyons (2008) showed that exposing middle school students to role models from the engineering professions "positively influenced African-American students' perceptions of engineering" (p. 208). Taningco (2008) conducted a

qualitative study of STEM professionals which revealed that Latinos who had successful careers credited having a Latino role model with their decision to choose a STEM profession. It should be noted, however, that minority students do not automatically benefit from role models who share their race, ethnicity, or cultural background. Shumow and Schmidt (2014) caution that students from underrepresented groups "tend to be intimidated by role models who look as though they never struggled" (p. 63).

There is some evidence that the gender of STEM role models is important for females. Milgram (2011) posits that "women and girls need to see female role models in the workplace that look like them" (p. 5). Lockwood (2006) conducted two studies with male and female undergraduates. "In both studies, results indicated that female participants were more inspired by outstanding female than male role models; in contrast, gender did not determine the impact of role models on male participants" (Lockwood, 2006, p. 36). In two experimental studies and one quasi-experimental study, Stout et al. (2011) found that female role models are more effective than male role models for improving STEM outcomes for women, including boosting their self-efficacy, improving their attitudes about STEM, and increasing their motivation to seek a STEM career. Young et al. (2013) conducted a study which showed that "female role models in STEM fields can increase a woman's implicit identification with science, while simultaneously decreasing, and indeed inverting, implicit gendered stereotypes" (p. 290).

In contrast to the aforementioned studies, Drury et al. (2011) reviewed correlational data from three universities. Based on their analysis of the empirical data, they concluded that "when it comes to recruiting, female role models may be no more effective than male role models in drawing women into STEM" (Drury et al., 2011, p. 266). In addition, two experimental studies by Cheryan et al. (2011) affirmed that female role models in STEM that embody common

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stereotypes, such as wearing unfashionable clothes and having nerdy pastimes, lowered women's beliefs that they could be successful. When identifying potential STEM role models, finding someone that female students can relate with may be more important than their gender.

Mentoring builds upon the power of role modeling by fostering a long-term relationship between the role model and their student(s). Kupersmidt et al. (2018) posit that STEM mentoring has three primary goals:

1. Change attitudes, beliefs, and plans related to STEM. Mentoring can help foster confidence and self-efficacy in STEM. It also can assist mentees in developing a STEM identity—the sense that they belong in a STEM course or career.

2. Boost participation in STEM. Mentoring can be a gateway to deeper STEM engagement, leading mentees to consume more STEM media, take additional STEM courses, participate in STEM extracurricular opportunities, and/or choose a STEM major for college.

3. Increase STEM skills, knowledge, and achievement. Mentoring can help students master the academic skills needed for success in STEM.

Kupersmidt et al. (2018) have also identified several challenges in implementing a STEM mentoring program:

1. Neglecting the relationship between the mentor and mentee. STEM mentoring can become overly focused on building academic skills or completing STEM activities. To avoid this, it is essential for mentoring programs "to offer mentors and mentees the time they need to get to know each other, to talk about things other than STEM, and to share a good laugh or connect in ways that will make their STEM work more authentic and meaningful" (p. 17).

2. Transportation issues. Mentoring can be difficult in rural or inner city settings if family members are asked to transport students to meet with a mentor at a STEM business or university. Mentors should meet at the mentees' school whenever possible. Sometimes differing schedules make it impractical for a group of mentors to travel to school at the same time. In such cases, the school may find it necessary to provide transportation to off-site locations.

3. Providing adequate meeting space. It can be difficult to find large open spaces in schools for mentors to meet with students and conduct hands-on STEM activities. Mentors should consider such space limitations when planning their mentee activities.

Kitts (2009) reports that although there are many opportunities available for mentoring students in STEM, "the number and coverage of such programs are still insufficient . . . at the 6-12 grade level" (p. 162). One of the main reasons for the inadequacy of mentoring programs at the middle and high school level is the shortage of qualified mentors due to the lack of underrepresented females and minorities working as STEM professionals (Stoeger et al., 2013; Syed et al., 2012). In addition to professionals working in the STEM fields, schools can look for qualified mentors for underrepresented students among faculty and student peers (Griffin et al., 2010; Phinney et al., 2011; Tsui, 2007), college students (Holmes et al., 2012), and alumni (Veenstra, 2014). Forming online STEM mentoring relationships has proven to be a successful strategy when nearby mentors have not been readily available (Blake-Beard et al., 2011; Stoeger et al., 2013; Stoeger et al., 2017).

Mentoring is a key strategy for keeping women in the STEM pipeline. Kahveci et al. (2006) documented that female undergraduate students who participated in a support program that included mentoring were more likely to persist in a STEM major. Farland-Smith (2009)

explored how mentoring affected the perceptions of middle school female students regarding science. In her study, students were mentored by a group of female STEM professionals as they participated in laboratory and field exercises. Surveys and journal entries indicated that the mentoring improved the girls' image of scientists and helped them develop a broader awareness of the human dimensions of STEM work, which is especially important since "girls at a young age form perceptions about the human aspect of the sciences that are narrow and limiting" (Farland-Smith, 2009, p. 415). MacPhee et al. (2013) conducted a longitudinal study of a mentoring program for underrepresented students enrolled in STEM at a large public university. The female students in the study started college with lower confidence in their academic abilities than men, even though they entered college with similar grades. By graduation the academic self-efficacy of the females in the mentoring program was similar to the self-efficacy of male students. Dennehy and Dasgupta (2017) conducted a longitudinal experimental study to assess the effects of mentoring on female undergraduate students in engineering. Results confirmed that "female (but not male) mentors protected women's belonging in engineering, self-efficacy, motivation, retention in engineering majors, and postcollege engineering aspirations" (Dennehy & Dasgupta, 2017, p. 5964).

Research indicates that fostering healthy mentoring relationships is especially powerful for retaining underrepresented students of color in STEM. For example, in a study of the Benjamin Banneker Scholars Program, minority students enrolled in STEM consistently rated having a faculty mentor as having the greatest impact on their academic performance (Kendricks et al., 2013). Wilson et al. (2012) analyzed the impact of a STEM mentoring program at a major university on undergraduate minority students who were underperforming academically. The mentoring program included the use of STEM faculty, peers, advisors, and postdoctoral

researchers. Results showed that minority students in the mentoring program were more likely to persist in STEM than the national average for all undergraduate STEM majors. A longitudinal study of high school students by Syed et al. (2012) found that underrepresented minority students in STEM valued having a mentor who shared their background, and as contact with matched-background mentors increased, minority students had a greater sense of identity with STEM. Slovacek et al. (2011) suggest that "for minority students whose mentor is also a minority, that relationship can serve as a powerful reminder that the prevailing stereotypes of minorities in the sciences can be overcome" (p. 26). Poirier et al. (2009) affirm that mentorship programs "are integral to retaining URMs in STEM education and careers" (p. 2).

**Family Support**

Research shows that families play a critical role in the interest and persistence of underrepresented students in STEM. Atwater and Brown (1999) suggest that "parents and the extended family's involvement in schools and science classrooms may be indispensable" (p. 47) for student learning. For example, parents can assist underrepresented students in STEM by encouraging them to take advanced courses (Shumow & Schmidt, 2014). Perez-Felkner et al. (2017) attest that social support from parents can "scaffold students through challenges and help girls counter their own and others' lower beliefs" (p. 8) about their academic abilities in the STEM subjects. Besides direct involvement with school, families can also assist students on an informal level. For example, Bell et al. (2009) emphasize that "family visits to museums or science centers" (p. 97) can complement STEM instruction at school. In addition, one of the main ways that students end up participating in science clubs or STEM camps is because their parents made a decision to enroll them (Bell et al., 2009).

Corbett and Hill (2015) state that parents play a key role in helping "their daughters to

develop interest and confidence" (p. 108) in STEM fields such as engineering and computer science. They set forth the following ways that families can influence how girls perceive themselves in relation to STEM:

- Promote a growth mindset. Parents can teach their daughters that the brain works like other muscles, and the more they exercise it, the stronger it will get. The road to success in STEM is not due to innate talent, but passion, persistence, and commitment to self-improvement.

- Acquaint girls with various STEM career opportunities at an early age. Help daughters learn about professions such as engineering and computer science, especially since women are underrepresented in these fields.

- Encourage daughters to take advanced coursework, especially in mathematics.

- Introduce girls to adults they can identify with who work in STEM fields.

- Question others who maintain that fields like computing are only for those who already have strong programming skills.

- Provide opportunities for daughters to work with boys and sons to work with girls.

- Encourage daughters to take things apart and put them back together again.

- Help daughters understand that STEM is socially relevant, and can provide them with a platform for working with and helping others.

These strategies can also be successfully employed by parents for engaging children of color in STEM.

A qualitative study by Baker and Leary (1995) investigated the factors that lead girls to choose a STEM career. The research team interviewed female students in Grades 2, 5, 8, and 11. The girls with the greatest interest in pursuing a STEM career attributed their love of math and

science to a parent or grandparent who worked in or had an avocation in STEM. Moran et al. (2009) conducted a study of a program supporting youth from low income families which showed "that their parents (especially mothers) remained their most important resources to staying on track to college" (p. 351). In a study by Razfar (2012) that assessed the ability of Latino students to comprehend math strategies related to probability, "the role of the parents was particularly significant. They engaged the children and mediated their learning . . . in ways that other adult facilitators by themselves were unable to do" (p. 73). Razfar (2012) noted that parents were able to draw on their children's funds of knowledge to help them develop mathematical concepts and probability strategies through the use of Spanish and informal math terminology, as well as discussing mathematical principles based on activities from home.

Talley and Martinez Ortiz (2017) conducted a mixed methods study to determine if students of color differ from their white peers in the ways they develop an interest and persistence in STEM. Results from focus groups and student surveys revealed that family support is a statistically significant factor in the decision of minority students to choose and persist in a STEM major. Samuelson and Litzler (2016) conducted a qualitative study that gathered data from interviews with minority engineering students at 11 universities to determine the various forms of cultural capital that students of color rely upon to persist in STEM. Family support and encouragement was cited as an important factor in students' motivation to continue in their engineering program. For example, a Latina student commented:

> Motivation? A lot of my family. My dad and I are very close. I talk to him at least every day just about—like right now he's helping me with my job search for internships. We're very close, and he always tries to remind me, 'Remember why you got into this.' Just chug through it. He's like, 'Just don't even think about it, about how stressful it is, just get through it.' Because it will be over soon. (p. 106)

Likewise, a study by Charleston et al. (2014b) found that for African American students pursuing

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computer science degrees, "parental and familial encouragement was deemed an essential

cultural factor affecting participants' success" (p. 409). Some of the ways that the African

American parents in the study supported their children in computer science included offering

verbal encouragement, providing financial support, and seeking educational opportunities for

their children such as enrolling them in computer camp or asking a friend or colleague to teach

their child programming. A study on middle school student access to upper-level mathematics by

Berry (2008) identified several ways that families support the success of students of color in

math, such as guarding opportunities, setting high standards (e.g., placing a high value on

education), and serving as resources for math (e.g., helping their children with homework).

Parental advocacy is particularly crucial for students of color to navigate the STEM pipeline. A

parent in Berry's (2008) study noted:

> My expectations are higher than the teachers' expectations. Black students have to do more to get noticed in school. As parents, we had to request for my child to be tested for AG [academically gifted]. Black parents have to make requests and be in the schools to get their child noticed. I don't accept anything; I write notes and ask questions. Black parents have to be involved with their child's education and not settle for the mediocrity that schools sometimes let Black children get away with. (pp. 476-477)

Family support for girls and minorities in STEM can be strengthened in several ways. For

example, parents can be provided with materials about the importance of the STEM fields and

how to discuss these topics with their children (Rozek et al., 2017). Shumow and Schmidt (2014)

contend that parents are able to provide greater support to their children if they are

knowledgeable of the many career opportunities available by studying math and science. Talley

and Martinez Ortiz (2017) affirm that "outreach efforts that inform parents and families about the

opportunities in STEM careers and illustrate that these careers are for everyone" (p. 23) will lead

more girls and students of color to enter and persist in the STEM pipeline. For underrepresented

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students who do not have strong family support at home, schools can foster close bonds with students by creating small advisory groups that resemble "the familial, creating school-based family support systems" (Perez-Felkner, 2015, p. 16).

**Out-of-School Time (OST) Programs**

Providing students with access to out-of-school time (OST) programs is a proven strategy for enhancing knowledge, sparking interest, and developing skills in STEM, particularly for girls and racial/ethnic minorities that are underrepresented in the STEM pipeline. OST programs include a wide variety of activities such as STEM camps, coding clubs, museum visits, nature programs, robotics competitions, and science clubs. OST programs in STEM are typically offered afterschool, on weekends, and/or over summer break (Froschl & Sprung, 2014).

OST programs provide an important venue for engaging underrepresented youth in fun STEM activities, which can set them on the path toward an eventual career in the STEM fields. Riegle-Crumb et al. (2011) contend that "enjoyment of science is . . . an important driver behind gender difference in career aspirations at younger ages, at least in the case of White and Hispanic girls" (p. 472). A study by VanMeter-Adams et al. (2014) found that extracurricular activities have a greater influence on stimulating student interest in STEM than traditional classroom experiences. OST programs also provide a platform for girls and students of color to explore STEM in a relaxed atmosphere without the fear of getting the wrong answer or taking risks (Froschl & Sprung, 2014).

A substantial body of research has demonstrated the benefits of OST STEM programs for girls. For example, Weber (2011) evaluated the California University of Pennsylvania STEM Initiative (CSI), which provided two "Girls' Nights Out" for middle school girls. Each "Girls' Night Out" event included a series of learning stations that featured hands-on engineering and

science activities that were designed to generate career awareness and interest in STEM. Pre- and post-surveys indicated that "the students' career goals and plans for enrolling in STEM-related courses changed as a result of their participation in the project" (Weber, 2011, p. 20), with the number of girls wanting to pursue an engineering-related career increasing by over 18%.

Tyler-Wood et al. (2012) conducted a longitudinal, quasi-experimental study to analyze the effectiveness of Bringing Up Girls in Science (BUGS), an afterschool environmental science program for 4th and 5th grade girls. Their findings documented statistically significant gains for participants in their science knowledge compared to a matched control group. In addition, the participants were tracked longitudinally through their entrance in college. Girls who participated in BUGS in 4th and 5th grade had a statistically greater interest in a STEM career upon college entrance than students in a control group. Dubetz and Wilson (2013) developed a STEM program for middle school girls called Girls in Engineering, Mathematics, and Science (GEMS). The program included a series of Saturday morning workshops which provided hands-on STEM activities for participants. Data collected over a three-year period showed that student interest in STEM increased by 35% after attending a GEMS workshop. Froschl and Sprung (2014) assessed the impact of Great Science for Girls, an OST STEM initiative funded by the National Science Foundation. Over 90% of participants in Great Science for Girls indicated that the program increased their interest in STEM.

A longitudinal study conducted by Melchior et al. (2018) evaluated several leading robotics programs—FIRST LEGO® League for grades 4-8, FIRST Tech Challenge for grades 7-12, and FIRST Robotics Competition for grades 9-12. "While both young women and men in FIRST showed significantly greater gains than their comparison group counterparts, the gains for female FIRST participants were significantly greater than those for program participants as a

whole" (Melchior et al., 2018, p. 9). In addition, girls who were alumni of one or more of the FIRST robotics programs had statistically significant gains in both their interest in pursuing an engineering-related degree and their selection of engineering courses during their first year of college.

Research also validates that OST programs are an effective strategy for engaging underrepresented students of color in STEM. Miller et al. (2012) conducted a study of ITEAMS (Innovative Technology-Enabled Astronomy for Middle Schools), an OST program that targeted underrepresented minority students. They found that minority students who participated in ITEAMS made statistically significant gains in STEM subject matter knowledge. Fadigan and Hammrich (2004) evaluated WINS (Women in Natural Sciences), a museum-based science enrichment program for low income high school students from urban, single parent households. The majority of students participating in WINS were from minority groups, including 83% African American and 4% Latina. Findings indicated that "the majority of participants perceived the science content they learned in WINS as having an influence on their education and career decisions" (Fadigan & Hammrich, 2004, p. 855). More than 90% of the participants went on to attend college, and over half pursued degrees in STEM-related careers.

Denner et al. (2009) studied the impact of an afterschool program for middle school Latina students called the Girl Game Company (GGC). Students participating in GGC worked in pairs to learn coding in order to develop computer games. Pairing students with a partner was an intentional strategy to encourage students to take risks, something they might have been afraid to do if they were working alone. Survey data indicated that students joined the program because it allowed them to spend more time with their friends. The students continued their involvement in GGC because designing computer games provided an opportunity to use their creativity. The

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researchers concluded that programs like GGC "hold promise for engaging an underserved group of Latina girls and setting some of them on paths to IT-intensive careers" (Denner et al., 2009, p. 33).

Duran et al. (2014) investigated the impact of the FI[3]T Project, an afterschool collaborative designed to help underrepresented minority students learn about information technology in the STEM fields. Participants came from a Midwestern school district where the high school graduation rate was less than 25%. The study found that the FI[3]T Project had a significant impact on the development of the students' IT skills and their understanding of the use of information technology within STEM. In addition, more than half of the students in the study indicated that their participation in the FI[3]T Project either maintained or increased their interest in pursuing a STEM-oriented career.

Scott et al. (2014) assessed an OST project for middle and high school students called COMPUGIRLS. 74% of the participants in the program were Latina, 19% were African American, and 7% were Native American students. Each COMPUGIRLS session was centered on a particular social justice issue connected to the students' life experience. The participants applied the computer science skills they learned in COMPUGIRLS to analyze the social justice issues and describe solutions. Scott et al. (2014) found that as a result of the students' participation in the program, "their technological self-concept and confidence in operating systems use grew significantly compared to those of a control group" (p. 266).

Young and Young (2018a) conducted a study of a randomly selected sample of more than 3,000 African American students from across the United States. They found a direct, positive relationship between student participation in OST STEM programs and the likelihood of taking advanced science courses in high school. They concluded that engagement in OST STEM

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activities are "a viable consideration for parents, teachers, and other educational stakeholders seeking to improve Black student participation in advanced science coursework" (Young & Young, 2018a, p. 56). A similar study by Young and Young (2018b) found that participation in OST STEM programs had a statistically positive effect on mathematics achievement for African American students. Caplan (2018) evaluated two summer programs (Junior Research Scientists and ComED Youth Ambassadors) that were offered to inner city youth in Chicago. He found a statistically significant change in STEM content knowledge among participating students. However, the study did not find a statistically significant change in attitudes toward STEM.

Allen et al. (2017) evaluated 160 OST programs across the nation. Approximately 70% of the programs in their study were school-based and 28% were community-based (2% were neither school nor community-based). Their study evaluated a diverse student sample, including groups traditionally underrepresented in STEM such as African American (25.05%), Latino (13.90%), and Native American (2.04%). 10.44% of the students in the sample belonged to more than one minority group, and almost a third lived in a home where English was not the primary language. The study found that OST programs were associated with "significant increases in STEM career interest, STEM career knowledge, and STEM activity participation" (Allen et al., 2017, p. 18). Young et al. (2017) conducted a meta-analysis of OST STEM program studies. They initially reviewed 84 studies, but after applying a set of inclusion criteria, the final pool for the meta-analysis consisted of 15 studies encompassing 20 independent effect sizes. Their meta-analysis found that OST STEM programs have a statistically positive impact on all students regarding STEM interest, including female students and racial minorities.

Evaluating the design of various OST STEM programs for girls and minorities, Migus (2014) determined that the most effective programs include the following attributes:

- Feature a youth-centered design based on students' needs and assets

- Provide for learning that is open-ended, inquiry-based, and hands-on

- Relate content to students' life experiences

- Offer opportunities to build technical skills

- Target college and career readiness

- Establish supportive peer relationships

- Connect students to positive role models and mentors

- Maintain a small student-to-adult ratio

- Afford opportunities for family support

- Are provided on a continuing basis instead of a single event.

Based on a review of research of afterschool and summer programs, Howard-Brown et al. (2012) report that OST activities produce the following benefits for students: "(a) improved attitudes toward STEM fields and careers, (b) increased STEM knowledge and skills, and (c) higher likelihood of graduating and pursuing a STEM career" (p. 4). Due to such benefits, Howard-Brown et al. (2012) encourage educators to utilize OST programming, especially with those who are underrepresented in the STEM fields.

Despite the documented benefits of OST learning opportunities in STEM, access to such programs can be problematic for girls and students of color. Sadler et al. (2012) report that girls often have "fewer opportunities or feel less welcome in science-related clubs and activities" (p. 424) than male students. In addition, although many urban areas provide OST STEM programs, "the fees may exclude many traditionally underserved populations" (Young et al., 2017, p. 69). Bell et al. (2009) observe that OST learning opportunities "often privilege the science-related practices of middle-class whites and may fail to recognize the science-related practices

associated with individuals from other groups" (p. 212). Also, OST programs may fail to provide culturally relevant instruction, diverse staff, and/or bilingual materials, leading underserved students to feel unwelcome (Bell et al., 2009). Finally, when OST programs describe their efforts to increase the participation of underrepresented groups in STEM as outreach, they convey the message that STEM belongs to "the cultural repertoire of the dominant culture" (Bell et al., 2009, p. 213) rather than the heritage of all students.

**Research Experiences**

At the undergraduate level, providing underrepresented students with real-world research experiences has been shown to enhance their analytical and communication skills while fostering the development of peer support networks (Wolfe & Riggs, 2017). Undergraduate research is usually a voluntary, out-of-class experience that engages students in the authentic work of professional communities of practice. Undergraduate research experiences (UREs) are typically offered over the summer, with students working in venues such as government labs, research universities, nonprofit agencies, or corporate research facilities under the guidance and supervision of faculty advisors or research scientists.

Undergraduate research experiences have been documented to benefit young women in STEM. For example, Harsh et al. (2012) found that female students were more likely than male students to cite their participation in an undergraduate research experience for maintaining their interest and increasing their self-efficacy in STEM. In addition, "women reported that URE participation often played a formative role in [their] pursuit of advanced STEM degrees" (Harsh et al., 2012, p. 1369). A study of an undergraduate research program at Texas Tech University confirmed that such experiences increase both the confidence and motivation of women to pursue STEM careers (Campbell & Skoog, 2004).

Undergraduate research experiences (UREs) are also beneficial for students of color. A study by Hathaway et al. (2002) found that students of color who participated in undergraduate research experiences "were significantly more likely to pursue graduate education than were students of color who did not participate in undergraduate research" (p. 621). In addition, a study by Ghee et al. (2016) demonstrated that the participation of students of color in a summer research experience was significantly associated with a greater understanding of their career options available in the STEM fields. Research by Espinosa (2011) found that women of color who participated in undergraduate research experiences were significantly more likely to persist in STEM than those who did not.

Carpi et al. (2017) conducted a case study of an undergraduate research experience called the Program for Research Initiatives in Science and Math (PRISM) program at a minority-serving institution (MSI). Their case study found that both females and students of color increased their self-efficacy in science and their understanding of available career paths in STEM. Carpi et al. (2017) concluded that undergraduate research experiences are "a potent tool to address the traditional under-representation of groups in the sciences" (p. 191). However, they caution that students of color often attend minority-serving institutions that do not have the resources to provide the quantity and quality of research experiences that are available to students at more affluent universities. Furthermore, Bangera and Brownell (2014) observe that students of color are often shut out of undergraduate research experiences due to the limited research opportunities available and the highly selective processes used to determine participants for URE positions.

Undergraduate research normally involves experiences that students participate in voluntarily outside of their regular coursework. However, a study of recent STEM graduates by

Vieyra et al. (2011) examined if mandatory research produces the same benefits as students self-selecting into such experiences. Results of their study suggest that mandatory research experiences produce similar benefits as research opportunities that students choose to participate in on their own. Since minority students are less likely to participate in optional research experiences than white students, Vieyra et al. (2011) recommend that "institutions or programs that desire to increase the number of underrepresented students in STEM fields may wish to consider implementing mandatory research experiences for targeted populations" (p. 18). Similarly, a study by Rodenbusch et al. (2016) indicates that students from diverse populations are significantly more likely to graduate with a STEM degree if they complete a course-based undergraduate research experience (CURE), demonstrating that research experiences are efficacious for underrepresented students even when they are a required component of their coursework. And while the extant literature almost exclusively focuses on the advantages of providing research experiences for undergraduates, there is some evidence that early research experiences can foster STEM interest and participation at the high school level as well (Zhe et al., 2010).

**Additional Strategies**

Several additional strategies have proven to be effective for promoting the success of underrepresented students in STEM. Providing training in spatial skills can reduce or eliminate the gender difference in such abilities. Since it is well-documented that stereotype threat has a negative impact on the persistence of underrepresented students in STEM, taking concrete steps to break down stereotypes can help students overcome barriers to success. Hiring a diverse faculty and providing sustained professional development on effective instructional practices can also assist schools with meeting the needs of females and students of color in STEM.

Spatial ability is a significant predictor of both academic achievement and career attainment in the STEM fields (Wai et al., 2009). One of the reasons that girls may underperform in STEM subjects and choose a career outside of STEM is that their spatial skills are lower than boys (Hill et al., 2010). Fortunately, there is an ample body of research which validates that spatial skills are malleable. For example, Taylor and Hutton (2013) used origami and pop-up paper folding to promote 3-D spatial thinking with a group of fourth grade students. Both boys and girls in the intervention group showed gains in their spatial thinking. While boys and girls rated the activities as equally difficult, girls considered the lessons to be more fun than boys did, indicating that properly designed spatial training has the capacity to engage the attention and interest of girls and "help mitigate gender disparity in STEM disciplines" (Taylor & Hutton, 2013, p. 450).

Sorby and Baartmans (2000) conducted a longitudinal experimental study to assess the effectiveness of a course for improving 3-D spatial visualization skills for freshmen engineering students. Results showed that students who took the course had statistically significant gains in their spatial abilities and outperformed students in a control group in their subsequent engineering graphics courses. In addition, female engineering students who took the course were more likely to persist in engineering than female students in the control group. Uttal et al. (2013) conducted a meta-analysis of 217 research studies on the effectiveness of spatial skills training. Their meta-analysis found that training in spatial skills produced an average effect size of 0.47, with both women and men making significant improvement in their spatial skills. They posit that such spatial skills training "could pay substantial dividends" (Uttal et al., 2013, p. 352) for expanding the participation of females in STEM.

Spatial training is also effective for minority students. Like girls, many minority children

have lower spatial skills than white students, since they are less likely to participate in activities that develop spatial thinking such as playing three-dimensional computer games or enrolling in computer-assisted drawing (CAD) classes (Sorby, 2012). A study conducted by Blasko et al. (2009) found that a series of short training modules improved the performance of both female and minority students on the Purdue Spatial Visualization Task: Rotation (PSVT:R) test. A study by Cooper et al. (2015) demonstrated that a spatial skills curriculum for high school students improved the computer science performance of Hispanic students. Research by Sorby (2012) found that African American and Native American engineering students had significantly lower spatial skills than their white peers, as measured by the PSVT: R test. However, participation in a one-credit course on spatial thinking had a statistically positive effect on the students' course grades in introductory STEM courses, as well as retention and graduation rates in engineering. Sorby (2012) concluded that "spatial skills training could play a critical role in enhancing student success, particularly for women and underrepresented minorities" (p. 3).

One of the chief barriers to women's success in STEM is stereotype threat (Hill et al., 2010; Nosek & Smyth, 2011). The literature attests that when deliberate steps are taken to counter prevailing stereotypes, barriers to STEM success are broken down, particularly in mathematics. For example, Forbes and Schmader (2010) conducted a series of studies on the effects of counterstereotypic training on women's math performance. Their research found that when women received specific training that females are good at math, they increased their working memory capacity and performed better on a difficult math test. An experimental study by Marx et al. (2005) found that when college students were exposed to information about a female student excelling in mathematics, they performed better on a math assessment than a control group. Marx et al. (2005) maintain that when females receive positive information that

challenges traditional stereotypes about their academic abilities, they can "use this information as evidence that the stereotype is not always applicable to their group and that they too may be able to overcome its negative effects" (pp. 433-434).

Good et al. (2008) conducted an experimental study of students enrolled in an advanced math course at a large public university. All students in the study were administered the same math test. Prior to taking the assessment, one group of participants was informed that the test had been previously administered across the nation, with no gender differences in the results. The control group did not receive this information. The study found that female students who were informed that men and women scored equally on the test outscored the male students, while in the control group, males outscored female students. Good et al. (2008) concluded that reassuring female students regarding their math abilities "can help females at any stage of their mathematics education approach their potential and increase their numbers in mathematics and science professions" (p. 27).

Barriers to STEM success due to stereotype threat can also be mitigated for students of color. An experimental study by Aronson et al. (2002) demonstrated that when African American undergraduates under stereotype threat were provided with information that human intelligence is not fixed but malleable, "they reported enjoying and valuing academics more and they received higher grades" (p. 123) compared to students in a control group. A randomized experimental study by Cohen et al. (2006) with a group of middle school students found that when stereotype threat was reduced through interventions focused on student affirmation, students of color earned significantly higher grades. Another experimental study with middle school students revealed that Latino students under stereotype threat also received higher grades as a result of self-affirmation activities (Sherman et al., 2013).

Schools can also have a positive effect on the success of students underrepresented in the STEM pipeline via their hiring and professional development practices. Research by Master et al. (2014) suggests that one of the ways that female teachers benefit female students in STEM is by reducing the threat of negative stereotypes. They found that girls enrolled in STEM courses were more concerned than boys about negative stereotypes if they had a male teacher, but not when they had a female teacher. Consequently, Master et al. (2014) propose that "when there are known or assumed gender differences in performance in a subject—schools should work to ensure that there are sufficient female teachers available" (p. 91) to teach STEM subjects.

Carrell et al. (2010) analyzed a data set of more than 9,000 students who graduated from the U.S. Air Force Academy over a seven-year period. The students in the data set had been randomly assigned to core courses in the STEM fields. The study revealed that female students performed significantly better in math and science courses when they had a female professor. In addition, having a female professor in introductory STEM courses was "a positive predictor of long-term STEM success" (Carrell et al., 2010, p. 1142). Stearns et al. (2016) analyzed longitudinal data that tracked the academic performance of all public school students in North Carolina from 7th grade through graduation from college. They found "a positive and significant association between the proportion of female math and science teachers in high school and young women's probability of declaring a STEM major" (Stearns et al., 2016, p. 99) in college.

Dee (2004) conducted a study of the impact of teacher race on academic performance. Using data from the Tennessee Project STAR class-size experiment, where both teachers and students were randomly assigned to classrooms, Dee (2004) found that having a teacher of the same race had a statistically significant impact on the math achievement of African American students. However, Hobbs and Sawer (2009) caution that hiring staff that share the same race as

their students is not a silver bullet. Their work with the educational programs of the Oregon State University Extension Service revealed that some Latino staff members were unable to gain the trust of Hispanic parents and students, particularly if there were substantial differences in social class. "On the other hand, non-Latino staff who possessed the needed bilingual/bicultural skills and who could relate to the people were very successful" (Hobbs & Sawer, 2009, p. 10).

To meet the needs of racial and ethnic minorities in STEM, Kaser (2010) recommends hiring a teaching staff that reflects the school's enrollment diversity. In addition, she suggests that staff members who work with diverse populations should be sensitive to cultural differences, hold students to high academic standards, provide students with the supports they need to be successful, and have the capacity to work with a variety of learning styles and ability levels. Schools need to select and train teachers who know how to "draw in, rather than keep out, females and students of color" (Goode, 2007, p. 73). Consequently, schools should make efforts to enhance the capacity of faculty to teach STEM to underrepresented groups through sustained professional development, particularly in proven pedagogical practices and inclusionary strategies that foster a positive classroom environment (Killpack & Melón, 2016).

In summary, the number of women and students of color who leave the STEM pipeline is disproportionate to their white male counterparts. However, research has validated a number of effective strategies that can help mitigate this inequity. Culturally relevant pedagogical approaches have been successfully employed for engaging underrepresented groups in all STEM subjects by making instruction pertinent to their lived experiences. The use of role models and mentors enables underrepresented students to picture themselves in STEM careers and gives witness to how an individual can overcome barriers along the STEM pipeline. The interest and persistence of underrepresented students in STEM can be augmented through family support and

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encouragement. Affording students access to out-of-school time (OST) programs is a proven strategy for enhancing knowledge, sparking interest, and developing skills in STEM, particularly for female students and racial/ethnic minorities that are underrepresented in the STEM pipeline.

Real-world research experiences have been shown to enhance the analytical and communication skills of underrepresented students in STEM while boosting their confidence and motivation to pursue STEM careers. Providing training in spatial skills can reduce or eliminate the difference in such abilities that sometimes segregates women and students of color from their white male peers, especially in engineering. Since it is well-documented that stereotype threat has a negative impact on the persistence of underrepresented students in STEM, taking concrete steps to break down stereotypes can help students overcome this barrier to success. Finally, hiring a diverse faculty and providing sustained professional development on proven STEM instructional practices can assist schools with meeting the social and pedagogical needs of females and students of color in STEM.

CHAPTER III: RESEARCH METHODOLOGY

## Introduction

This chapter outlines the purpose of the study, the salient research questions, and the research paradigm and design. An explanation of the research methodology is presented, describing the setting, sampling strategies, data collection techniques, and procedures for data analysis. Possible ethical issues are also considered, as well as the study's validity, trustworthiness, and significance. The chapter concludes with a brief summary.

STEM education develops critical thinking and problem solving skills, fosters creativity and innovation, and promotes scientific, technical, and mathematical literacy (Erduran, 2020). Providing students with robust instruction in the STEM disciplines is essential for creating a highly talented STEM workforce and ensuring our nation's economic growth in the global marketplace. However, women and racial/ethnic groups such as African Americans, Latinos, and Native Americans are notably underrepresented in STEM (Ong et al., 2018). With America's growing diversity, it is critically important for our schools to increase the participation and success of minoritized groups in STEM education. The shortage of females and students of color in the STEM pipeline "perpetuates entrenched economic and social inequities" (Stearns et al., 2016, p. 87), limiting their access to highly paid STEM careers. In addition, their underrepresentation limits the diversity of insight, perspectives, and creative ideas needed to drive innovation and problem-solving in STEM (Egan, 2011, Kilmartin & Pimentel, 2014).

A review of the research literature in Chapter II indicated that little is known about how principals address the needs of females and minoritized racial and ethnic groups in STEM. Scholarship in the area of STEM leadership is largely silent regarding how principals cultivate institutional commitment to serve the needs of underrepresented groups in STEM, as well as the

problems and challenges they face in doing so. The present study responded to this gap in the literature by exploring the behaviors and practices employed by school leaders to enhance the participation, commitment, and success of females and underrepresented racial and ethnic groups in the STEM disciplines. As a former principal who served in a school with a sizeable Latino population and the father of three daughters, I am particularly interested in learning how school administrators foster an environment where females and other students minoritized in the STEM pipeline can thrive.

## Research Questions

The following research questions were developed to guide the design of this study:

1. What problems or challenges do principals encounter in addressing the needs of underrepresented students in STEM?

2. What are the culturally responsive leadership behaviors and practices principals employ when implementing a STEM program that is responsive to the needs of underrepresented students?

3. What strategies are used by principals to increase the interest and persistence of underrepresented students in STEM?

## Research Paradigm

The philosophical assumptions underlying this study flow from the critical or transformative paradigm. A research paradigm is a "belief system, world view, or framework that guides research" (Willis, 2007, p. 8). Creswell (2014) observes that a critical or transformative paradigm is central to research regarding marginalized individuals and "issues such as empowerment, inequality, oppression, domination, suppression, and alienation" (pp. 9-10). In the critical paradigm, "inquiry is directed not towards understanding for its own sake, but

towards understanding as a tool to be used in the on-going process of practical transformation of society" (Fossey et al., 2002, p. 720). The critical paradigm aligns well with the purpose of this study, which sought to identify the key leadership behaviors and practices of school principals that reduce the minoritization of females and students of color in STEM and encourage underrepresented groups to thrive.

Research influenced by the critical paradigm is characterized by fundamental respect for cultural norms, recognition of the societal consequences of privilege and oppression, and the promotion of social justice (Kivunja & Kuyini, 2017). It aims to help those who are marginalized to gain agency and empowerment (Kivunja & Kuyini, 2017). Qualitative research methodologies informed by a critical paradigm provide opportunities for mutual learning and self-reflection (Fossey et al., 2002). It is therefore my hope that this study will assist both the researcher and participants with gaining new knowledge and insight about underrepresented students in STEM and help schools foster greater equity within the STEM pipeline.

<div align="center">**Research Design and Methods**</div>

I selected a qualitative design for this study. According to Creswell (2014), "if a concept or phenomenon needs to be explored and understood because little research has been done on it, then it merits a qualitative approach" (p. 20). While leadership is a key attribute in schools that have improved student learning outcomes in STEM (Honey et al., 2014), research regarding how principals provide leadership in specific content areas such as math and science is limited (Lochmiller et al., 2012). Davis (2015) confirms that "although there is a large volume of research literature on effective educational leadership practices in general, there is not a great quantity of research specifically focused on leadership in relation to STEM education" (p. 3). Kilmartin and Pimentel (2014) posit that school "leadership can influence minority students and

women in STEM career fields and has yet to be investigated in depth to determine best practices"

(p. 50). Further, Sampson (2018) attests that little is known about how principals' "leadership

styles influence decisions of equity in addressing underrepresentation of women, and specifically

women of color, in STEM fields" (p. 14). Due to the paucity of research on this topic, a

qualitative design was necessary, as there was not enough information to determine the important

variables to test in a quantitative approach (Creswell, 2014).

The following sections provide an overview of the research methods that were used for

the design of this study, including a description of the setting, sampling strategies, data collection

techniques, and procedures for data analysis.

**Research Setting**

The setting for this study was public middle and high schools where the principal has

experienced success in responding to the needs of underrepresented students in STEM. The

research literature reveals that the middle and high school years are a pivotal time for

underrepresented students as they progress through the STEM pipeline, especially since it is

during this time period that they are introduced to advanced coursework in mathematics and

science. Fouad and Santana (2017) attest that "skill development [in STEM] during high school

is crucial, as the next important juncture is college when major decisions are made for entrance

into the STEM field" (p. 29). Unfortunately, while female high school students take as many

STEM classes as male students, they tend to enroll in less rigorous courses (Farinde & Lewis,

2012; Riegle-Crumb & Moore, 2014). In addition, African American and Latino students are as

likely to foresee themselves working in a STEM career as their white classmates (Alvarado &

Muniz, 2018), but the number of URMs taking rigorous coursework in STEM is far less than

white and Asian students (NSB, 2018; West-Olatunji et al., 2010). Furthermore, female students

have similar levels of confidence and engagement in STEM at the elementary school level, but this erodes during their middle and high school years (Hayden et al., 2011; Kelly & Zhang, 2016; Kerr & Robinson Kurpius, 2004; Sadler et al., 2012; Stoeger et al., 2013; Streitmatter, 1997), validating the critical importance of supporting the needs of underrepresented students at this educational juncture.

I selected public schools as my research setting for several other reasons. Glesne (1999) cautions that "previous experiences with settings or peoples [*sic*] can set up expectations for certain types of interactions that will constrain effective data collection" (p. 26). Since I have spent my entire educational career in private schools, I felt it was advantageous for me to conduct the study in public schools where I have not previously known or worked with the school administrators. Another advantage of using public schools rather than private schools was that it helped me approach the context with a fresh pair of eyes open to new understandings. When a researcher is already familiar with a particular school setting, their "angles of vision are narrowed by preformed assumptions about what is going on" (Glesne, 1999, p. 25).

**Type of Study**

A qualitative comparative case study design was utilized for this study. A case study can be defined as "the study of an issue explored through one or more cases within a bounded system (i.e., a setting, a context)" (Creswell, 2007, p. 73). Case studies entail intensive research about an individual, a group of individuals, or an organization for the purpose of forming generalizations about them (Yusoff et al., 2018). The case study method is commonly employed when the researcher wants to understand "the experiences and perceptions of participants" (Mabry, 2008, p. 215). The case study method enables the researcher to arrive at "an invaluable and deep understanding—that is, an insightful appreciation of the 'case(s)'—hopefully resulting in new

learning about real-world behavior" (Yin, 2012, p. 4).

Comparative case studies are also known as multisite, cross-case, multicase, or collective case studies (Merriam, 2009). A comparative case study "involves collecting and analyzing data from several cases" (Merriam, 2009, p. 49) in order to identify common themes within each case and across cases (Creswell, 2014). I selected a comparative case study approach because I wanted to explore and compare the leadership practices, experiences, and behaviors of principals who have successfully led schools that are responsive to the needs of underrepresented students in STEM. A comparative case study approach helped me identify common traits among principals working in a variety of sites to gain insight into effective leadership when working with females and other minoritized students in STEM. Gathering data from multiple cases allowed me to "produce a more compelling and robust case study" (Yin, 2009, p. 260) and increase the generalizability of my findings.

**Sampling Strategies**

A purposeful (or purposive) sampling strategy was used for this study. Purposeful sampling involves the selection of "information-rich cases to study, cases that by their nature and substance will illuminate the inquiry question being investigated" (Patton, 2015, p. 265). Creswell (2014) confirms that the researcher using purposeful sampling chooses sites and participants "that will best help the researcher understand the problem and the research question" (p. 189). Purposeful sampling is frequently used by qualitative researchers because a random sampling of cases to study "might easily fail to yield the most informative sites or samples of human subjects" (Mabry, 2008, p. 223).

To select participants for this study, I identified middle and high school principals who met the following criteria:

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1. Minimum of five (5) years of school administrative experience;

2. Served as the principal of their present school for at least three (3) years;

3. Worked in a school where students of color comprised at least 25% of enrollment;

4. Respected for their exemplary leadership in working with underrepresented females and URMs in STEM.

I obtained the assistance of Cognia, a large nonprofit school accreditation organization, to help with the identification of principals from their network of STEM-certified schools who met these criteria. In addition to accrediting schools, Cognia offers a STEM certification program for schools that demonstrate a robust and effective STEM focus. Cognia's STEM certification performance standards are relevant to this study. For example, Standard 1 states: "School/program provides equitable opportunities for students to engage in high quality STEM learning" (Cognia, 2020, p. 4). For a school to achieve STEM certification, a team of administrators and teachers, including specialists in STEM, conduct a rigorous onsite review to confirm that the school is achieving Cognia's STEM certification performance standards.

I readily acknowledge that the fourth criteria—principals who are respected for exemplary leadership in STEM—was subjective in nature, but Mabry (2008) affirms that "selection may be based on reputation" (p. 223) in qualitative research. Regarding the number of participants and sites included in my sampling, Creswell (2014) suggests that case studies "include about four to five cases" (p. 189). Therefore, working with Cognia, I identified twelve cases that met the selection criteria to ensure that I would have at least four principals agree to participate in the study.

**Data Collection Techniques**

Qualitative research typically involves the collection of multiple sources of data (Creswell, 2014). The data collected in the present study included interviews and the collection of documents and artifacts relevant to each case. Semi-structured interviews with open-ended questions were used for this study to ensure that the research questions were adequately addressed while preserving a conversational tone between the researcher and participant. An unstructured approach might not have elicited sufficient feedback about the research questions, while a structured interview might have compromised the participant's freedom about what to share and how to share it (Bryman, 2016). An interview guide was developed with predetermined questions, but the semi-structured approach allowed for flexibility about the order of questions and their wording. The semi-structured interviews also facilitated the use of "probative follow-up questions and exploration of topics unanticipated by the interviewer" (Mabry, 2008, p. 218).

Creswell (2014) recommends that the qualitative researcher develop an interview protocol. For the semi-structured interviews, an interview guide was used, listing predetermined questions and follow-up probes. Each interview was digitally recorded, transcribed, and shared with each participant to ensure accuracy. In addition to recording and transcribing interviews, I maintained an interview journal to capture important demographic information (i.e., date, time, place, participant) and take notes.

In addition to semi-structured interviews with each principal and the review of documents and artifacts relevant to each case, I had hoped to spend time at each site observing the principal working with teachers, students, and other stakeholders. However, due to COVID-19, the direct observation of principals in their natural settings was not possible. Nevertheless, I was able to

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triangulate the data by interviewing teachers, staff, and parents regarding their principal's work with underrepresented students. I am confident that the data collected in this study has enabled me to portray the goodness at work among exemplary school leaders in STEM and transfer that knowledge to others.

**Data Analysis Procedures**

Qualitative research typically includes the analysis of data from multiple sources including participant interviews, observations, documents, artifacts, and the researcher's reflexive notes (Creswell, 2014, Patton, 2015). The use of multiple sources enables researchers to triangulate data to draw conclusions from a variety of vantage points, forming a more coherent whole (Creswell, 2014). To facilitate the analysis of data gathered during the case studies, I created an electronic database to store and organize the information I collected so that I could "locate specific data during intensive analysis" (Merriam & Tisdell, 2016, p. 233). Using the information in the database, my analysis procedures were based on the six steps recommended by Creswell (2014):

**Step 1**. I transcribed the semi-structured interviews with the assistance of transcription software from Otter.ai, making manual corrections as needed. I typed notes from reflexive journaling. Documents and visual artifacts were scanned for electronic storage.

**Step 2**. I reviewed all data to get a global impression. This helped me gain a general sense of the information that was collected from each participant and the overall substance and meaning of the data.

**Step 3**. Taking an inductive approach, I reviewed the data again and hand coded it based on emerging patterns, themes, and categories. To assist with this procedure, I utilized Tesch's (1990) coding process:

- I carefully reviewed all data and recorded any ideas that cropped up as I read through the material.

- I selected one interview transcription and read through it. I reflected on its underlying meaning and recorded my thoughts about topics in the margins. I repeated this procedure for all interview transcriptions.

- Next, I listed all the topics in a spreadsheet, making one column for each interview transcription. I compared the topics and grouped similar topics together.

- The emerging topics were abbreviated as codes. I then went back through the data and began using the codes in the appropriate places where the topics were found. During this preliminary coding, I remained open to any new topics that emerged from the data and assigned codes to them as well.

- I went back through the list of topics and searched for descriptive words that could be used to lump together relevant categories or themes. I then matched up categories that appeared to be interrelated.

- I assigned a final code for each theme. The category codes were alphabetized to ensure that I did not inadvertently duplicate codes.

- I went back through all the data sources, matching up the material that fell into each theme. I then performed a preliminary analysis of the data in each category to see if it was relevant to my research questions.

- As a final step in the coding process, I went back through the data and recoded as necessary so that I would have a useful structure for reporting my findings.

**Step 4**. I analyzed the coded data within each case and across cases, looking for interrelationships and variations across cases and themes. Next, I created a description of the

setting for each case, including "a detailed rendering of information about people, places, or events" (Creswell, 2014, p. 199). In particular, I identified specific quotations from the dataset that supported the major themes that had emerged.

**Step 5**. The descriptions and themes from the previous step were used to develop narratives to tell the story of each case and discuss the overall themes that cut across multiple sites of exemplary STEM leadership.

**Step 6**. The final step in data analysis is when the researcher interprets the findings. Fossey et al. (2002) observe that qualitative findings ultimately "involve the researcher's own thought, reflection and intuition" (p. 729). Creswell (2014) affirms that qualitative research findings are based on "the researcher's personal interpretation, couched in the understanding that the inquirer brings to the study" (p. 200). With this in mind, I interpreted the findings in light of the research on culturally responsive school leadership (CRSL), which is the theoretical lens underlying my study. Khalifa et al. (2016) define CRSL as "the ability of school leaders to create school contexts and curriculum that responds effectively to the educational, social, political, and cultural needs of students" (p. 1278). By interpreting the data through the CRSL framework, I gained a deeper understanding and appreciation of the major implications of the study for effective STEM leadership with minoritized populations.

<center>Consideration of Possible Ethical Issues</center>

A number of safeguards were taken throughout this study to protect the integrity and confidentiality of the subjects and to ensure the security of the collected data. The research plan was submitted to the Illinois State University Institutional Review Board (IRB) to confirm that adequate protections were in place for all participants. In addition, Creswell (2014) states that "researchers need to obtain approval of individuals in authority (e.g., gatekeepers) to gain access

to sites and to study participants" (p. 96). Therefore, before any principals were invited to be part of the study, I obtained the consent of their district superintendent. All principals, teachers, staff, and parents who agreed to participate in the study signed a consent form (Creswell, 2014). The consent form outlined the purpose and procedures of the study, the voluntary nature of participation, the potential benefits of participation, their freedom to withdraw from the study at any time, and their right to privacy and confidentiality (Creswell, 2014). Collected data was secured by storing it in a password protected folder on my personal computer. To further protect the anonymity of the participants, I stored transcripts, descriptions, notes, and the like by assigning pseudonyms.

### Validity/Trustworthiness

To ensure the validity of qualitative research, trustworthiness must be considered before the study takes place (Glesne, 1999). Creswell (2014) suggests that qualitative researchers employ multiple strategies to secure the validity and credibility of their study. Consequently, I used the following approaches described by Creswell (2014) to enhance the validity and trustworthiness of my research:

**Member Checking**. Member checking is a validation process where "those observed and interviewed are asked to confirm, elaborate, and disconfirm write-ups" (Mabry, 2008, p. 222). I asked the participants to review interview transcripts for accuracy. I also shared with them my data analysis and results to provide an opportunity for them to provide further clarification or correct misunderstandings.

**Triangulation**. Triangulation is a common validation method in social science research. It involves the collection of data from multiple sources such as interviews, observations, and documents and then "checking the degree to which each source confirms, elaborates, and

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disconfirms information from other sources" (Mabry, 2008, p. 222). In the present study, I

compiled data from semi-structured interviews with the principals. To validate the principal

interviews, some of the teachers, staff, and parents associated with the cases were also

interviewed to get more information regarding the principals' work. To further validate the data,

artifacts and documents relevant to each case were collected. Using multiple data sources

enabled me to develop a coherent rationale for the study's findings.

**Peer Debriefing**. I identified a disinterested colleague to review the study to ensure "that

the account will resonate with people other than the researcher" (Creswell, 2014, p. 202). By

asking a peer to review the analysis, I benefited from his feedback about things I overlooked and

his insight regarding my interpretation of the data.

**Researcher Bias**. "Subjectivity is always a part of research from deciding on the research

topic to selecting frames of interpretation" (Glesne, 1999, p. 105). I acknowledge that my

educational experience and reactivity were threats to the trustworthiness of this study. As a

former principal who worked in a school with a sizeable Latino student population, I have

formed strong opinions about what constitutes effective STEM leadership when working with

underrepresented groups. In addition, as a white male educator who grew up attending a middle

class school with little diversity, I undoubtedly hold prejudices about the ability of females and

students of color to excel in the STEM disciplines, particularly if they come from low-income

communities. To counter my biases, I considered my subjectivity throughout the study and

reflected on how my attitudes, values, experiences, and opinions might "shape, skew, distort,

construe, and misconstrue" (Glesne, 1999, p. 109) the data I collected, analyzed, and interpreted.

**Significance/Contributions**

This study is significant because it gathered data that contributes to the general body of research regarding the leadership attributes of school principals that are responsive to the needs of underrepresented students in STEM. The study provides practical guidance for current principals regarding the specific leadership strategies that promote the participation and success of female students and URMs. The study is also valuable for higher education institutions and professional development providers because it identifies best practices that should be included in principal preparation and continuing education programs to empower principals to transform the experiences of girls and students of color in the STEM fields.

To address the need for reciprocity, I granted participants access to the data collected from their site throughout the research process, engaged in member checking, and shared the results of the study with them. In addition, Glesne (1999) notes that "the interviewing process particularly provides an occasion for reciprocity" (p. 127). During the participant interviews, I listened carefully and expressed my gratitude for their cooperation with the study. I also asked thoughtful follow-up questions to help them reflect more deeply on their leadership, fostering a "context for personal exploration" (Glesne, 1999, p. 127) and self-discovery for the participants, which will hopefully assist them with furthering their leadership expertise and craft.

**Summary**

This chapter described the research design and methodology that guided the study. A qualitative comparative case study design was used to examine the leadership strategies and practices of principals in public middle and high schools who have a professional reputation for successfully addressing the needs of underrepresented students in STEM, and the problems and challenges they face when doing so. A purposeful sampling strategy was employed to identify

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appropriate cases for the study. Data was gathered through semi-structured interviews with the

principals who served as the cases for the study, interviews with some of the teachers, staff, and

parents associated with the cases, and the collection of documents and artifacts relevant to each

case. The steps used for data analysis and interpretation were described. Possible ethical issues

were addressed to ensure that each principal's participation was voluntary and to protect their

right to privacy and confidentiality. Procedures such as member checking, triangulation, and peer

debriefing were enumerated to enhance the trustworthiness of the study. Finally, a brief

explanation was provided about potential benefits for the participants and their school

communities and how the study contributes to the research literature and contemporary practice.

CHAPTER IV: RESULTS

## Introduction

A qualitative comparative case study was conducted to examine the culturally responsive leadership behaviors and practices that exemplary principals employ to address the underrepresentation of girls and students of color in STEM. The study also examined the challenges that such principals face in confronting inequitable practices and transforming the culture of their schools so that underrepresented students in STEM can thrive. Specifically, the study sought to answer three research questions:

1. What problems or challenges do principals encounter in addressing the needs of underrepresented students in STEM?

2. What are the culturally responsive leadership behaviors and practices principals employ when implementing a STEM program that is responsive to the needs of underrepresented students?

3. What strategies are used by principals to increase the interest and persistence of underrepresented students in STEM?

The chapter begins by providing a description of the cases to assist the reader with understanding "the context or setting that influenced how the participants experienced the phenomenon" (Creswell, 2007, p. 61). Next, the emerging themes generated from an analysis of the data are presented. Finally, the chapter concludes with a brief summary of the findings.

## Description of Case Background and Context

Four principals served as the cases for this study: Ed Coleman, Dr. Janice Taylor, Elena López, and Brianna Young (pseudonyms). The following sections provide a narrative description of each principal's background and leadership context.

**Ed Coleman**

Ed Coleman holds a master's degree in educational administration and has recently completed state requirements for the superintendent licensure. He has 18 years of administrative experience overall and has worked in the field of education for 24 years. During his career, he has served as a teacher, assistant principal, principal, and director of external affairs. He is currently working on a doctorate in educational leadership.

Mr. Coleman grew up in a military family—his stepfather served in the army. He remarks, "I'm what people call a military brat." As a result, he encountered many moves and cultural experiences throughout his childhood. He graduated from high school in Berlin, Germany. He observes, "I think that has something to do with my trajectory to become an educator. . . . I felt really comfortable in being on army bases with communicating and collaborating with people from all over the world."

Throughout high school, Mr. Coleman hated math classes. He did not have a clear plan for a future in a STEM career, but when he went to college, he decided to major in mechanical engineering. He recalls, "I thought that engineers made a lot of money." As he started taking calculus in college, he "realized that this math thing is not too difficult." Experiencing success in several calculus courses, Mr. Coleman began to like math so much that he switched his major from mechanical engineering to math education. He recounts, "I started to actually enjoy math, and . . . felt like I had an obligation . . . to go back and help other students to do better with math, because I thought maybe it is the teacher that impacts our perception."

Mr. Coleman began his teaching career as a high school math instructor, and he later switched to the middle school level. His experience in mechanical engineering prior to becoming a math teacher made STEM education a natural fit. He indicates, "I have always been leaning

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more towards STEM, even in how I taught math." In order to help his students understand mathematical principles, Mr. Coleman engaged them in hands-on projects such as building bridges and other structures, which integrated math and engineering.

For the past seven years, Ed Coleman has served as the principal of Roosevelt Preparatory STEM Academy (pseudonym). Roosevelt Prep is a public school located in a large urban city in the Midwest. It was created approximately 15 years ago through a unique partnership between a metropolitan school district, a private nonprofit research firm that specializes in bringing emerging scientific and technological advances to industry, and the state's flagship university. Roosevelt Prep is housed on the university's campus and serves students from 23 school districts, with half of the admission slots reserved for the large urban school district which operates the school. Admissions are based on a non-selective lottery system. Mr. Coleman notes that "there are no prerequisites. Students just need to fill out an application and then they are randomly selected to come."

Roosevelt Preparatory STEM Academy has a diverse student population. The high school enrolls approximately 600 students, with students of color comprising more than 60% of enrollment. Black, non-Hispanic students make up the largest racial/ethnic subgroup. Almost 40% of the students are classified as economically disadvantaged. The four-year graduation rate is 95%. According to Mr. Coleman, most students begin taking college courses by the beginning of their junior year. Over 90% of the senior class has earned college credit, and many graduates continue their education at the flagship state university where Roosevelt Prep is located. Mr. Coleman is proud "that we have a high rate of acceptance to the big school here . . ., the highest acceptance rate of any high school in the state."

**Dr. Janice Taylor**

Dr. Janice Taylor has been an educator since 1996, and has 21 years of administrative experience as an assistant principal, principal, and district personnel director. She began her career as a third grade teacher, and also taught fourth and fifth grade summer school. Early in her teaching career, she taught elementary school during the day and volunteered in adult education in the evenings. Dr. Taylor eventually left the classroom to teach adult education full time, where she worked in a variety of settings including prisons. However, she says that she "missed the school piece—making a difference with the students," so she returned to working with children fulltime.

Dr. Taylor decided to become a teacher (and later a school administrator) because she discovered early in life that schools often do a disservice to children:

> I was not a good student in school. I was one of those kids that can really push your buttons. But it was because a lot of times, if I didn't understand why we were doing something, I would ask questions. Then I was being terrible—I was one of those students who would question—teachers didn't like that. And being a teacher, I started to see where I thought things weren't done for the child . . ., so I went into administration because I wanted to be that person who made decisions that would help children.

Dr. Taylor has a doctorate in educational leadership and is certified as both an elementary and secondary school principal. She also holds certification as a superintendent and human resources director. Since 2005, she has served as an adjunct professor at several universities.

For the past ten years, Dr. Taylor has served as the principal of Franklin Middle School (pseudonym), a public school located in a rural community in the Southeast. The school serves approximately 650 students in grades 6-8. Students of color make up about 80% of the student body; the majority of students are African American. Three-fourths of the student body has been classified as economically disadvantaged. One out of five students has been identified with

special learning needs. Dr. Taylor characterizes her school as "one of those 'neighborhood in the hood' schools" and notes that the community has experienced "what we call white flight."

At one time, Franklin Middle School had a thriving International Baccalaureate (IB) program. However, the state enacted legislation that exempted owner-occupied residential property from property taxes for school operations. Dr. Taylor observes that "it has brought nothing but financial woes. . . . There was no backup plan, so now we are always destitute." The loss of taxpayer support eventually forced the school district to drop the IB program shortly after Dr. Taylor became Franklin's principal.

**Elena López**

Elena López has worked in the field of education for the past 25 years. She holds a bachelor's degree in elementary education and a master's degree in educational administration. She began her career as a first grade teacher, and then moved into a kindergarten position for several years. Fluent in two languages, Mrs. López taught in bilingual classrooms and also served as a reading coach. Her school district also tapped her to serve as a language acquisition specialist, charged with training and mentoring teachers throughout the district who were working on their ELL endorsement. After ten years, she left the district to work as a regional executive director with the Parent Institute for Quality Education (PIQE), a nonprofit focused on bringing schools, parents, and the community together as partners to help children attain economic and social equity through education. From there, she transitioned into a position in higher education as the executive coordinator of a program designed to broaden the diversity of students enrolling in a nearby state university.

Mrs. López grew up in Las Cruces and is proud of her Mexican-American heritage. Growing up in a Spanish-speaking home, she initially struggled when she started attending

school as a child.

> My early years in elementary [school] were difficult. I was learning to speak English as my second language while simultaneously attempting to learn the grade-specific content, including reading and writing. I persevered because I had amazing teachers . . . who believed in me and valued who I was and my culture.

As Mrs. López was exploring career options during her first year of college, her childhood experiences helped her realize "how big an impact a good teacher could have on a young student," and she decided to enter the teaching profession. Mrs. López hopes that she is able to "touch the lives of my students the same way [her teachers] touched mine all those years ago."

For the past nine years, Mrs. López has served as principal of Collegiate STEM Magnet School (pseudonym), a charter school operated by a state university. Mrs. López notes that Collegiate STEM is "one of the few [schools] in the nation that are actually chartered by a university, so that makes us quite unique." Collegiate STEM is located in a suburb of a major city in the Southwest. The school is open to all—there are no prerequisites for admission, with students selected by lottery. It serves approximately 800 students in grades 5-12. Over half of the student body is comprised of students of color, and 20% of the school's enrollment is classified as economically disadvantaged. Approximately 35% of students identify as Hispanic. The four-year high school graduation rate is 98%.

**Brianna Young**

Education is a second career for Brianna Young. She earned a bachelor's degree in biology and worked for several years as a microbiologist. However, getting married and raising a family led her to pursue her true passion in education.

> Being a minority, there have been a few instances, quite a few instances, where I wasn't expected to do much. Or if I did perform, it was considered a fluke or there was cheating involved. . . . I took that attitude into this space.

After obtaining a second bachelor's in secondary education, Mrs. Young began her educational

career as a high school chemistry and biology teacher. Next, she was hired by her school district

to serve as an instructional coach in science, a role in which she analyzed assessment data,

evaluated pedagogy, and promoted best practices in science education throughout the district.

When the district decided to transform Jefferson High School into a STEM school, Mrs. Young

was hired to serve on a teacher leadership team to design the curriculum and system processes.

Once the rechristened Jefferson Polytechnic High School (pseudonym) was operational,

Mrs. Young served as the chief learning officer and science department chair for several years.

She had no intention of becoming principal, but circumstances dictated otherwise.

> I really didn't want to be principal, it just kind of came up. The principal that had led our
> building announced that she was retiring. Because our school was designed around
> teacher leadership . . ., teachers felt really comfortable saying, 'We should see if we can
> get someone from within our ranks to move right into that space.' And so I was
> approached about doing it. . . . That following year, I applied and got the job. . . . With
> me being in a leadership role already, it wasn't a hard leap for me to go into the
> principalship because I had already been doing a lot of those things.

Mrs. Young has been recognized repeatedly for her exemplary leadership in STEM education.

She has received the Minorities in Mathematics Hero Award and the National Society of Black

Engineers Golden Apple Award. She has served as a division director for the National Science

Teacher Association (NTSA) Committee for Multicultural/Equity in Science Education, and she

is a past member of the advisory board for the NTSA journal, *The Science Teacher*.

For the past eight years, Briana Young has served as the principal of Jefferson

Polytechnic High School. Jefferson Polytechnic is a public school located in the inner city of a

large urban area in the Midwest. It is one of the oldest schools in the country west of the

Allegheny Mountains, founded in the early 1850s on land that was donated by a prosperous

businessman to support the development of a school to provide poor families with a free

education. After more than 150 years in operation, Jefferson was transformed into a STEM high school in 2010. It currently serves about 975 students in grades 7-12. Students of color make up more than 95% of enrollment. The percentage of students classified as economically disadvantaged is 99%. Almost 30% of the students at Jefferson Polytechnic have special learning needs, and 5% are considered homeless.

**Summary of Principals' Background and Leadership Context**

Each principal described above served as the administrator of a Cognia STEM-certified school and worked with an underserved student population. However, there were notable differences in the school communities in which they worked. Table 1 presents an overview of the educational background and leadership context for each principal.

**Table 1**

*Case Overview*

| Cases[a] | Ed Coleman | Dr. Taylor | Elena López | Brianna Young |
|---|---|---|---|---|
| Highest Degree | M.A. in Educational Administration | Ed.D in Educational Leadership | M.Ed. in Educational Administration | M.Ed. in Curriculum & Instruction |
| Years in Current Position | 7 | 10 | 9 | 8 |
| Years of Experience in Educational Administration | 18 | 21 | 15 | 12 |
| Principal's School[a] | Roosevelt Preparatory STEM Academy | Franklin Middle School | Collegiate STEM Magnet School | Jefferson Polytechnic High School |
| School Type | Public | Public | Charter | Public |
| Region | Midwest | Southeast | Southwest | Midwest |
| Location | Urban | Rural | Suburban | Inner-city |
| Grades | 9-12 | 6-8 | 5-12 | 7-12 |
| Enrollment | 594 | 657 | 788 | 974 |
| Race/Ethnicity | | | | |
| Black, Non-Hispanic | 40.8% | 73.1% | 5.6% | 88.2% |
| White, Non-Hispanic | 36.9% | 20.1% | 43.5% | 4.9% |
| Multiracial | 6.5% | 2.9% | 10.7% | 4.5% |

**Table 1 Continued**

| | | | | |
|---|---|---|---|---|
| Hispanic | 4.1% | 3.0% | 34.9% | 2.1% |
| Asian/Pacific Islander | 10.6% | 0.8% | 4.6% | < 0.5% |
| American Indian | 1.1% | < 0.5% | 0.8% | < 0.5% |
| Other Subgroups | | | | |
| Economically Disadvantaged | 38.3% | 75.6% | 20.5% | 98.8% |
| Special Needs | 7.2% | 20.4% | 10.9% | 28.0% |
| Homeless | N/A | 0.9% | N/A | 5.0% |
| High School 4-Yr. Graduation Rate | 95.0% | N/A | 98.2% | 87.6% |
| Teachers with Advanced Degrees | 48.1% | 85.0% | 75.7% | 64.6% |

*Note.* School data from National Center for Education Statistics (NCES)

[a] Pseudonym

## Data Collection

Data about each case was gathered through semi-structured interviews with the principals. To validate the principal interviews, some of the teachers, staff, and parents were also interviewed to get more information regarding the principals' work. Carol Johnson and Tyler Doherty were interviewed regarding Ed Coleman's work; Kathy Simmons, Allyson Smith, and Patricia Evans were interviewed about Dr. Taylor's leadership; Faith Myers, Paula Trevino, and Sheila Weber were interviewed about their experiences working with Elena López; and Janet Davis participated in an interview about Brianna Young's leadership. Table 2 provides a list of these participants, their roles, and how long they have worked with the principals in this study.

**Table 2**

*Interview Participants*

| Participant Name | Case | Years with Principal | Role |
|---|---|---|---|
| Carol Johnson | Coleman | 3 | Dean |
| Tyler Doherty | Coleman | 7 | Teacher |
| Kathy Simmons | Taylor | 7 | Teacher |
| Allyson Smith | Taylor | 10 | Teacher |
| Patricia Evans | Taylor | 4 | Teacher |

**Table 2 Continued**

| | | | |
|---|---|---|---|
| Faith Myers | López | 9 | Teacher |
| Paula Trevino | López | 6 | Teacher |
| Sheila Weber | López | 6 | Parent |
| Janet Davis | Young | 8 | Technology Coordinator |

*Note*. Pseudonyms have been used to protect confidentiality.

To further validate the data, artifacts and documents relevant to each case were collected. The artifacts and documents provided additional details about each principal's background and leadership context, as well as the principal's work serving underrepresented students in STEM education. A list of the artifacts and documents collected for this study can be found in Table 3.

**Table 3**

*Artifact and Document Sources*

| Case | Description |
|---|---|
| Coleman | Principal's biography |
| Coleman | Student work (Design Challenge presentations) |
| Coleman | Lesson plans/schedule for student design project |
| Coleman | Annual report from school foundation |
| Coleman | New parent orientation presentation |
| Coleman | School frequently asked questions document |
| Coleman | State Dept. of Ed. educator and enrollment data |
| Coleman | NCES school profile |
| Coleman | School history and goals |
| Coleman | Community invitation to school international festival |
| Coleman | School website |
| Taylor | State Board of Education staff and enrollment data |
| Taylor | NCES school profile |
| Taylor | Videos of family STEM night, school STEM day, and intergenerational program |
| Taylor | School STEM goals |
| Taylor | Cognia STEM certification assessment report |
| Taylor | School website |
| Taylor | Poster of STEM design process |
| Taylor | Principal's biography |
| Taylor | Article about school achieving Cognia STEM certification |
| Taylor | School brochure |

**Table 3 Continued**

| | |
|---|---|
| López | School brochure |
| López | NCES school profile |
| López | Principal's biography |
| López | School website |
| López | Promotional video about school |
| López | State Dept. of Ed. educator and enrollment data |
| López | Article about principal receiving national award |
| López | Photos |
| López | School budget |
| Young | NCES school profile |
| Young | District school guide |
| Young | Principal's biography |
| Young | STEM pathways course list |
| Young | School website |
| Young | Video about training diverse students for STEM professions |
| Young | State Dept. of Ed. educator and enrollment data |
| Young | List of strategic partnerships |
| Young | Article about mentoring program |
| Young | Photos |

The data was triangulated using the information collected from the semi-structured interviews with each principal; the interviews with teachers, staff, and parents who worked with the principals; and the artifacts and documents collected for each of the cases. The use of multiple data sources enabled the researcher to gain a richer understanding of the cases while increasing the validity and reliability of the findings.

## Research Findings

The following section presents the research findings for each case. The findings are organized by the emerging themes that reflect each principal's perceptions of the barriers and obstacles they face when addressing the needs of underrepresented students in STEM, the culturally responsive leadership practices that characterize their work with students who have

been minoritized in STEM, and the strategies they employ to increase the interest and persistence of underserved students. A cross-case analysis of the research findings is presented in Chapter V.

**Ed Coleman**

*Barrier: African American Male Educational Attainment Gap*

Principal Coleman considers ongoing data analysis essential for monitoring the academic progress of his students and evaluating educational practices at the school. A central focus of his data analysis is examining equity of student opportunities and outcomes. A hallmark of Roosevelt Prep is the opportunity for juniors and seniors to take college courses in high school— more than 90% of seniors have earned college credit by graduation. Several years ago, Mr. Coleman became interested in disaggregating data about the number of students who participated in college classes during high school. He discovered that African American males at Roosevelt Prep were not taking college classes at the same rate as their peers.

Research shows that female students are historically underrepresented in the STEM fields and are more likely to struggle academically in STEM courses than their male counterparts (*e.g.*, Martin et al., 2016; Provasnik et al., 2016; Snyder et al., 2018). However, according to Carol Johnson, dean of students at Roosevelt Preparatory STEM Academy, "it's African American males that struggle" at their school. She adds, "We know that from test scores, we know that from data."

*Barrier: Lack of Unity Around School's Core Beliefs*

Mr. Coleman is justifiably proud of the philosophy that guides teaching and learning at Roosevelt Prep. He asserts, "Our belief is that all students can do what we teach them and train them to do." However, not all stakeholders share this core belief. He remarks, "We have faced some . . . resistance in the past." While Mr. Coleman believes strongly in the growth mindset—

that his students' talents and abilities can be developed through encouragement and hard work, some of the staff "have the fixed mindset," believing that one's intellect is static.

Roosevelt Prep serves students from 23 school districts in the area. Some of those school districts are considered among the highest achieving districts in the state, while others have a reputation for low achievement. This is a core part of the school's mission. Mr. Coleman observes that Roosevelt Prep's "whole purpose, the reason we exist, is to provide rigorous and high quality STEM education for a diverse population." Not all stakeholders agree with this mission. Mr. Coleman recounts that he has "had conversations with parents of the very high achieving districts that have students here. They'll wonder why we don't focus solely on recruiting those students." These parents often complain to him that the school should set a high bar for students to get accepted [admissions at Roosevelt Prep are by non-selective lottery].

### Barrier: Leadership Time Constraints

Effective principals focus their time on teaching and learning (*e.g.*, Robinson et al., 2008; Shaked, 2018). Unfortunately, principals are often constrained from devoting the time they desire to attend to instruction (Shaked, 2018). This is the case at Roosevelt Prep, where Carol Johnson observes that Mr. Coleman is "pulled into a lot of meetings, and I wish he didn't—he probably wishes he didn't either." Such time constraints affect both students and staff. Ms. Johnson says that teachers would "like to see [Mr. Coleman] in our classrooms interacting more with our students. . . . We want [him] there with the kids doing the projects, as much as a principal can be." Ms. Johnson adds, "That also goes . . . [for] the staff too. It makes us feel like we're cared about, like we're supported, so that we're able to support the students in turn."

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*Barrier: Resource Challenges*

Operated through a unique partnership among an urban school district, the state's flagship university, and a large nonprofit research institute, one would assume that Roosevelt Preparatory STEM Academy is never lacking in resources to address student learning needs. However, that is not always the case. Tyler Doherty, a teacher at Roosevelt Prep, sees a number of students coming to the school "who have language barriers." Unfortunately, the school does not provide English Language Learner (ELL) services for these students. Carol Johnson says that although Roosevelt Prep would like to hire an ELL teacher, it doesn't "have a room to put them in, let alone the funding." She encourages families needing language support to enroll their children elsewhere. Adds Mr. Doherty, "I think that [the] communication barrier can be a deficit here, more so than other places, because we simply don't have the resources to help."

*CRSL Practice: Courageous Leadership*

Mr. Coleman has displayed courageous leadership in responding to the needs of students who have been marginalized in their STEM journey. He reflects on an experience he had early in his career as a school administrator:

> I had a group of students who came and said, 'Hey, we feel underrepresented. We don't feel respected. . . .' And I had to take an honest look at this group of students and, you know, wonder why. And there was clear evidence that they definitely were not being heard at that time.

Ever since that experience, Mr. Coleman insists that students learn to stand up for themselves. As a result, Roosevelt Prep students will "advocate for themselves and say, 'I didn't quite understand this. I'd like to remediate. I'd like to retake this test." It takes courage for a principal to invite students to engage in self-advocacy and vow that their voices will be heard.

### CRSL Practice: Culturally Responsive Curriculum

One of the ways that Ed Coleman engages minoritized students at Roosevelt Prep is by fostering a culturally responsive curriculum in the school. Each year, students are given a design challenge related to a problem in the local community. Past topics have included issues affecting people of color in the city where Roosevelt is located, such as the opioid challenge, food insecurity, and infant mortality. Mr. Coleman notes that this year's topic for the design challenge was easy to identify due to the police brutality that led to the death of George Floyd. Roosevelt teacher Tyler Doherty elaborates:

> We always try to incorporate some sort of STEM real world problem [into the design challenge], but then with the social justice challenges across the country this summer, [Mr. Coleman] decided to do a social justice focus. So we asked our kids to create a solution in some capacity, big or small, to address all those necessary components of social justice. . . . We just wanted to harness the kids' individual concerns. . . . We had students address female gender inequality in the medical fields. We had kids that looked at death penalty issues. They covered the gamut on the wide range of things that they could focus on with social justice.

During each year's design challenge, teams of students pool their STEM thinking and use technology in creative ways to solve concerns that affect their families and communities. For example, to improve access to equitable health care, a team of female students developed an app that women of color could use to document the prenatal care they receive and the medical treatment that is provided to them when giving birth.

Mr. Coleman discusses the critical importance of providing a culturally responsive curriculum with his faculty throughout the school year. He remarks that "it's a stated expectation and something that we monitor and have conversations about, not every week, but certainly consistently." Regarding the STEM curriculum, Mr. Coleman says that he expects his teachers to be "intentional about making it relevant to the students' lives." He also suggests that making

cultural connections throughout the curriculum is not as difficult as some educators believe it is. He observes that "it's a lot easier than some may think to find those connections in all of the content areas that have some relation to our students' experiences."

### *CRSL Practice: Developing Welcoming Spaces for the Local Community*

Mr. Coleman believes it is necessary for principals to be "willing to listen and work with all groups" that make up the local community. One of the ways he connects with his local community is by hosting an annual cultural night at the school. Mr. Coleman feels that these types of events are especially important for fostering a welcoming environment in a school that has "students whose parents come from Asia, Africa, you know, from all over the place." Teacher Tyler Doherty confirms that Roosevelt Prep's annual cultural night is an event "where people are encouraged to represent their primary cultural backgrounds and bring in food and music."

Roosevelt Prep has a significant population of Muslim students. To respect the customs and values of the Muslim community, Mr. Coleman encourages students to celebrate Eid al-Fitr, one of their principal religious festivals. He requests that his teachers "be mindful of the fact that [Eid] might impact some . . . students who may not be able to eat at certain times of day or may need to slip out for a couple minutes and do a quick prayer." Dean Carol Johnson notes that the annual cultural night provides Muslim students with another opportunity to "come with their Eid outfits and . . . get to wear them again." She adds that the local community loves the opportunity to share and celebrate their varied cultural traditions, and that it has really helped teachers and administrators connect with Roosevelt's diverse student population. She reports that the "kids are really excited about that. They're really excited to go and show off . . . their best." According to Mr. Coleman, events such as Roosevelt Prep's annual cultural night provide him with a great

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opportunity to be "mindful of the culture and its practices" so that he can appreciate the community's values and forge a closer connection with parents and students.

### CRSL Practice: Forming Positive Student Relationships

Mr. Coleman believes that fostering positive relationships with students is fundamental for achieving the high expectations he sets for the students at Roosevelt. According to Mr. Coleman, "Relationships are critical. I think if you're going to have a rigorous and challenging curriculum, you have to make sure that there's a lot of support." Carol Johnson, a dean at Roosevelt Prep, has observed how Mr. Coleman cultivates positive relationships by talking with the students before and after classes. She describes him as "a very kind person," and his demeanor provides a calming influence for students. Ms. Johnson perceives that when Mr. Coleman walks through the hallways, it "helps build that capacity—just talking to the kids. If they have that relationship, they know there's somebody out there that can support them." Faculty member Tyler Doherty affirms that Mr. Coleman "is certainly a welcoming individual by nature."

The importance of building strong relationships with students extends to the teachers as well. Mr. Coleman strongly encourages all staff members to get to know their students and let them know they have someone who cares about them. He attests:

> Number one, when we consider the success of students and the opportunity, I should say, for success for our student body, first of importance would be that we need to have a staff that is caring and sincere—how they care about students and want students to do well, a staff that's committed to doing the work that it takes to ensure that students are successful, a staff that students can identify with and really build strong relations with.

He believes that one of the reasons that Roosevelt Prep is so successful with its diverse student population is due to the care and support they receive from the faculty and administration. He says, "We are taking care of groups of students who might not feel comfortable in other places,

in other schools, and may not feel like they are being cared for."

*CRSL Practice: Fostering Equity and Inclusion*

Mr. Coleman is passionate about fostering an equitable environment at Roosevelt

Preparatory. He believes that one of his most important tasks as a principal is "to make sure that

the expectations that we put in place will be inclusive of all students." Mr. Coleman has found

equity audits to be invaluable for fostering an inclusive environment in his school. He recalls:

> I had to take a look at the data and see how consistent are we with our expectations for
> mastery, and is our expectation for mastery in the classroom a fair process to the point
> where it's not hindering an unequal amount of minorities from achieving the same goals
> or opportunities that everyone else is receiving. . . . One of the things we were interested
> in seeing in the data is how many of our African American students were able to be on
> track to participate in [college coursework] in comparison to their white constituents.
> And we did see that there was a . . . gap in the number of African American students that
> were able to reach and begin taking college classes at the same rate as their peers. So you
> know what has to happen if we do find that the data shows that there's a disparity is that
> we have to address it. And that's what we did.

Regular equity audits have assisted Mr. Coleman and his teaching staff in closing this gap so that

all students have equal access to and mastery of challenging coursework during their high school

years. During faculty meetings, Mr. Coleman reports that he routinely asks his teachers, "When

we look at your classes each semester and throughout the semester, what percentage of your

students are reaching mastery their first time around?" Tyler Doherty, a teacher at Roosevelt,

confirms that Mr. Coleman promotes a STEM environment that is inclusive of all students:

"He's really emphasized addressing at-risk youth and looking at their data, their test scores, and

seeing how do we bridge that gap."

*CRSL Practice: High Expectations for All*

Ed Coleman is firmly convinced that all students in his school can achieve at high levels,

regardless of their race or socioeconomic status. He believes that "you just have to find what it is

that they need to reach that level of success." Mr. Coleman continually reminds the teachers in his school that every student is capable of great things.

> I hope that all of my teachers . . . believe what I do and how I conduct myself when I say that students, every student, can grow and improve from the place that they are when we first receive them here. I believe my leadership is pointing teachers in that direction—to have a belief that we can impact students in a major way, based on how much we are willing to invest in them, and how much we are willing to shape their education in a way that helps them to understand the world. We have more power than I think we realize as educators. We just need to find a formula that works for every child.

At the beginning of each school year, Mr. Coleman harnesses the positive energy of his students, who all hope to make the honor roll, as a springboard for helping them accomplish their goals. He challenges teachers to tap into the students' dreams of earning straight As for the school year and reinforce with their students, "That's who you are, and that's what you're going to do." Then throughout the school year, he works closely with the faculty to make sure they have high expectations for all students regardless of their background.

### CRSL Practice: Instilling a Growth Mindset

Ed Coleman articulates a growth mindset at Roosevelt Prep. He never stops preaching to students and staff that "all students can do what we teach them and train them to do." He hopes that every student can develop a growth mindset while they are enrolled at Roosevelt Prep. He explains, "Having a growth mindset, knowing that we can influence and have a positive impact on every student on their path towards mastery, that's our ultimate goal." To foster the growth mindset, he has implemented a mastery curriculum at the school.

Mr. Coleman is proud to confess that "one of the things that we do here at [Roosevelt] that's a little different than some of the traditional schools is we have an expectation of mastery." Carol Johnson, a dean at Roosevelt, explains what Mr. Coleman means by mastery:

> We're a mastery-based school. So [Mr. Coleman] is always reiterating what mastery is,

how do we get kids there, and various strategies to get there. Mastery for us is 90% or above, students are expected to earn 90% to pass. . . . It's very clear what his views are.

One of the things that sets Roosevelt Prep apart from many secondary schools is that it does not track class rank. Mr. Coleman says that with a mastery curriculum, there are far too many students who earn a 4.0 grade average. Tracking class rank is also complicated by the high percentage of students at Roosevelt who are enrolled in college coursework their junior and senior years. Mr. Coleman is far less concerned with letter grades than with ensuring that all students "[have] a mastery understanding of the material." He believes that one of the main reasons minoritized students drop out of the STEM pipeline during their high school years is that they never mastered key concepts in one or more of their STEM courses.

One of Mr. Coleman's strategies for helping students achieve mastery is eliminating strict timelines for completing coursework and exams. In a traditional school, students move through the curricular sequence whether they have earned an A or a D in a particular class. He thinks the elimination of a strict timeline is critical for helping all students achieve mastery.

> One way that mastery helps is if a student is working in a class and they're not doing well, they're not getting 90% or better, which is our expectation on their work. [With mastery], there's no time constraint to how long they have to understand the material. So they can continue to redo—remediate is the word we like to use—the material until they do understand it.

Mr. Coleman has added a special term at the end of each quarter to provide extra time for students to achieve mastery if they have not yet done so in one or more of their courses. He has also built time into the weekly schedule for students to attend 'office hours' with their instructor in any class where they need additional help to reach mastery. After hours tutoring is also available.

Mr. Coleman admits that achieving mastery takes a tremendous amount of effort for both

his teachers and students. But he feels the effort is clearly worth the investment, especially for

helping students who have been historically underrepresented in STEM to be successful:

> I'm a former math teacher myself, and I think you can't be a good math teacher unless
> you have a growth mindset, because . . . you can continue to learn as long as you have the
> next formula or . . . the next process in place. I think STEM kind of connects in that way.
> You have to understand that the more you know and the more that you . . . learn about the
> processes, the better overall you can become. If there's one thing that I would hope that
> our diverse body of students would learn from STEM, it would be to have a growth
> mindset and to understand that there is a process they can follow to be more successful.

Mr. Coleman is unwavering in his belief that minoritized students can reach the high bar that has

been set for them. He asserts, "We maintain consistency in what we expect from each group no

matter who the students are."

### *CRSL Practice: Intentionality in Hiring*

Mr. Coleman believes that one of the key ways a principal can impact outcomes for

students who have been historically underrepresented in STEM is through their intentionality in

hiring a diverse and affirming staff. He reports that he is "very intentional about seeking out

individuals who share the belief that given enough time, and enough support and resources, all

students can be academically successful." When hiring new teachers, he tries to find candidates

who care about children, can relate well with students, and are willing to invest whatever work it

takes to ensure that all students succeed. He also recognizes the importance of building a STEM

teaching staff that reflects the diversity of the student population:

> There is a proportion of students who, just by the nature of their environments, connect
> better and more quickly with those staff members who look like them. And I think we
> would do a disservice to our organization if we didn't seek out more staff who can fit that
> bill. So when students are seeing themselves as diverse and being exposed to staff who
> are equally diverse, I think it certainly does provide them with more confidence in
> becoming professionals.

> One of the reasons that Roosevelt Prep does not have a greater number of minorities

among its STEM faculty is that few minorities apply when openings are posted by the district office. Mr. Coleman has taken steps to remedy this challenge by broadening the applicant search.

> Our goal this year . . . has been to change our process for how we are looking for those candidates. We didn't want to just say, 'Well, there's just not enough minorities out there looking for jobs in this field.' We . . . reflected on it and said, 'Well, maybe we're looking in the wrong places. Are we reaching out to the HBCUs? Are we reaching out to some of the other hiring programs that cater to minorities?' And hopefully that will provide us with more candidates this time around than we've looked at in the past. . . . We decided this time to see if we could venture out and share our postings in different areas that might be more visible to a diverse population.

When pressed about the degree of importance he places on hiring a diverse STEM faculty, Mr. Coleman reports, "I'd say it's extremely important." He perceives that students of color relate better to a diverse staff, and that such relationships positively contribute to student achievement.

### CRSL Practice: Leveraging Professional Development

Ed Coleman is convinced that ongoing staff development is vital to the success of students who have been historically marginalized in the STEM fields. He submits, "You can't support students . . ., knowing that we will provide them with the resources and the support that they need to be successful, and then not do the same for teachers, because that's where the message comes from." He adds, "Our job as leaders is to help others to grow, and that's pretty much our whole job in the organization. We should be influencing staff . . ., growing and building and encouraging them, so they will help . . . students to grow."

One of Mr. Coleman's professional development targets has been helping teachers and staff confront biased perceptions of their students. He recognizes that perceptions affect reality, and he does not want deficit thinking to become a hindrance to student success. He has also provided "additional training on how staff members perceived each other." Mr. Coleman has observed how negative perceptions disrupt the collaborative and cohesive culture that must exist

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on a staff in order to provide quality instruction, particularly because STEM education is integrative and requires teachers to plan and work together across traditional academic boundaries. In addition, Mr. Coleman provides his instructional staff with ongoing training in mastery learning and differentiated instruction, remarking that "all students learn at different rates in different ways." His ultimate goal through teacher training, support, and encouragement is to assist the faculty with embracing his core belief that all students can be successful in school regardless of their race, cultural background, and/or socioeconomic status.

### CRSL Practice: Meaningful Role Models and Mentoring

Roosevelt Preparatory has partnered with dozens of STEM businesses and several area universities to provide opportunities for students to experience firsthand what different STEM pathways are like. In addition to college level coursework, students are placed in internships with STEM professionals in their particular area of interest. Among the fields available for students to explore are biomedical technologies, engineering design, agribusiness, and environmental science. Mr. Coleman maintains that placing students in real world internship experiences is the best way for a STEM school like Roosevelt Prep to ensure that students have authentic role models and access to people who can provide the long term mentoring relationships they need to be successful.

Setting up a successful program like the one at Roosevelt is not something that can be done overnight. Mr. Coleman remarks that "it's certainly a process of relationship building over the years." But he thinks the effort to forge such relationships with the local STEM business community is well worth his time, given the opportunities the school is able to provide students to network with STEM professionals and engage in cutting-edge research and design. He maintains that one of his chief tasks as principal is to ensure "that when we place a student . . .,

we have staff that monitor the relationships" so that all students have a meaningful experience. He observes that the mentoring relationships that develop are especially helpful for students as they transition from high school to college.

### *CRSL Practice: Providing Students with Voice*

Sometimes teachers and administrators fail to recognize the lived experiences of students. Mr. Coleman has encountered this firsthand:

> I had a group of students who came and said, 'Hey, we feel underrepresented. We don't feel respected. . . .' And I had to take an honest look at this group of students and, you know, wonder why. And there was clear evidence that they definitely were not being heard at that time.

As a result, he has been particularly sensitive to providing students with a voice in their learning. Carol Johnson confirms that giving students a voice is important to Mr. Coleman, "He does solicit feedback that way, that has been [his] most effective strategy in the past." Mr. Coleman regularly checks in with students by maintaining an open door policy, distributing surveys, and conversing with students in the hallways between classes.

Mr. Coleman is proud that Roosevelt Preparatory STEM Academy provides multiple ways for students to take ownership of their learning. He indicates that at Roosevelt Prep,

> students begin to learn to advocate for themselves and say, 'I didn't quite understand this. I'd like to remediate. I'd like to retake this test. I'm going to come to office hours. I need to have some more support, some more help on this.' So we give students ample opportunity to continue to learn, and in order to do so, they have to advocate for themselves.

Mr. Coleman believes that all STEM learners, particularly those from marginalized communities, must be given a voice in the learning process in order to succeed.

*CRSL Practice: Reflection*

Ed Coleman considers regular reflection essential to his growth and effectiveness as the administrator of a STEM-focused school. His self-reflection has helped him identify hidden biases that have inhibited his ability to be a transformative leader.

> One of the things that I really had to grapple with as a black man myself is that I . . . had a bias towards some of our underperforming African American students. And I had to reflect on how I was planning and how I was responding, even to discipline . . . how I was communicating to staff about students who were underperforming. So I think biases exist. Everyone has them. And to not reflect or to seek out what your biases are, so you can begin to address them, it's kind of malpractice. You know, every human being has them. So of course, every educator has them. So if we're not seeking them out and trying to make sure that we realize that they exist, we're just not doing a good job, and we're not being honest with ourselves as educators.

Mr. Coleman recognizes that such self-reflection is an essential step for developing the critical consciousness needed for principals and teachers to provide minoritized students with equitable access to STEM learning.

*CRSL Practice: Strategic Partnerships*

As described previously, Roosevelt Prep was founded through a unique partnership between a metropolitan school district, the state's flagship university, and a private nonprofit research firm that specializes in bringing emerging scientific and technological advances to industry. Therefore, since its inception, the school has relied heavily on business and community partnerships to further its mission. Mr. Coleman has continued to expand these partnerships during his tenure as principal. According to Mr. Coleman, today Roosevelt Prep has "partnerships with over 100 different community groups and businesses." These organizations assist the school by offering opportunities for students to shadow STEM professionals or participate in internships. They also provide speakers and professional development for the school.

Among the many partnerships the school has developed over the years, doctoral students in chemistry, physics, and engineering from the school's sponsoring university dedicate a year of their studies to work with Roosevelt STEM teachers to augment instruction. Several prominent corporations sponsor the school's robotics team, and firms such as Accenture have provided apprenticeship opportunities for students. Mr. Coleman attributes his success in establishing partnerships with the business community and various nonprofit organizations to relationship building. He reflects:

> It's certainly a process of relationship building over the years. . . . We think we're doing a good job as far as connecting with community partners. It really kind of stems out of relationships we've established over the years and continuing to think outside the box about who we want to reach out to next.

While the role of the principal is important, he also thinks that students play an important role in fostering and enhancing relationships with community partners. He remarks that one of his responsibilities as a school leader is "making sure that students understand the importance of the relationships that we have built with partners and the part that they play in maintaining and enriching those relationships."

### *Strategy: Building Confidence*

Ed Coleman wants all students, regardless of their background, to develop confidence in their abilities and thrive in their academic journey. However, he does not necessarily care whether they persist in the field of STEM or choose a different career path.

> Our goal is primarily that our students have a STEM way of thinking. They think STEM, which means they think critically, and they are able to—this sounds repetitive—have a design way of thinking in order to problem solve. So it's never really been our goal that all students that come and graduate remain or focus on STEM. The goal is that students know how to engage, collaborate, do teamwork, and all those other aspects of STEM, like someone in a STEM field might be able to do.

He adds that he is "proud of the fact that we can take kids from any background and put them

through the process and allow them to grow to the point where they can be really confident about themselves."

***Strategy: Job Shadowing and Internship Experiences***

One of Mr. Coleman's key strategies for getting underrepresented students interested in STEM is to provide job shadowing and internship opportunities where students can engage in real-world STEM experiences. He has found that such opportunities often help students persist in their pursuit of a STEM career:

> If you were interested in becoming a pediatrician, for example, and you start off taking a few science classes here at [Roosevelt], and then you . . . had an internship with a pediatrician, and then take a couple classes here and there, what we find is that those students become, if nothing else, even more focused on that career. . . . I think the hands-on experience that students have during their internships . . ., I've seen it strengthen the students' desires to be in the careers that they've chosen and not wane a bit.

Mr. Coleman believes it is a no-brainer that "in any school, you want students to have an opportunity to rehearse or to try out a career they're thinking about." For him, job shadowing and internships either provide students with the motivation they need to continue their STEM journey, or such experiences help students discern that a particular STEM path is not right for them. He observes, "Maybe a student wanted to be to be a doctor, and they did an internship to be a phlebotomist. And then they figured out that they hate seeing blood and they're like, 'Well, I probably shouldn't do this.'" Mr. Coleman perceives that either outcome is highly beneficial for underrepresented students. He fears that too many students spend several years in college before they discover a particular STEM career isn't right for them. At that point, they may lack the funds they need to switch academic programs and pursue another career trajectory.

*Strategy: Making STEM Fun*

Another strategy that Mr. Coleman employs to get underrepresented students interested in STEM is to provide as many opportunities as possible to make STEM learning engaging and fun. One of the ways he does this is by scheduling a two-week intersession in January where students needing more time to master content can complete their courses, while those who have already achieved mastery can take a variety of fun electives such as digital painting, robotics, and career exploration classes taught by professionals from businesses such as Accenture. Mr. Coleman reports, "We've got things like glassblowing and/or ACT prep . . ., different things that they can choose that might be fun or informative."

Surprisingly, robotics has proven to be a great way to increase the interest and persistence of female students in STEM. A field that is traditionally dominated by high school boys, at Roosevelt Prep the robotics team is led by girls. Mr. Coleman recounts:

> We have a nationally renowned robotics team. . . . And this might be a little bit of a sidebar, but I want to tell about them, because they are led by a team of females. The leader of the team is a young woman. And I think the top three on the team are girls. . . . That team is comprised of, at least half of the team of about 50 kids, are girls. That team works with FIRST Robotics, and those girls are extremely excited!

He believes that a key factor in getting so many girls to join the robotics team has been his hiring practices, where a majority of math and science courses are taught by women. The role modeling and mentoring they provide each day in the classroom has given female students in his school confidence that they can hold their own with anyone, whether it be robotics competitions or engineering design contests.

**Dr. Janice Taylor**

*Barrier: African American Male Educational Attainment Gap*

While many schools find it challenging to keep girls in the STEM pipeline, at Franklin

Middle School, it is African American boys that concern Dr. Janice Taylor:

> When we started looking at [the] data, we were looking at our male population, because
> our female students, even though it's true that . . . girls will check out later on, our male
> students are the ones that are not engaged in science, in math classes, especially since
> reading is a strong component of math nowadays.

When comparing academic achievement data for boys and girls, she found a gender gap, with

African American boys struggling in reading, math, and science. Dr. Taylor has also noticed that

the academic struggles of her male students persist beyond middle school. She recognizes that

"they're not taking those upper level [STEM] courses when they go to the high school."

*Barrier: Educator Bias*

Dr. Janice Taylor is a highly successful African American woman with a real compassion

for helping all children thrive. She firmly believes that income inequality should not dictate

inequitable educational outcomes for children. To that end, she believes that teachers need to

understand and value the life experiences of their students in order anticipate potential learning

differences and meet children where they are at. However, she is disappointed that some of her

teachers lack empathy for disadvantaged students.

> My district . . . used to have a program. When they brought teachers into the district, they
> would put them on school buses and they would drive them through the neighborhoods,
> so they could see where the kids came from. And some people, their hearts are just so
> hard, it doesn't matter—none of that matters to them. So that is a frustrating thing for me.

While Dr. Taylor believes all children are capable of engaging in challenging academic work,

some of her teachers do not. It is not uncommon for her to hear her teachers say, "Well, my

honors students will be able to do that, but my regular students can't." She has also noticed with

her faculty that if a child "is a behavior problem, but they're very, very intelligent, a lot of times they're dumbing down."

### *Barrier: Low Parent Involvement*

Parents play a critical role in fostering the interest and persistence of underrepresented students in STEM. However, parental involvement is frequently a challenge at the middle school level. As Dr. Taylor observes,

> The middle school is that time period where parents, for whatever reason . . .., they kind of feel like the kids don't need them anymore. So that is real difficult for us. It's a constant battle. . . . We had a parent academy, where the instructional coach went through all of the programs. . . . We provided the academy two or three times for the parents, and only a couple of them signed up.

Dr. Taylor attributes the lack of parental involvement at the middle school level to a variety of factors, from parent burnout to having younger children at home that require their time and attention.

### *Barrier: Resource Challenges*

According to the state board of education, three-fourths of the students at Franklin Middle School are economically disadvantaged. Ensuring that the school has sufficient resources to provide equitable access to education is a continual challenge for Dr. Taylor.

> I recognize students' backgrounds; I recognize their color. . . . Sometimes you get real frustrated when you have high poverty students, and you provide every piece, of course, that you can do. And because of their environment, you're not getting the results that you expect. . . . And it's not because you don't think those students can learn. It is just you don't feel like you have the resources and the support.

As a result, Dr. Taylor and her staff often have to provide for student needs out of their personal funds.

Franklin Middle School's financial woes can be traced to a state law enacted about fifteen years ago that exempted owner-occupied residential property from taxes for school operations.

The school's thriving International Baccalaureate (IB) program was cut as a result. Without the IB program, Dr. Taylor searched for alternative ways to ensure that Franklin could provide rigorous and relevant instruction for its students. After researching various options, she decided to transition Franklin Middle School into a STEM school. But the financial hardship faced by the district made such a transition extremely challenging. When she approached the district about becoming a STEM school, Dr. Taylor recalls the superintendent telling her that she "had to make the transition without any additional resources." Unlike wealthy suburban schools, Franklin Middle School has had to provide a robust STEM program without access to adequate funding.

*Barrier: Shortage of Qualified Teachers*

In order for schools to provide quality STEM education for all students, they need to hire and retain a highly qualified cadre of STEM educators, particularly when working with diverse student populations (Nguyen & Redding, 2018). As Franklin Middle School has transitioned from an IB school to a STEM school, this has been a challenge. Dr. Taylor observes that "in the beginning, the more that we learned about it, we were a bit overwhelmed, because we thought maybe we couldn't do it." Allyson Smith, who has taught at Franklin for the past ten years, concurs that it has been a problem "making sure that all of the teachers understand all of the components of STEM." Especially in the beginning of the school's transition, Dr. Taylor noticed that "teachers were not understanding that . . . STEM was about problem solving and how to start, how to integrate STEM in all subject areas." This was especially difficult for the ELA teachers at Franklin. Allyson Smith recalls that "the ELA teachers were kind of floating out there" as they tried to integrate STEM into their reading and grammar courses. While many of these early challenges have been overcome with time and experience, faculty member Kathy Simmons notes that teachers still struggle with "trying to integrate [the] critical thinking piece

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that comes along with STEM."

*CRSL Practice: Courageous Leadership*

In order to provide a STEM environment where historically underrepresented students can thrive, there have been many occasions where Dr. Janice Taylor has displayed courageous leadership. When a new state law dried up property tax revenue for schools, Dr. Taylor's superintendent cut Franklin Middle School's International Baccalaureate (IB) program. With the loss of the IB program, Dr. Taylor decided to convert Franklin into a STEM school, but she needed to secure funding for the transition effort. But the demographics of Franklin's school community stood in the way. Patricia Evans, a teacher at Franklin Middle School, credits Dr. Taylor for the courage she displayed in securing the funds needed for the transition.

> Initially getting started, one of the challenges was based on our reputation. We have a rival school that has students that attend there from more influential families. And so historically, most of the money would go to that school. So [Dr. Taylor] had to fight for us to receive funding from the district and support, just so we could even get started with our STEM program. . . . So I don't think our program would be what it would be had she not gone to the measures she did in fighting for us.

When Dr. Taylor was told by her superintendent that she could not have additional funding to pay for Franklin Middle School's transition to STEM, she did not accept no for an answer. As she recalls,

> When I came here I said we need to do something because the superintendent told me that I couldn't do IB anymore. He said I had to make the transition without any additional resources. So it's like, 'Okay, I need to add certain things to our curriculum, but you're telling me I can't have any additional resources?' Well, when I went to visit [a STEM school in her state], they had Medical Detectives, they had all these other things. So I asked the principal, 'How did you get these programs?' And he said that [career & technical education] funds paid for them. I said, 'Well, how is that, because I'm being told I can't use [career & technical education] funds at the middle school?' He said, 'That's not true. . . .' So I went back to the district office, and I told them exactly what I was told. . . . I was able to pull down Medical Detectives, aerospace and engineering, and . . . robotics.

Another way that Dr. Taylor has displayed courageous leadership is by challenging the deficit thinking of others. Sometimes her teachers 'dumb down' the academic rigor for students with behavioral issues, or they lower their expectations for children who are not honors students. She also has to deal with teachers who think that rural schools like Franklin cannot provide the quality of programming available to children attending wealthy suburban schools. Dr. Taylor remarks that "the first thing that teachers always say, if I take my population to a very rich school, they're gonna say, 'Well, we can't do that.'" One of the strategies that Dr. Taylor uses to overcome such deficit images is to arrange for teachers to visit similar schools that have successfully implemented an inclusive STEM program. She advises that "you have to take teachers to the best places where STEM is working, and it has to match your population."

*CRSL Practice: Developing Welcoming Spaces for the Local Community*

Several years ago, Dr. Janice Taylor decided that she needed to find a way to foster a stronger bond between her school and the local community. Allyson Smith, a teacher at Franklin Middle School, recalls that "[Dr. Taylor] thought that it would be a great idea if we were to bring in members of our—she tries not to call them older—our more seasoned generation to come in and make connections with our students." Dr. Taylor describes the purpose of the group as follows:

> I have a program called intergenerational, and it's meant to bring the older and younger generations together. . . . I start my intergenerational program by first meeting with our students, our seventh and eighth graders, and we talk about what topics are relevant to them. . . . We take the topic that they want to talk about, we plan on activities, we bring in the community members, and we always do a STEM activity in our intergenerational meetings.

The intergenerational meetings take place once a month. Any community member who wants to participate is welcome to join. Each adult is assigned a group of students to work with. They

share lunch together, discuss topics of interest to the students, and conclude each meeting with a small STEM project. At the end of the school year, the students and community members take a field trip to a local business associated with one of the adults who has participated in the intergenerational meetings. Dr. Taylor attests that the intergenerational program has strengthened the community's connection and investment in the school's STEM program.

Allyson Smith also believes that the intergenerational meetings have been a tremendous way for Dr. Taylor to engage the community and leverage their support. She observes:

> [In] our intergenerational program . . ., we work hard to integrate STEM into those meetings with our community members along with our students. And by talking with them, and with them seeing it in action and actually working with the kids on STEM projects, [Dr. Taylor] was able to encourage them to get involved.

In addition to the intergenerational meetings, Patricia Evans reports that Dr. Taylor has established "a STEM advisory board. It incorporates community members, parents, and business leaders in the area. And last year . . ., we met every quarter to discuss the goals and the direction of the school." Kathy Simmons adds that Dr. Taylor also engages the community by inviting parents and business leaders "to be a part of our School Improvement Council which helps us plan year-to-year."

### CRSL Practice: Forming Positive Student Relationships

Dr. Taylor indicates that the conversion of Franklin into a STEM-focused school has led to stronger relationships between teachers and students due to the project-based learning that is a constitutive element of their STEM program. She reports that "when the teachers started doing more projects, more hands-on, they got to talk to the children more, and then they started to build a relationship with the students." She believes that forging positive relationships with students is particularly critical in a school with a high percentage of economically disadvantaged children:

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I find that with our students, one of the reasons why the gang problem is very bad anywhere is not only economics, but it's also a sense of belonging. So the more that you can put your students in a situation where there's a sense of belonging, the better.

In her experience, strong student-teacher relationships give students a sense of belonging, leading to greater levels of engagement and fewer behavioral disruptions in the classroom.

While Dr. Taylor tends to frame the importance of positive relationships in terms of teacher interactions with students, there is no question she also enjoys a strong relationship with students. Patricia Evans recounts how Dr. Taylor "walks around the school and visits classrooms and participates with the kids." Allyson Smith affirms that Dr. Taylor is "very involved and the students see that. . . . When we have our STEM days, she pops in and she talks to the kids, 'What are you making? What are you doing?'" Dr. Taylor's high level of visibility and active engagement in her students' STEM activities helps build the positive relationships that are critical to sustaining a strong learning climate.

### CRSL Practice: Fostering Equity and Inclusion

Allyson Smith, a teacher at Franklin Middle School, feels that one of Dr. Taylor's greatest attributes is her commitment to developing a school that is equitable and inclusive. Ms. Smith observes that "one of the biggest things is that she [Dr. Taylor] made sure that every single child on campus had access to the STEM programs that we're offering." Regular equity audits have helped Dr. Taylor build an equitable and inclusive school. The equity audits typically involve disaggregating and analyzing test data. For example, Dr. Taylor points out that last year, "when we were looking at our data, our African American male students were struggling." However, she asserts that equity audits should analyze more than just academic achievement data. She also believes "you have to watch the way students are treated in the classroom, how they're spoken to, how they're graded." Her classroom observations indicated that African

American males in the school were not engaged in their STEM classes, particularly because contemporary math and science courses involve a lot of reading.

Dr. Taylor uses equity audits as a springboard to rich conversations with her faculty about how to make Franklin Middle School more inclusive. Last year, when an equity audit disclosed the struggles of African American male students, she met with the teachers several times to develop strategies to increase the engagement and participation of African American boys in STEM courses. She recalls that during these meetings,

> I asked them, 'Number one, what are the characteristics of a middle school student?' Then I asked them, 'What are the characteristics with your male students? What are they struggling with?' And of course, they said their male students play around in class. They don't like to read, you know, different things. So I said, 'Okay, if these are the things that the male students are doing, that you know that they're doing, then what can we do as teachers? How can we change our strategies?'

### CRSL Practice: Instilling a Growth Mindset

To promote a growth mindset at Franklin Middle School, Dr. Janice Taylor makes use of NWEA MAP data. She explains, "Students know what their range is, so when we get their MAP score, they set a goal for their growth." Dr. Taylor encourages teachers and students to celebrate growth. She believes that giving students ownership of data concerning their achievement and academic growth ultimately increases their motivation and engagement in STEM. Teacher Kathy Simmons agrees, adding that Dr. Taylor expects the faculty to regularly talk to their students "about their growth and finding [the] intrinsic value of their growth."

Dr. Taylor admits that she is more concerned about how much her students are growing in their collaborative skills and maturing in their work ethic and knowledge than the actual letter grades they earn. She feels that when students can tangibly see how they have made progress, they are incentivized to push further and continue their journey through the STEM pipeline.

Patricia Evans, a teacher at Franklin Middle School, validates that Dr. Taylor places a greater

emphasis on process (growth) than product (grades):

> In STEM, it is not about the grade, it's about the process for her [Dr. Taylor]. The fact that the students can actually sit there and collaborate together and have a conversation about what it is that they're trying to accomplish. Not necessarily that they've accomplished the task—it's the process involved and seeing how the kids grow from start to finish. I think that's how she defines the success of the STEM program.

Kathy Simmons confirms that "her [Dr. Taylor's] idea of success is growth."

### CRSL Practice: Intentionality in Hiring

To build a staff of STEM educators that can provide robust instruction to all students

regardless of their gender, race, or ethnicity, Dr. Janice Taylor uses the interview process to

separate highly qualified teachers from those who only pretend to know about STEM.

> I ask them about STEM and how would they apply it. If they're applying for a math position . . ., 'Okay, give me specific examples of how you would integrate this in your class. And what does that mean?' And it's funny, because you'll start an interview and a person will say, 'Yeah, I know STEM.' Asking those deep questions to people that really do know STEM, they will have ideas; the ones that they have just heard the title, they can't answer those questions.

Dr. Taylor also looks for educators who will "treat everyone with dignity and respect."

She places a high priority on hiring a diverse staff that can effectively engage Franklin Middle

School's African American male population. She says, "I look for teachers that are going to

understand that, number one, my male population is going to be the hardest to motivate and to

engage." During the interview process, she asks each candidate, "How are you going to connect

to those students?" She remarks that she likes to use a lot of scenario-based questions to discover

how each candidate might approach the challenges of working in a high poverty school. Dr.

Taylor is proud that she has been able to build a diverse and highly qualified staff over the past

ten years. Patricia Evans has participated on a number of interview teams with Dr. Taylor. She

confirms, "When we do interviews—and I've had the privilege of sitting in on the interviews and being on those panels—we really have done a good job with getting a diverse group of people."

### CRSL Practice: Leveraging Professional Development

The first thing Dr. Janice Taylor did when she decided to transition Franklin Middle School into a STEM school was to seek out training for her teachers. Having limited funds for professional development, she contacted a nonprofit STEM consortium in her state to find out what resources were available. They put her in touch with another school that had recently made the same transition. After contacting the school and discovering that their principal and curriculum director were retiring, Dr. Taylor was able to hire them as consultants for a small fee. After providing teachers with foundational training in the principles of STEM education, she decided to take them to see it in practice.

> I started taking the staff to visit different schools that were identified as STEM, because one of the first things that teachers had to do is they had to see it, to understand it, in order for them to believe that it could be done. . . . I took my teachers to actually see it. You have to take teachers to the best places where STEM is working, and it has to match your population so teachers can't say, 'Oh, our kids can't do this.'

Since Franklin Middle School had been an IB school prior to its transition to a STEM school, Dr. Taylor directed her teachers to start comparing IB learning objectives and activities to STEM standards. Her hunch was correct, as her teachers "started seeing that they were already doing portions of STEM and that it wasn't totally new." Once her teachers started feeling more comfortable with STEM, Dr. Taylor brought in consultants to train the staff in the engineering design process.

A key to the successful progression of professional development at Franklin was that the teachers and principal shared the experience together. Dr. Taylor recalls, "I had to promise my teachers when we started this STEM journey that we would work together." Her patient yet

persistent leadership was a key to ensuring that the transition didn't demoralize them. "I would just ask, whenever they were upset or feeling overwhelmed, 'Okay, what's overwhelming you?'" Dr. Taylor adds, "You have to listen to your teachers, you have to make sure they have the training."

Kathy Simmons thinks that Dr. Taylor's professional development leadership was a critical element in Franklin Middle School's successful transition from IB to STEM. She recalls,

> I would have to say her biggest contribution was the professional development, the PDs that she offered us. She had folks coming in, she had the experts come in and work with us hands-on. . . . We were able to see how STEM has been integrated in some of the schools . . . and see some of the outdoor environmental programs that are at the middle school level. And even the elementary level, it just blew my mind, because I was like, 'Wow, this is what we can work towards.' Definitely it's not something that happens overnight. But having the advantage of being able to attend the professional development has been probably the biggest contribution for all of us.

Her colleague Patricia Evans adds, "I don't think we would have gotten our STEM accreditation had she not been the type of principal she is. She pushed us to go beyond the limit. She incorporated every opportunity there is for professional development."

Allyson Smith suggests that the strong emphasis Dr. Taylor placed on training the faculty on the fundamentals of STEM thinking and design are essential for ensuring that all students at Franklin Middle School are receiving high quality STEM instruction. In her view, if some teachers lack an understanding of STEM education and how to integrate across academic disciplines, some of the students will be deprived of equitable access to STEM. Ms. Smith says that Dr. Taylor addressed this concern by ensuring "that everybody understood what STEM is and how to make it work . . . in their classroom."

### CRSL Practice: Meaningful Role Models and Mentoring

Dr. Janice Taylor believes that role models and mentors serve a unique role at Franklin Middle School. In her experience, they provide underrepresented students with the inspiration and coaching they need to persist through the STEM pipeline, especially in difficult content areas such as chemistry or physics. For example, several years ago she partnered with a local university to bring in a female physics professor to assist with physics instruction. Dr. Taylor recalls that "she started coming in and teaching lessons at our school to show the kids . . . that they could do it. . . . And that was her passion—to try to help spread it to more female students." Dr. Taylor also formed a Women in STEM committee at her school to help identify female role models and mentors for students.

Another key way that Dr. Taylor identifies STEM role models and mentors is through the intergenerational program. The intergenerational program pairs Franklin Middle School students with adult members of the local community. They meet monthly to discuss topics of interest to the students and work on STEM projects together. The intergenerational program has been an effective way for Dr. Taylor to recruit role models and mentors. Allyson Smith confirms, "By talking with them [intergenerational participants], and with them . . . actually working with the kids on STEM projects, [Dr. Taylor] was able to . . . encourage them to get involved." Patricia Evans notes that Dr. Taylor uses mentors to help underrepresented students develop greater confidence in their STEM abilities: "If a child is having trouble or struggling, she'll find a mentor for that child. So I think those are the ways that she primarily helps them feel more confident about STEM."

***CRSL Practice: Providing Students with Voice***

One of the ways Dr. Taylor provides students with a voice in their STEM learning is by giving them a wide range of electives to choose from. Kathy Simmons, a teacher at Franklin Middle School, recounts:

> I'll tell you in the words of one of our STEM accreditors. When it came to having a catalogue of electives, they couldn't fathom how in the world we manage that. You know, most schools have like a handful of electives and that's it. And we had lots of electives!

The reason that Franklin is able to provide such an array of electives is attributable to a decision Dr. Taylor made when the school first transitioned from an IB school to a STEM school. Due to limited resources to implement STEM, she turned to the teachers for help. She recalls that she asked the faculty, "If you could have a passion class where you could bring your talents to the table, what is it that you want to teach?" Many of the teachers surprised her with suggestions that had strong ties to STEM. For example, one of her PE teachers had a background in sports medicine, so she volunteered to teach an elective course on sports medicine. Altogether, Franklin Middle School is able to provide over 40 electives for students. Dr. Taylor feels that it is important that "the students get to choose the STEM classes that they want to be in," as it increases their interest and engagement in the learning.

Within their STEM classes, Dr. Taylor expects the teachers to provide students with a voice in both the projects they work on and the ways they can demonstrate their learning. She observes that many of her teachers use choice boards to give students the ability to select the learning activities they are going to complete. Regardless of the strategy, Dr. Taylor maintains, "When they have presentations or projects, they know that the students should have a choice in how it's done." Dr. Taylor also values the voice that students can give outside of the classroom.

Several years ago, she created a student forum that meets monthly to discuss the things students would like to change around the school. The meetings are run by the students, and Dr. Taylor implements their recommendations whenever feasible.

### *CRSL Practice: Reflection*

Dr. Janice Taylor says that she engages in self-reflection "all the time." Her goal when she reflects is to "always think about a child's background." Dr. Taylor indicates that she has a tendency to expect transformation to take place immediately. Reflection has helped her develop the patience that is needed to make enduring change to the culture of a school. She observes, "You have this vision, and you want to just take off running, and sometimes you have to back up and you have to realize, 'I can't pull these people too fast.'" Self-reflection has also helped Dr. Taylor come to terms with the disappointments she has encountered in building a school that ensures every student receives a robust STEM education. She notes that "sometimes you get real frustrated when you have high poverty students, and you provide every piece . . . that you can do, and because of their environment, you're not getting the results that you expect."

Dr. Taylor also encourages her teachers to engage in critical reflection, and she frequently guides them in this process. She states, "I want to see what their reflection process is." When data revealed that African American males in her school were not sufficiently engaged in mathematics and science, she helped the faculty reflect on the problem and how they could more effectively meet the needs of the students. She recalls, "I had several meetings looking at what we could do. What kind of behaviors are you seeing with the males? Why are they being disengaged? And how could we counter that?" The reflection process led Dr. Taylor and her staff to develop a school fraternity for African American males, the first such fraternity at the middle school level in the state.

*CRSL Practice: Strategic Partnerships*

Dr. Taylor uses discretion in establishing partnerships with community organizations. She begins by asking, "What are our objectives? What are our standards? What do we have in the community to use as a resource?" She thinks it is a mistake for principals to partner with a business or nonprofit without a clear objective in mind. She insists, "When I reach out to the businesses, I'm looking for specific resources." Her goal is to leverage community assets to help all students in her school flourish in STEM.

Dr. Taylor has tapped into a variety of community assets during her tenure as principal. She partnered with a local college to start a biology club in her school. She convinced the same institution to loan an assistant professor to Franklin to teach 3D printing. When she wanted to engage both parents and students about STEM careers, she partnered with the local career center to sponsor an engineering night and a coding night at her school. When the seventh grade wanted to learn about weather, she reached out to the Red Cross, who worked with the students to create severe weather kits. Other partnerships have filled professional development needs for her math and science teachers.

A unique way that Dr. Taylor expands her pool of business partners is by hosting an event she calls 'Principal for a Day.' She invites members of the business community to spend a day in the school to tour the school, visit classrooms, talk to students, and speak with the teachers about how a partnership between the business and the school could have a positive impact on children. Dr. Taylor explains that "hopefully, when they actually come into your building and they spend all day, you'll get a business partner afterwards." Patricia Evans attests that the community partnerships Dr. Taylor has developed have helped underrepresented students at Franklin Middle School expand their horizons about possible career paths. She reports:

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The biggest industries we have in [our community], you either work for the school system, you work in the factory, or you work at the hospital, and a lot of kids, that's all they see. So by getting these professionals in, STEM careers in, they're seeing other opportunities that exist and that it is possible for them to do that in [our community].

### Strategy: Job Shadowing and Career Days

One of the ways that Dr. Taylor has increased the interest and persistence of Franklin Middle School students in STEM is through job shadowing and other career awareness activities. Each February (on or near Groundhog Day), the school hosts Job Shadow Day, where students are sent off campus to shadow professionals working in a variety of STEM fields. To facilitate this work, Dr. Taylor hired a career specialist for her school, who is tasked with planning and coordinating STEM career experiences for the students. Past activities have included everything from classroom speakers and career days to structured field experiences for students. Dr. Taylor feels that exposing students to a variety of careers at an early age stimulates their interest in STEM, particularly for students historically underrepresented in the STEM fields who often do not have direct exposure to STEM careers in their families or neighborhoods.

### Strategy: Making STEM Fun

Dr. Taylor believes that the best way to get underrepresented students interested in STEM and willing to persist through the STEM pipeline is to make STEM engaging and fun. She notes:

We try to keep up with things that are exciting to kids. I had a teacher here who did drones—it was a hobby for him. So we added drones, we added the aerospace engineering program at the Career Center. We try to include things that students really like such as robotics.

Over the years, she has added more than 40 elective courses for students to choose from in addition to their general subjects. To motivate students to persist in their coursework, she opened up a game room. Students are rewarded for their academic work with time in the game room. This has especially helped her middle school boys, who are often reluctant to complete their

homework. She has also provided incentives for students to reach their academic goals. Working

with their teachers, each student sets academic growth targets based on NWEA MAP scores.

Students are rewarded for reaching or surpassing their expected growth. As Dr. Taylor reports:

> If they met their target goals, we have kind of like our mini field day for the students. The students got to pick the activities like face painting, and oh my goodness, we got a hold of the old Atari kind of video games, so they got to play video games. They got to choose the activities for the field day, that was a celebration for them.

Dr. Taylor also schedules periodic STEM nights at the school, where parents and students can

participate in hands-on experiments presented by STEM professionals. Dr. Taylor says that such

experiences "show the kids that [STEM] was fun."

Dr. Taylor says that she looks for opportunities to extend student interest in STEM

whenever she can. She knows that most children love contests and challenges, so when she

learns about such events that are STEM related, she encourages teachers and students to

participate. To demonstrate the impact that a STEM contest can have on children, Dr. Taylor

shared a vignette about a global engineering design competition she learned about several years

ago called *Cubes in Space*. In this global competition, middle and high school students were

invited to propose and design experiments to launch into space on a NASA sounding rocket or a

zero-pressure scientific balloon. Several students at Franklin Middle School had their scientific

experiments selected to launch into space, including a student that had been placed in the custody

of the county children's home.

Dr. Taylor recently asked her students how the school's transition from an IB school to a

STEM school has impacted their learning. She was overjoyed that "the kids were able to identify

that their classes started becoming more engaging, they started doing more hands-on projects, the

classes were fun." This confirmed to her that she has successfully charted a course that is helping

minoritized students persist in the STEM pipeline. Dr. Taylor indicates that "when the students can tell you . . . 'I love coming to school on Wednesday for coding,' or 'Oh, I love my medical detective class—it makes school exciting for me,'" she knows her leadership is fostering a school environment where underrepresented students can thrive in STEM.

### *Strategy: Student Clubs*

Dr. Taylor has found that STEM-related extracurricular programming such as before and after school clubs are an effective way to stimulate student interest in STEM. Many of the clubs that are available to Franklin Middle School students provide them with the opportunity to participate in STEM-related activities such as robotics competitions, Science Olympiad, and various field studies. Dr. Taylor is especially proud of the Black Greek Letter Academic Society that her school developed, the first such fraternity at the middle school level in the state. As previously noted, African American males at Franklin Middle School frequently struggle academically. The fraternity was created to promote and recognize academic excellence. Fraternity members have a code of conduct, and they must meet and maintain grade point and behavioral criteria to be members. Dr. Taylor feels that the strong interpersonal relationships and positive peer pressure afforded to fraternity members helps the students persevere in STEM. As evidence, she says that since the fraternity was founded in 2018, the percentage of African American males in her school enrolling in Algebra I has more than doubled.

### Elena López

### *Barrier: Expectations of Sponsoring University*

Collegiate STEM Magnet School is one of the few charter schools in the nation operated by a university. While its affiliation with a major state university provides ample opportunities for collaboration and resource sharing, it also comes with a price. Several university departments

use Collegiate STEM to conduct research, which can be disruptive to the school's instructional program. Principal Elena López attests:

> We had a couple projects this past year where the university . . . was testing some things out, so they asked us to partner with them. They utilized our students to help them with some of the testing. . . . We don't want to . . . always let those types of things guide our projects. . . . That was one thing that we learned, because I think this year, we had three of those projects . . ., so we were feeling like that really didn't allow for choice or voice from the kids as far as where they wanted to take a project. We were basically giving them [the students] the criteria we had to meet. . . . We just felt like it was a little too much. That's part of the reason that they [the students] rebelled at the end.

Mrs. López recognizes that collaboration with university research is both necessary and beneficial. But unless the school has input on which research projects to implement, the length of project time, and comparable criteria, it can have a detrimental impact on student engagement.

### Barrier: Lack of Unity Around School's Core Beliefs

Elena López is proud to proclaim that Collegiate STEM Magnet School is a growth mindset school. She believes that all children can take on challenging work and learn. As a result, the school has moved away from tracking and ability grouping, especially in the middle grades, where "all students take the same coursework." Unfortunately, some parents have not been supportive. According to Mrs. López, "We definitely did struggle with the whole tracking [concept], because I think it got to the point where parents were expecting it. You know, 'My student is a lot smarter.'"

A similar problem has been dealing with parents who expect their student to earn an A in every course because they see high grades as the pathway to getting college scholarships. Mrs. López says, "That's so tough for us. I hate that as an administrator." She does not believe that everything that is important to learn and to be able to do in STEM can be measured by traditional grades. She also believes that struggling with STEM is part of the learning process. She

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observes:

> I just wish that there would be a program that would not necessarily measure grades but would measure your ability to struggle a little bit, because I think that's another thing I say to a lot of our parents, a lot of our teachers, a lot of our kids, 'It's okay to struggle in algebra, that's part of the process.'

Rather than placing an overemphasis on traditional letter grades, Mrs. López says that a core purpose of Collegiate STEM Magnet School is to help students develop the higher level thinking skills they will need to be successful in STEM and in life.

### Barrier: Resource Challenges

As a charter school operated by a major state university, Collegiate STEM has ample resources at its disposal. Nevertheless, the school faces challenges with ensuring that students have the resources they need to learn. Paula Trevino, who has taught at Collegiate STEM for the past six years, feels that the school has "growing challenges, and I would say most recently it's been . . . students with income needs and students with social emotional needs." Mrs. López agrees, adding that "some of them didn't have breakfast so they're hungry and they can't concentrate." Serving students from a wide geographic area and multiple school districts, Collegiate STEM does not provide bus transportation for families, presenting yet another challenge in serving blue collar families. Sheila Weber, president of the parent board, is also concerned that in a project-based school such as Collegiate STEM, some families do not have the needed materials. She questions, "How do we get our kids supplies at home?" Mrs. López has found it necessary to solicit donations to provide for the needs of children in her school who do not have sufficient access to the supplies and materials they need to be successful in STEM.

*Barrier: Shortage of Qualified Teachers*

With a growing Latino population at Collegiate STEM, Mrs. López has made a concerted effort to expand the number of bilingual teachers at the school. However, this has proven to be problematic, as regular education teachers who are fluent in both Spanish and English are in high demand. She notes that "every time we interview somebody, for whatever reason, they end up not joining us." Nevertheless, diversifying the faculty and staff remains a top priority for Mrs. López: "We really want to work on trying to diversify our staff because our students have definitely become more diverse over the years and I think that will continue."

Once teachers have been hired by the school, acclimating them to project-based STEM instruction can also be challenging. Mrs. López observes that "when we have new teachers, they kind of struggle with that piece." She also finds that her teachers "get so nervous about planning for project-based learning . . . because they're not able to . . . [just] checklist off the standards." And while her middle school teachers are typically comfortable with implementing small group learning experiences, she finds that her "high school teachers have a tougher time with not doing as much lecture and doing more of the Socratic seminar or doing more small group" work.

*CRSL Practice: Courageous Leadership*

Collegiate STEM is a charter school operated by a state university. Several university departments use the school to conduct research, which can negatively impact student learning. Elena López maintains that many of the university's projects do not "allow for choice or voice from the kids." During one such research project, the students "rebelled at the end." As an administrator, she has to walk a tightrope between meeting the university's research expectations and the needs of marginalized students. Mrs. López has engaged in courageous leadership as she pushed back against the number and length of such projects. She insists that "even if we do have

to collaborate [with the university] . . ., we need to really choose those projects and collaborations."

### *CRSL Practice: Forming Positive Student Relationships*

Paula Trevino, a teacher at Collegiate STEM, says that "one of her [Mrs. López'] biggest strengths is she's so relational." Sheila Weber agrees: "She is really relationship driven." Mrs. López also describes relationships as one of her major strengths: "I think I'm just super friendly and talkative with all of our kids." She indicates that she likes "being silly with kids, you know, smiling with them, smiling at them, giving them a thumbs up or a fist bump." Mrs. López spends a lot of time in STEM classes, asking students about their projects and asking them questions to assist students in reassessing their design plans. She believes the time spent in classrooms with students is a big help in building positive relationships with them.

Mrs. López reports that a key to building positive relationships with students is making sure they know that she truly cares about them and that her love for them is unconditional:

> We've had, you know, drugs on campus. We had a young man in eighth grade decide he could bring it in and try to sell it. . . . Obviously, that was quite intense. But I think he knew the entire time and throughout the process how much I cared about him and how much I knew this wasn't anything that was going to define him. . . . I don't think for a second he felt that I thought any less of him or that I cared for him any less.

Mrs. López also expects her teachers to form strong relationships with their students, particularly those who struggle. She reports, "I always try to tell the teachers to make connections with those . . . that you struggle with, because that will move mountains." She maintains that relationship building "shapes a culture that helps all of our families and students feel like they belong and this is their school." In turn, she feels that a strong sense of belonging leads to more successful academic outcomes for her students. Paula Trevino agrees: "I think when you feel that warm acceptance and ability to take risks and thrive, I think that's just good

practice for STEM."

*CRSL Practice: Fostering Equity and Inclusion*

Like many school administrators, Mrs. López used to fall into the trap of colorblind ideology, which focuses on treating all students as equally as possible, often at the expense of racial and cultural diversity. However, this changed when she "started exploring and learning more about the access portion" of learning. To promote an authentic vision of equity and inclusion at Collegiate STEM, Mrs. López intentionally considers the race, ethnicity, gender, and cultural background of children:

> Everyone has different needs. So I'm not going to worry about making myself provide the exact same thing for every student, because that isn't what's fair or equal or equity, right? That doesn't happen. There's no such thing as that for anyone—not for kids, not for adults.

Mrs. López' focus on equity and inclusion has led her to actively recruit more Latino STEM instructors who understand and value the cultural heritage of Hispanic students. Recognizing that many students lack access to the supplies they need to complete STEM projects, Mrs. López has worked closely with the parent-teacher organization to ensure that each classroom can provide students with the necessary supplies to be successful. PTO President Sheila Weber confirms that such efforts assist Collegiate STEM with providing "an even playing field for all students."

One of the more interesting ways that Mrs. López has fostered an equitable and inclusive school environment is her openness to expanding STEM program access in ways that were not initially anticipated. For example, several years ago when she partnered with Girls Who Code to increase opportunities for female students to become interested and engaged in STEM, other students in the school felt excluded.

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> The first year we had Girls Who Code, a young man came to me and said, 'Well, I'm just so upset. Why can't I be part of that? It's only for girls.' I said, 'Well, you can join if you would like to,' and he joined.

Mrs. López soon had several boys that wanted to be part of Girls Who Code, so she opened up access to the program based on gender and/or interest in computer programming.

### CRSL Practice: Instilling a Growth Mindset

When characterizing the STEM program at Collegiate STEM, Elena López indicates, "We're very much a growth mindset school." She drills into teachers and students that it is okay to try and fail—it is part of the learning journey. Mrs. López promotes the growth mindset in her school through a focus on mastery of state learning standards. She explains:

> We're a standards-based or mastery-based school. So that really helps . . . because students know, even if they fail this time, as long as they can show us that they're working toward understanding and being able to fully show mastery of the content, they can take the test again. I think that approach definitely helps us, especially when it comes to STEM and some of the more challenging areas like chemistry and physics.

Mrs. López has set the threshold for mastery at Collegiate STEM at 80%. As long as students can demonstrate a proficiency of 80% or higher, they are considered to have achieved mastery of the content. For students who struggle to reach mastery, Mrs. López reports that her teachers provide extra time and plenty of opportunities for students to redo assignments and retake exams. She also provides additional supports such as tutoring to ensure their success, and she has even worked with students over holiday breaks to provide more time for reteaching.

Mrs. López believes that instilling a growth mindset is especially helpful for female students, who otherwise may have given up on STEM. She remarks, "As we see our girls especially move up into the older grades, they've been exposed to this way of thinking. . . . They know that they can take risks, and they . . . know that perfection isn't expected." She adds, "We always try to say to them that a healthy struggle is okay, it's normal." Paula Trevino clarifies that

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Mrs. López' definition of growth is much broader than mere academic performance. She

indicates, "[Mrs. López] not only looks at it as academic or achievement growth, but I think she

looks at their well-being, too."

Mrs. López strikes a careful balance between the end goal of content mastery and the

growth mindset, which tolerates imperfection along the learning continuum. While others may

disagree, she believes that it is vital to instill a growth mindset in students in order to reach

mastery in the STEM subjects.

> We don't expect that they're perfect. I think that's part of our growth mindset as well. I
> think it definitely helps with everything within the STEM fields. As long as they continue
> working towards either solving a problem or just using their creativity—as long as
> they're doing those types of things and able to take risks, then we're providing an
> excellent education for our students.

Mrs. López suggests that the growth mindset, with its tolerance for imperfection, in no way

diminishes the rigor of the academic program at Collegiate STEM. Parent Board President Sheila

Weber agrees: "We do mastery based learning, so we don't crank out worksheets."

### CRSL Practice: Intentionality in Hiring

Elena López has struggled to add Hispanics to the instructional staff at Collegiate STEM.

When she interviews teaching candidates who share her ethnic and cultural background, she

reports that they often accept a job offer elsewhere. Besides herself, she states that there are only

three or four other Hispanics on staff. However, Mrs. López is determined to change this trend in

the years ahead: "We are really working hard as we start to look at candidates for next year in

diversifying our faculty." One area where she feels she has had great success is with hiring

women to teach STEM, which she believes is critically important for the girls who attend the

school.

Paula Trevino, a teacher at Collegiate, acknowledges that Mrs. López is "definitely trying

to diversify our staff as much as she can." Ms. Trevino thinks that hiring a diverse staff helps foster stronger connections between teachers and students since "we can have kind of a face for every student." Sheila Weber, president of the parent board at Collegiate STEM, is pleased with the priority that Mrs. López has given to hiring women. She reports, "Our science teachers and our math teachers in the high school and the middle school are all women." Faith Myers, who has taught at Collegiate STEM for more than ten years, agrees that one of Mrs. López' "greatest skills is her ability to get the right people on the bus." Ms. Myers adds that Mrs. López is "very good at interviewing and knowing what is needed in the school and aligning that to the mission."

### CRSL Practice: Leveraging Professional Development

Mrs. López expects all teachers to incorporate STEM thinking and activities into their day-to-day lessons, not just teachers who are traditionally associated with STEM disciplines such as math and science. She has noticed that this is especially difficult for new teachers, so she provides training for new faculty members on incorporating STEM into all content areas. Another area that she focuses on is Response to Intervention (RtI) training. Mrs. López is acutely aware that all too frequently, students of color slip through the cracks. When students struggle academically, she wants to ensure that her teachers have "strategies that are going to help them when they feel like, 'Oh, I don't know what else to do.'" In addition to RtI training, she has put together a committee to coach teachers on providing effective academic supports for children.

Mrs. López believes strongly in culturally responsive instruction. She has provided training on culturally relevant pedagogy to her faculty, and culturally responsive practices are frequent topics at faculty and PLC meetings. Faith Myers, a teacher at Collegiate STEM, feels that Mrs. López has done an excellent job offering the professional development teachers need in order to provide a STEM education that is inclusive of all students. She observes:

We have diversity training, professional development, making sure that we are aware of any biases that we hold on to as teachers and to address those. There is professional development throughout the year so that we make sure that we as teachers are aware of those things so that we can address them.

She believes that the training that Mrs. López provides the staff on a regular basis has done much to ensure that "any child, whatever culture, whatever race, whatever challenges they have . . ., they are still part of that enrichment in STEM."

### CRSL Practice: Meaningful Role Models and Mentoring

As a Latina, Mrs. López is especially concerned that female students and students of color at Collegiate STEM have plenty of role models. To address the needs of females in her school, she has been intentional about hiring female teachers. Sheila Weber, a teacher at Collegiate STEM, confirms that

our science teachers and our math teachers in the high school and the middle school are all women. I think she [Mrs. López] invests in them, and they in turn invest in their students and really provide a role model for them to be into STEM.

To provide additional opportunities for students to be exposed to STEM role models, Mrs. López partnered with Girls Who Code, which offers an afterschool coding class. She also capitalized on Collegiate STEM's presence on the campus of a state university to partner with Women in Science and Engineering (WISE). Through the partnership with WISE, women working on degrees in engineering and related STEM fields volunteer at Collegiate STEM to tutor students, serve as guest speakers, help teachers with STEM projects, and assist with afterschool special interest clubs. Mrs. López says that the female engineering students often use her school's cafeteria to present their design projects to their professors, providing "really great exposure for our girls as well."

To provide role models and mentors for students of color at Collegiate STEM, once again

Mrs. López capitalizes on the close proximity of a state research university. As she documents:

> As far as Hispanic students, the way that we've been able to approach getting them more engaged is that we collaborate with a team of engineering students here on our campus. They put together what they call a Baja Buggy Club. They make their own Baja bug, it's like a dune buggy. . . . They join a national competition every year. With this group of kids, a lot of them are males, but we actually are seeing a lot more females as well. We also see a lot of students that are Hispanic and so that's a double whammy for us. . . . They serve as a role model, working on some of these projects that encourages kids at our level to think, 'Oh, I can go all the way to college and do stuff like that, too.' We were able to connect a lot of our Hispanic and even African American and Asian American kiddos to some of those engineering students that serve like informal mentors.

In addition to the strong presence of Hispanic university students that serve as role models and mentors for students of color at Collegiate STEM, Paula Trevino feels there is another important role model that is sometimes overlooked. She reflects, "Because she's a Latina, I think she [Mrs. López] is a flagship for other Hispanics that look to her as an example . . ., as a model of academic excellence. She's a billboard for what it means to be a very successful minority woman."

### *CRSL Practice: Providing Students with Voice*

Elena López reports: "Our students know that they can definitely have choice and voice" in their learning at Collegiate STEM. She adds that students are "able to explore different things, utilize different resources, take things where they want to go, [and] work with things that interest them." She encourages her teachers to provide frequent opportunities to discuss projects with students and find out "where they want to take the project next." One of the things she has discovered, however, is that teachers need to maintain parameters on student work to ensure that student choice and voice does not lose sight of the essential question(s) that are integrated into a given STEM unit to ensure meaningful learning outcomes for students.

Another way that Mrs. López provides students with voice is by maintaining an open

door policy. She says, "I think giving voice stems from that as well, because then students . . .

know they can just walk in." She recalls a parent sharing that "it just baffled her that her sixth

grader said, 'Oh, I walked into the principal's office,' or 'I'm going to see if my teacher allows

me to go in and . . . talk with Mrs. [López] about it.'" Due to the freedom students feel in

approaching the principal, they did not hesitate to approach her last year when they were upset

about the length and lack of flexibility regarding a project the school's university sponsor was

testing at Collegiate STEM. Their feedback helped Mrs. López understand that it was time to

push back against some of the university's expectations, which were becoming detrimental to the

learning climate in the school.

### *CRSL Practice: Reflection*

Reflection is part of the soul at Collegiate STEM Magnet School. Elena López proudly

reports that her school has "a little motto or tagline—we want reflection, not perfection." Mrs.

López says that the entire school community—administration, faculty, and students—recognize

that critical self-reflection is the vehicle for continuous improvement. She believes that missteps

and detours are inevitable along the road to achieving one's vision, but "as long as you can

reflect about it, then you have the ability to change . . . and make it better the next time." Not

only is daily reflection a part of her administrative routine, calling others to reflect is "really a

big part of the way that I lead." While the end goal may not be perfection, Mrs. López hopes that

challenging teachers to reflect will lead to more equitable STEM learning outcomes for the

students at Collegiate STEM:

> With teachers, I definitely push that [reflection]. . . . I'm sending them a message or
> talking about . . . 'What do you need to change? How are you going to reflect and change
> the next quarter so that you make sure that you are able to teach everything that you need
> to teach, and teach it in a way that kids are understanding?'

*CRSL Practice: Strategic Partnerships*

Compared to most principals, Mrs. López feels she has a big advantage when it comes to establishing fruitful partnerships with the local community. She remarks, "A bonus for us is the fact that we are located on a university campus. That definitely helps because our community includes the different colleges within the university. They're definitely our partners." This partnership benefits her school by providing a steady stream of guest speakers, collaboration on STEM research projects, and ready access to STEM role models and mentors who are female and/or people of color. Students at Collegiate STEM are able to take up to two courses at the university each semester at no charge, which helps students from low income families build up a significant amount of college credit in high school without resorting to college loans. In addition, the partnership with the university has led to the formation of an academy structure at Collegiate STEM. Each high school student can choose from among six academies for their academic track, with each academy corresponding to a particular college at the university, such as engineering, business, or health.

Another major source for partnerships has been through Mrs. López's relationships with parents. She has been able to collaborate with a number of major corporations in the surrounding metropolitan area where school families work. Besides providing students with access to job shadowing opportunities and participation in research, business partners often visit Collegiate STEM to enlighten students about career choices and the steps they should follow to achieve their goals. Mrs. López states that such partnerships would not be possible if not for the strong ties her parents have to these businesses. She admits, "Honestly, the way that we're able to link with each of these organizations, each of these community partners, is because of our parents."

### *Strategy: Afterschool Clubs*

Mrs. López is concerned about sustaining the interest and persistence of females in STEM. She remarks, "We have to really start getting girls super excited about the STEM field." A strategy that has worked for her is partnering with Girls Who Code and Women in Science and Engineering (WISE) to provide a variety of afterschool clubs and activities that are particularly aimed at girls. She explains:

> We've started providing after school clubs and opportunities for the girls especially. . . . I think the biggest thing that we have found, as it pertains to girls in STEM, is that a lot of times due to those difficult middle school and high school teenage years—there's just so much with peers and, you know, not wanting to look dumb or look like you're asking a dumb question or those types of things.

Mrs. López believes that afterschool clubs and activities that are specifically geared toward girls provide her female students with a safe space to ask questions and take risks.

An afterschool program that has been especially successful in serving underrepresented students at Collegiate STEM is the robotics team. According to Mrs. López,

> robotics isn't specifically for girls, but a large portion of our robotics team in high school is made up of girls, and it has all walks, not just white, but we have Hispanics, we have African American members, boys and girls. But we do have girls who have definitely stepped up and are confident.

Mrs. López perceives that to the degree she can leverage afterschool programs such as Girls Who Code and the robotics team to instill confidence in females and students in color, she is not only arousing their interest, but more importantly enabling them to persevere in STEM. She stresses that success is when students are "willing to take risks and try something even if at first they fail," which she believes is a prerequisite for persistence in the STEM pipeline.

### Strategy: Project-Based Learning

One of Elena López' core strategies for sustaining the interest of underrepresented

students in STEM is project-based learning. She notes that she has been "working with all of our

teachers to make sure that they're incorporating . . . STEM projects within their day-to-day"

instruction. Mrs. López believes that project-based learning animates subjects such as physics

and chemistry, generating the interest students need to persist in STEM. She reports:

> We're introducing them [students] to project-based learning and to STEM education and
> what it actually looks like, what it actually feels like for students. And then once . . . the
> kids actually get to experience it, then I think they're hooked, because then they're
> asking, 'Well, when's our project time?'

## Brianna Young

### Barrier: Educator Bias

As a black woman leading an inner city school, Brianna Young realizes she has a

problem at Jefferson Polytechnic High School: "The majority of our students look like me, and

the majority of their teachers don't." The color of one's skin is not the issue—it's the negative

thinking that often emanates from well-intentioned people. Mrs. Young explains:

> Just because you see a young black child doesn't mean that they're poor or hungry. It
> doesn't mean that their home is in the projects. It doesn't mean any of that. But
> sometimes in an urban space, people's idea of what that stereotypical child will look like
> is . . . 'Oh, I've got to close these learning gaps in him and I've got to. . . .' You know,
> they automatically go to a deficit way of thinking.

Mrs. Young expects all children, regardless of their race or family background, to be

taught with academic rigor aligned to grade level standards. But many of her teachers lower their

expectations, much to her dismay. Mrs. Young maintains that "it's a civil rights issue when

teachers decide to not teach the core curriculum at the grade level that's expected because of

trying to make up for other things that might be going on in a student's life." She laments that

many teachers have "grown up in a system that is surrounded by bias, low expectations for kids in the city." Because of deficit thinking, her teachers are often slow to get around to what they should actually be teaching. For example, some teachers focus on providing rewards for their students such as pizza parties or watching football games. Mrs. Young believes, "We don't need to give a pizza party when we could . . . do a really cool PBL that would accelerate them and get them excited about learning about rockets."

### Barrier: Expectations of State Board of Education and Local School District

Like schools across the nation, Jefferson Polytechnic must grapple with state testing mandates and the negative impact these tests have on teaching and learning, such as the narrowing of the curriculum and the loss of valuable instructional time. Mrs. Young says that state testing is especially detrimental in an inner city STEM school:

> The state report card, you know, has been a challenge for us. I mean, we had Fs for years. . . . We had to have real concrete, hard conversations about what we would be able to do and hold on to as a design principle of our school in terms of project-based learning, because project-based learning takes a really long time. . . . You have to make all the connections and it takes training. . . . When you have a district that's saying you've got to be on Chapter 23 by April so that you can take the state test, it becomes a challenge.

Janet Davis, who serves as a technology facilitator at Jefferson, agrees: "To really design a school that's outside of the box, you have to be willing to rally against state testing mandates and offer your curriculum in a different sequence than what the district requires." While Mrs. Young does her best to keep teachers focused on the school's STEM curriculum and project-based learning design, she is frustrated that "teachers are getting a mixed message from the district in terms of what their expectations [are]."

*Barrier: Leadership Time Constraints*

Mrs. Young would like to spend the majority of her time visiting classrooms, interacting with students, supervising teachers, and having meaningful conversations with the staff about STEM education. However, principals wear a multitude of hats, and many of her responsibilities take her away from teaching and learning.

> I think all principals have to be focused on how you can keep the main thing the main thing. . . . [However] you have to worry about the plant operator, and you've got light bulbs out, and you know, all of the things you're running. I always said I was running a small city. You're the mayor, you're the city manager, you're the HR, you're all of it, right? And sometimes with not enough help or the right help to help you do that.

Pulled in so many different directions, it can be difficult for Mrs. Young to follow her true passion for helping all students grow into the best version of themselves.

*Barrier: Low Parental Involvement*

Like many high schools in her district, Mrs. Young finds it difficult to keep parents connected and involved in their child's education. One of the key reasons parent involvement is especially challenging at Jefferson Polytechnic is due to its inner city location and the economic hardships faced by the families it serves (98.8% of school families are classified as economically disadvantaged). Mrs. Young says, "I know that my parents work and they work a lot. Some of them, prior to the pandemic, were working two and three jobs." Such schedules are not conducive to family STEM nights nor orientation meetings where parents can learn how to support their student's academic goals. Mrs. Young posits that another reason parents do not participate in such activities is because they are caring for younger children or grandchildren at home. Others do not participate because they had negative experiences when they were in school. Regardless of the circumstances that affect parental involvement, Mrs. Young offers, "I know one thing about our parents is that they love their kids."

*Barrier: Overemphasis on ELA and Math*

As a former microbiologist, Mrs. Young knows firsthand that students of color can thrive in STEM. However, in the field of education, providing robust STEM instruction often takes a back door to covering basic skills in English/Language Arts and mathematics.

> There's been a great lack of attention paid to anything outside of ELA and mathematics in any school district that's dealing with kids in the urban core. So as you talk about the application of the skills through engineering and technology, the application of science, there's a hurdle there, because so much of the work in . . . education has been about closing the gaps in literacy and mathematics.

Mrs. Young recognizes that students of color need foundational skills in literacy and mathematics to be successful in STEM. However, in an attempt to compensate for reputed achievement gaps, she feels that there is an overemphasis on reading and math as siloed subject areas, particularly at the elementary and middle school levels. This makes it difficult to keep minority children on track as they move through the STEM pipeline, particularly in developing their abilities in technology and engineering.

*Barrier: Resource Challenges*

When Mrs. Young led the transition of Jefferson Poly into a STEM academy, the district did not provide all of the resources she needed to design a project-based curriculum for the school. She states that since the school's inception, she has "had to go out and raise money for different things, find money to do so many unique things we wanted to do." In addition to being shortchanged by the district with furnishing classrooms with the requisite STEM supplies, Mrs. Young did not receive adequate funding to provide students with 1:1 technology. As a result, she had to approach a major corporation in her community and ask them to provide her school with used computers. She adds that "there definitely has been a need for me to go out and just keep beating the drum loudly about what we need at the school that was outside of what the district

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was providing."

Mrs. Young's school serves a population where approximately 99% of students are economically disadvantaged. Consequently, many of the students attending Roosevelt Preparatory STEM Academy experience regular food insecurity, lack access to adequate medical care, and need a secure place to live (5% of students are considered homeless). The resource challenges faced by families in the inner city presents an ongoing challenge for the school to fully engage students in a rigorous STEM program. Mrs. Young notes that it is hard for young people to focus on learning when they are worried about the well-being of their family or concerned about where their next meal will come from.

### CRSL Practice: Courageous Leadership

Brianna Young has challenged state testing and district curricular mandates that are frequently at odds with providing students with an efficacious STEM program. She perceives that state testing requirements narrow the curriculum, severely limiting opportunities for providing robust instruction, particularly for minoritized students. Mrs. Young's concerns are shared by Janet Davis, who remarks that "when teachers are going to prepare a kid for a [state] test, they are going to be hyperfocused on the test and not on PBL [project-based learning]." Mrs. Davis has also observed Mrs. Young push back against the expectations of the district when it was in the best interests of students:

> Anytime you're going to do a new approach to learning or you're going to start up a new design in a school, you have to figure out how you're going to overcome the hurdles, the typical obstacles that are set in place either by state mandate or district mandate. I think [Brianna] was always willing to go to bat for offering block scheduling, which the district didn't want us to do.

Mrs. Young has also displayed courageous leadership in securing needed resources for the school. She recounts:

I don't want to downplay the very generous role that [the district] has played in the success of [Jefferson]. They definitely provided, you know, textbooks and things like that. But in the early days, we had to fend for ourselves in terms of computers. We had to go out and get a relationship with [a major corporation] and get their used computers so that every kid could have a computer. We've had to go out and raise money for different things, find money to do so many unique things we wanted to do in terms of like how we even set up our classrooms. So there definitely has been a need for me to go out and just keep beating the drum loudly about what we need at the school that was outside of what the district was providing.

Mrs. Davis states that finding critical resources is something that Brianna Young excels at, especially when they are not available from the district: "[Mrs. Young] was exceptional about finding those resources."

### *CRSL Practice: Culturally Responsive Curriculum*

To assist her teachers in providing instruction that is culturally responsive and relevant, Mrs. Young partnered with UnboundEd to train her faculty on how to connect the curriculum to students' life experiences and the inequities they witness in their communities. She finds that STEM education lends itself well to culturally responsive topics and pedagogy:

We always focus on projects—project-based learning—as our key pedagogical structure, using a lot of inquiry based science. . . . So that allowed, I think, for a greater breadth of opportunity for linkages to culture. We did a whole [unit on] . . . Harlem Renaissance. And so there was the opportunity to bring in the historical narrative of what was going on, bring in the literature from that space . . ., talk about family connections, you know. Kids were given a space to talk about that in terms of historically how connected it was to their family and then go from there. We tried as much as possible to make it relevant to them. . . .

We were very inclusive of the information that happened last summer with Mr. Floyd. We try as much as possible to keep the topics connected to the students' backgrounds and where they come from. . . . I will tell you, though, we always go for making sure that it's not a topic that we avoid. We're not walking around acting like . . . Mr. Floyd wasn't killed and there wasn't this whole bunch of social unrest. And so researching that work, you know, is key. Research is a key part of STEM that doesn't get elevated enough.

Mrs. Young expects her teachers to continually identify new ways to link STEM learning objectives to the cultural experiences of students and their families. She was recently pleased to

observe one of the geometry classes examine patterns in quilts, together with a discussion

regarding "the narratives of the slaves and how they were told through quilts."

*CRSL Practice: Developing Welcoming Spaces for the Local Community*

To be an effective principal in an inner city school, Brianna Young believes that one of

her essential leadership functions is facilitating the exchange of ideas and resources between the

local neighborhood and Jefferson Polytechnic. She has established a partnership with a local

children's hospital to provide a health clinic in her school. However, the school health clinic is

not restricted to Jefferson Poly students. Mrs. Young shares:

> There's a nurse practitioner at our school five days a week, and they set appointments,
> and you can go there instead of, you know, seeing your doctor at the [local hospital]. As a
> service to our community, we also allow community members who have children of the
> appropriate age to come into the school and go directly into the clinic to be seen by a
> nurse practitioner. So it services not only our kids, but also kids that are in the
> surrounding area.

Mrs. Young is also proud of the fact that Jefferson Polytechnic operates a community

resource center on its campus. In addition to the health services that are shared with the local

community, Mrs. Young reports that the school is able to provide parent engagement programs,

career services, youth development activities, counseling, nutrition classes, and after-school

programs to the community. The community resource center also connects families with

nonprofit organizations that can provide help with food, utility bills, transportation, and rental

assistance. Mrs. Young indicates that the center not only benefits the community, but it also

serves as a vehicle for the school to identify people willing to engage with students as tutors,

chaperones, mentors, and/or guest speakers.

*CRSL Practice: Forming Positive Student Relationships*

Brianna Young knows how important positive relationships are for students in a diverse school. She says that her students "have the same needs as kids in the suburbs. They want to know that they matter." To build close relationships with students, Mrs. Young reports, "I treat every student, regardless of race, regardless of ethnicity, like they are mine." She also knows that large schools must be intentional about connecting students with caring adults, as the relational needs of individual students can easily be overlooked when they are part of a large group. Mrs. Young addresses this challenge by building advisory time into the schedule, with small groups meeting once or twice a week throughout the year. She notes, "Advisory was our key time for our kids to have an identified adult who was tuned in uniquely to their needs in a smaller setting. You only have about 10 to 12 kids meet in your advisory." Mrs. Young feels it is extremely important for each of her students to make "a connection with someone at the school who knew about whatever their challenges or their triumphs might be."

Mrs. Young also wants each of her teachers to form strong relational connections with their students. She perceives that the relationships teachers have with their students are vital for sustaining academic growth in STEM.

> I've always believed that the most powerful person in a student's life is the teacher and what they do in the classroom. How they approach them [the students] and the relationships that they have with them are most important in terms of creating an atmosphere where a student can deeply learn and access the curriculum.

To foster strong relationships between teachers and students, Mrs. Young sets aside time at the beginning of each school year for relationship building.

> The first two weeks of school, we always had a STEM boot camp. And inside of that boot camp, we really got to know our kids. Our grade level teams did intensified work on building relationships. So we did not start with traditional school. We started off the year with just doing a whole lot of work around . . . getting to know our kids.

Mrs. Young believes that strong relationships between teachers and students build mutual respect and trust, which fuels students' academic success. She submits that when students "trust us, they will move forward in whatever we're sharing with them in terms of academics."

### *CRSL Practice: Fostering Equity and Inclusion*

Brianna Young is passionate about providing an equitable and inclusive learning environment for all students at Jefferson Polytechnic High School.

> I haven't had anything that has changed my mind about the importance of making sure that all kids have equitable learning spaces. It just has to be. I don't care—white, black, Hispanic—I don't care, all kids deserve the absolute best period.

This passion extends to students with identified disabilities. Mrs. Young is especially proud of the fact that although her school has three specialized classrooms for students with significant behavioral and/or mental health needs, she has been able to "make sure that they have full access to the opportunities we offer inside of STEM."

Mrs. Young frequently uses equity audits to support her vision of equity and inclusion, utilizing data from state and local assessments.

> We looked at the trends . . . utilizing the data from the state tests mostly. The district also has a really cool interface . . . and we could have the students' teacher designed assessments in there. We could take that data and graph it and kind of see in general where the weak spots were. . . . And we teased it out in terms of the subgroups—African American, poverty, students with disabilities, gifted, and students that speak a different language, LEP students—and we could see the trends that were happening there.

Mrs. Young uses this trend data when working with teachers to develop appropriate instructional supports whenever a particular subgroup has an opportunity gap. In addition to equity audits, Mrs. Young builds an equitable STEM school by challenging cultural norms which pigeonhole students in particular career paths. For example, Janet Davis notes that Mrs. Young "always encouraged our male students to look at the underrepresented fields in health and females to look

at engineering."

### *CRSL Practice: High Expectations for All*

Mrs. Young acknowledges that maintaining high expectations for all students in an inner city STEM school can be difficult for both administrators and teachers. She wonders at times, "How can we be a STEM school and do all this school techie stuff and get kids engaged, excited, and motivated, and challenge their belief system about what they're capable of?" She has discovered that a key to realizing the high expectations she has for all students regardless of their color, gender, or family background is to ensure that they are actively engaged in challenging experiences that demystify STEM:

> In our school, they [the students] were actually doing it! They were actually having success doing . . . projects, being a part of scientific research, learning all of those aspects. We made the curriculum approachable for those kids, so it was no longer this mystery like, 'Maybe I can't do chemistry,' or 'Physics is really, really hard.'

While a substantial number of students come to Jefferson Polytechnic with gaps in their reading and math achievement, Mrs. Young is determined that the curriculum will not be diminished. She says that "if there are any gaps in mathematics capabilities . . . that kids come to us with, we still have the expectation that we're going to have rigor that's aligned to the grade level."

When reflecting on Brianna Young's leadership, one of the things that stands out for Janet Davis is Mrs. Young's unshakeable belief that all students at Jefferson Polytechnic can achieve at high levels in STEM:

> She truly believed that every single student, especially her African American students, could achieve in the STEM fields, could do well in math, could do well in science. She never would let anyone water down the curriculum or never challenge the kids.

Ms. Davis recounts that Mrs. Young frequently demands that her teachers give students rigorous work. "She always felt that kids, when challenged, would rise to the challenge."

### CRSL Practice: Intentionality in Hiring

Brianna Young is passionate about providing all students with a rigorous STEM program. This passion has a profound impact on how she approaches the hiring process. When she brings in teaching candidates for an interview, her practices are centered around onboarding people who share her vision and beliefs.

> All students can learn, being a teacher-led school, empowering all learners, regardless of their unique learning styles, to be successful in STEM—we incorporated that into the questions that we asked our candidates. And quite frankly, we turned down people who did not show an appreciation for those particular values.

She looks for teachers who have "the desire to approach their classroom and their leadership in the building differently than it may be in other buildings" in the school district.

Mrs. Young believes that a collaborative culture is essential for operating a school in the urban core, one where all staff members are working together to combat racism and the inequities that disrupt the journey of minoritized students through the STEM pipeline. One of the techniques she uses during the interview process to select candidates that can positively contribute to building a collaborative school culture is to pair two candidates together and engage them a role-playing scenario.

> We would do a role play with a candidate around developing an intersession idea. We would give them the scenario and the budget, and it would be another candidate not interviewing for the same position, but interviewing to be at the school, who would be their partner, and we would look at what they thought. I think they thought we were looking at the quality of their answers, but we weren't. It was really about can we discover how this person approaches relationships. Do they communicate well? Do they collaborate well?

Mrs. Young sees the ability of a candidate to participate in a collaborative culture to be "a North Star in terms of how we develop our work and how we onboard, how we select people to join the community."

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### CRSL Practice: Leveraging Professional Development

UnboundEd is a national organization that assists schools in identifying the ways that racism and bias impede students of color from having access to rigorous, grade-level instruction. Their organization provides thought leadership in the area of equitable education, as well as expert speakers and professional development seminars for teachers and administrators. Working in a school where students of color comprise 95% of enrollment, Brianna Young knew that UnboundEd was the right group to assist her professional development efforts at Jefferson Polytechnic. Several years ago, she took a team of teachers to California to attend a weeklong summit hosted by UnboundEd, and she declares that she "[has] been banging the drum loudly about that work ever since."

Mrs. Young recognizes that professional development must be a collaborative effort between school leaders and faculty members to be successful. She recounts how she went about building an equitable learning environment in her school:

> I was able to navigate it best by focusing on culture and empowering teachers to lead in their spaces by setting up professional development. I spent a lot of time on professional development, making sure that I was present, codesigning it with the teachers on the teams and in the departments, so that we would have this [shared] language that we could always speak about the work.

She developed what she refers to as Genius Hour, a time when she could have rich conversations with educators at either the team, department, or school level. Genius Hour is an opportunity for Mrs. Young to collaborate with teachers, department heads, and/or members of the administrative team around topics such as STEM pedagogy, culturally responsive practices, eliminating biases, and raising the bar on performance expectations for educators and students. Mrs. Young says that the goal of her professional development efforts is to help teachers engage all students in high quality, rigorous instruction regardless of their race, ethnicity, or family

background.

Janet Davis, a technology facilitator at Jefferson Poly, confirms that Mrs. Young has done an excellent job of "trying to come up with models in PD, to constantly innovate around PD" to promote an equitable STEM program for students. One innovation that has been especially helpful in assisting teachers in this work has been the GROW model of coaching. Mrs. Young provided training for the school's administrative team (including herself) and teacher leaders on how to coach instructors using the GROW framework (goal, reality, options, and will). She thinks it is important for everyone on her staff to understand the framework, "so that we [can] always be in a coaching session with [both] our peers and with the people that we supervise." The model has been so successful that she has even had teachers who were not part of the formal training ask if they could become part of the school's coaching cohort. Mrs. Young firmly believes "that the peer-to-peer coaching and all of those things will impact practices across the board and increase the academic performance of our students."

Another strategy that Mrs. Young has used to help minoritized youth persevere in STEM is the professional development she has provided to the faculty and staff on adverse childhood experiences (ACEs). At an inner city school like Jefferson Poly, many of the students have experienced and/or are experiencing childhood trauma. Mrs. Young elaborates:

> It's childhood traumas that you may have that might be impacting or coloring the way that you're seeing the world. It could be anything, from having an alcoholic father, or someone's parent dying early when you were young, those kinds of things. And so we did a whole lot of work with establishing for our teaching cohort what it means to understand trauma and to recognize that.

Mrs. Young considers adverse childhood experiences (ACEs) to be a major barrier for inner city minoritized students as they traverse the STEM pipeline. Through the professional development she has provided, the faculty and administration have developed a greater consciousness of the

adverse experiences that many students are coping with. In addition, the training has empowered teachers and staff to recognize the warning signs of ACEs, enabling the school to connect students to caring adults, mentoring, and counseling services to alleviate some of the negative effects that childhood trauma can have on STEM learning and academic achievement.

### CRSL Practice: Meaningful Role Models and Mentoring

Mrs. Young recognizes that all students need role models and mentors to be successful in STEM, whether they are at the top of their class or in need of remediation. To assist her with this work, she has partnered with a nearby university to provide an afterschool tutoring program. The university has loaned a graduate assistant to Jefferson Polytechnic who manages the tutors and mentors who work in the school. Mrs. Young says that the tutoring program provides "acceleration for kids that are ready to be accelerated, practice for those who need practice." In addition to afterschool assistance, Mrs. Young observes that many of her teachers will reach out to the program coordinator and request, "Can you send over some tutors to be in this room because I want every kid to have a one-on-one in this particular class." By pairing her students up with university students, Mrs. Young hopes to increase their STEM skills, boost their scores on college entrance exams, and help students develop concrete plans for continuing their academic journey beyond high school.

Another avenue that Mrs. Young has used to provide role models and mentors for students is through job shadowing and internship experiences. For example, she has partnered with several area hospitals and nursing programs to provide internship experiences for students interested in STEM fields such as microbiology, physiology, genetics, and medicine. To provide role models and mentors for students interested in plant and animal science, she reached out to the city zoo. Students are provided with daily hands-on work experience at the zoo in areas such

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as environmental science, conservation, and plant and animal care. She has also worked with a

nearby university to host mentoring days at Jefferson Poly. These events pair students interested

in fields such as engineering and information technology with STEM professionals who are

people of color. Mentoring days serve as a springboard for students to form lasting relationships

with STEM professionals who look like them. Mrs. Young feels that such relationships help

students visualize themselves having a meaningful and productive career in STEM.

### CRSL Practice: Providing Students with Voice

Mrs. Young believes that minoritized students who perceive they have a voice in their

learning are far more engaged in school. At the beginning of each academic year, she instructs

teachers to get to know each of their students and "honor the fact that they are an individual who

was free to express their opinion—to give them the opportunity to have choice." She also asks

them to adapt their teaching practices to give students a greater voice in their learning. She

expects the faculty to teach

> in a way that [makes] it more open – not just sit-and-get, rote memorization, and fill-in-the-blank, but much more about getting their opinion and allowing open discourse. . . . How they can make this more student focused, where they're giving them a question, and there's a project assigned to it, and the students have choice, freedom of choice of how they will present their project at the end.

When teachers assign STEM projects, she expects them to provide students with multiple ways

of demonstrating that they have mastered the material, not just through traditional assessments.

She perceives that students take real ownership of their learning when they are given the

"opportunity to express themselves differently."

In addition to teachers, Mrs. Young believes that it is imperative for principals to get to

know their students, too. She says, "They want to know that you're listening to them. They want

to feel like they have some ownership in this space." She adds, "I think for sure you've got to get

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in there with them. You can't be a leader who is not willing to get . . . into the student
organizations and find out exactly what's happening." Mrs. Young submits that when principals
get to know their students' interests and dreams, it leads to a greater level of student engagement
and persistence in STEM. She also believes that when school leaders give students a voice,
"they're not just a student, but part owner in a culture that's bigger than the building."

### CRSL Practice: Reflection

Brianna Young has been keeping a journal ever since she became principal of Jefferson
Polytechnic. She says that journaling is "a way of being really reflective of my day and thinking
about, you know, ways to get better." Over the years, she has compiled more than 50 notebooks
of reflective notes. While keeping a journal has helped her critically reflect on her leadership, she
has found another practice to be equally rewarding:

> I think self-reflection is highly important, but I also think coaching is as well. I mean,
> sometimes you can just think about, 'Oh, well, maybe I was being X, Y, and Z, and I
> didn't really consider whatever it was.' But having a coach … is a critically important
> next step. I'm a very reflective person in general, like I told you about my notebook
> system, the one that I have my personal journals. . . . But I also have a coach, someone
> that can talk to you about problems of practice, who can elevate something that maybe
> you're really not identifying through your reflection. . . . It [coaching] can really
> transform the way that you do your work as a leader.

Mrs. Young is adamant that coaching elevates her reflection to a higher level. She believes that
all principals who are dedicated to improving outcomes for students in the urban core should
leverage regular coaching sessions with a fellow administrator to help them critically reflect on
their leadership practice in a way that they would be unable to reflect on their own.

### CRSL Practice: Strategic Partnerships

Janet Davis says that Mrs. Young is "great at networking and engaging partners in our
school at all different levels." First among these relationships is the university that is

conveniently located in close proximity to the school. Mrs. Young says that Jefferson

Polytechnic and the neighboring university are strongly united in their desire to help students

from the inner city go to college. She remarks:

> [The university is] right across the street from our school, and we have an amazing
> relationship with them that was kind of like, you know, we both wrote our names in
> blood around how deeply we want to be committed to getting our kids to college.

This partnership has led to the creation of a vibrant afterschool program stocked with tutors from

the university, research internships for students, teacher training, and resources and technical

support for the school's engineering pathways and information technology programs.

Mrs. Young characterizes her role in fostering partnerships as that of a bridge builder.

She says that businesses and nonprofits are eager to help when they understand a school's needs

and see how their industry or area of specialization can contribute to the success of minoritized

populations. She submits, "My work . . . [is] trying to make a bridge from their world to our

world and to help them understand the value add." She is also selective in who she engages in

community partnerships for Jefferson Poly. As a gatekeeper, she "made sure that the connections

that we were bringing into the school were . . . meaningful for the students, and that it led to

something that could impact them."

Janet Davis insists that Mrs. Young has "worked really hard at the partner level and the

network level to bring needed resources to students." When Jefferson transitioned into a STEM

school, it did not have enough computers to provide one-to-one technology access. Mrs. Young

recalls that she "had to go out and get a relationship with [a major corporation] and get their used

computers so that every kid could have a computer." Since many of Jefferson's students live in

poverty, many of them go hungry outside of school hours. Mrs. Young addressed this by

partnering with a local foodbank to establish a food pantry in the school where students could get

groceries and toiletries. She notes that especially since the beginning of the COVID pandemic, "the take home food has been skyrocketing." Mrs. Young knows that hungry students cannot learn, "so we provide a lot of food, a lot of food." Janet Davis agrees that "those partnerships make a difference," especially for an inner city school.

### *Strategy: Intersession*

Mrs. Young says that intersession has been the biggest game changer at Jefferson Polytechnic for fueling interest and persistence in STEM. Twice a year, Mrs. Young's students enjoy a special week during which they work one-on-one with community partners on real-world STEM problems. For example, past intersessions have provided students with opportunities to work on global water challenges, program robotic applications, and study the impact of pollution on the local environment. Mrs. Young suggests that school leaders need to do more to disrupt traditional modes of instruction:

> The educational rationale for the intersession is that we believe that in order to adequately prepare students for the 21st century, we have to expand our thinking about what the classroom truly is. So that means that we have to give kids experiences that are not only inside the traditional four walls of a classroom, but outdoors and in partner organizations working with professionals in the field.

Mrs. Young says that intersession has enabled her school to provide students with "really rich, in-depth STEM experiences where they get to experience different cultures and different activities," providing motivation to further their studies in STEM fields. Intersession has also served as a valuable tool for linking underrepresented students to the community assets they need to persist in STEM beyond high school. Mrs. Young asserts that intersession enables all her students to "have connections to people in the community, to resources that can help support their journey that they choose once they leave us."

*Strategy: Project-Based Learning*

Mrs. Young believes that project-based learning is a critical strategy for engaging students in the inner city. She asserts, "Because we are mostly African American, and because we're mostly poverty, we know that project-based learning is the best strategy because it gets kids more engaged." She also states that she is "very worried about engagement and motivation, so we know that project-based learning is going to be the best way to handle that." Therefore, she has tried to "make that [project-based learning] be the linchpin of our design structure in terms of instruction" at Jefferson Polytechnic. Mrs. Young reports that project-based learning provides "for a greater breadth of opportunity for linkages to culture," which is essential for engaging the interest of minoritized populations in STEM. She also thinks that the collaboration and teamwork that are staples of project-based learning provide minoritized students with the communal bonds and support they need to press on in the STEM pathway.

## Summary

This chapter presented the findings from a qualitative comparative case study that examined the leadership of four exemplary principals in addressing the underrepresentation of females and students of color in STEM. The chapter began with a description of each principal's background and contextual information about the school community in which they engage in leadership. Next, there was a brief overview of the data collection process and the types of data that informed the findings presented in the chapter. Finally, each case was analyzed individually, with the findings organized around emerging themes. A cross-case analysis is provided in Chapter V, presenting the overall themes that emerged from a comparison of the four cases.

CHAPTER V: CROSS-CASE ANALYSIS

Chapter IV provided a within-case analysis that examined the leadership behaviors, practices, and beliefs of four principals regarding their work with students underrepresented in STEM. Creswell (2007) indicates that a within-case analysis should be "followed by a thematic analysis across the cases" (p. 75). Therefore, this chapter presents a cross-case analysis of the four cases included in this study. The initial themes that surfaced during the within-case analysis of interviews and documents are compared to identify similarities and differences. Meaningful linkages across the cases are determined to establish the comprehensive themes and subthemes that arise from the findings.

## Barriers to Meaningful Change

### Educator Bias

Two of the principals discussed the challenges they face in confronting bias against minoritized students. Dr. Taylor experiences frustration that some of her teachers lack empathy for disadvantaged students. In her district, newly hired teachers are bused through economically disadvantaged neighborhoods to gain a better understanding for the lived reality of the students they teach. Dr. Taylor observes that "some people, their hearts are just so hard, it doesn't matter—none of that matters to them. So that is a frustrating thing for me." She has also had to deal with teachers who have lower expectations for students who are not in honors courses and/or students who require individualized behavioral supports.

Mrs. Young has had to confront bias on multiple fronts—bias that targeted her personally as well as bias directed toward minoritized students. As a black woman, Mrs. Young submits that "there have been a few instances, quite a few instances, where I wasn't expected to do much. Or if I did perform, it was considered a fluke or there was cheating involved." She finds similar bias

rearing its ugly head in her school, often by well-intentioned teachers. For example, many of her teachers "automatically go to a deficit way of thinking," making stereotypical assumptions about black students growing up in the inner city. She laments that many teachers have "grown up in a system that is surrounded by bias, low expectations for kids in the city." Mrs. Young considers it to be "a civil rights issue when teachers decide to not teach the core curriculum at the grade level that's expected because of trying to make up for other things that might be going on in a student's life." She finds that many teachers are more focused on providing students with rewards like having pizza parties or watching football games in class instead of planning out engaging STEM projects for their students.

**Lack of Unity Around the School's Mission and Core Values**

In two of the cases in this study, principals reported challenges regarding the lack of unity around their school's core values. At Roosevelt Prep, Mr. Coleman states that their "belief is that all students can do what we teach them and train them to do." However, he has found that some of the teachers "have the fixed mindset," believing that intelligence is not malleable. He has also had to contend with parents who question why the school does not limit its enrollment to high achieving students, which runs contrary to the school's mission and purpose. As Mr. Coleman validates, Roosevelt Prep's "whole purpose, the reason we exist, is to provide rigorous and high quality STEM education for a diverse population."

Elena López has also been challenged by parents who do not buy into the school's core beliefs. Collegiate STEM is a growth mindset school that has moved away from tracking and ability grouping. According to Mrs. López, "We definitely did struggle with the whole tracking [concept], because I think it got to the point where parents were expecting it. You know, 'My student is a lot smarter.'" She also has to deal with parents who expect their child to earn an A in

every class. Mrs. López says, "I hate that as an administrator." At Collegiate STEM, the administration and staff believe that learning to struggle with challenging work is a big part of the educational process. The school focuses on growth and the development of critical thinking and problem-solving skills rather than the traditional letter grades emphasized by many parents.

## African American Male Educational Attainment Gap

While female students have been historically underrepresented in STEM, two of the cases in the present study reported that their challenge is closing the achievement gap for African American males. Several years ago, Mr. Coleman disaggregated data about participation rates in college courses for students attending Roosevelt Prep. He discovered that African American males were not taking college courses at the same rate as their peers. In addition, test scores and classroom assessments revealed that "it's African American males that struggle" in STEM. A similar concern exists at Franklin Middle School. Dr. Taylor observes that "our male students are the ones that are not engaged in science, in math classes, especially since reading is a strong component of math nowadays." She is also concerned that the achievement gap in STEM persists beyond the middle school years. Regarding African American males, Dr. Taylor submits that "they're not taking those upper level [STEM] courses when they go to the high school," perpetuating the achievement gap with their white peers.

## Disruptive Expectations and Mandates

Two of the cases described how mandates or expectations from upper levels of school governance structures can disrupt a principal's ability to provide for the needs of students who have been minoritized in STEM. At Jefferson Polytechnic, Mrs. Young has to cope with state testing mandates, as well as the restrictive curricular expectations of her school district that exist as a response to state testing. Mrs. Young firmly believes that project-based learning is the best

way to provide STEM education for minoritized students, but it is difficult to effectively utilize a project-based curricular design because of state testing. She reports, "When you have a district that's saying you've got to be on Chapter 23 by April so that you can take the state test, it becomes a challenge," since project-based learning requires a substantial investment of time for both teacher training and student work.

Mrs. López faces a similar disruption to project-based learning at Collegiate STEM. Her school is operated by a large state university that expects teachers and students to participate in highly scripted STEM projects to furnish data for its educational research studies. Mrs. López observes, "I think this year, we had three of those projects . . ., so we were feeling like that really didn't allow for choice or voice from the kids as far as where they wanted to take a project." With the university scripting such projects at Collegiate STEM for the benefit of its researchers, students lost their ability to have ownership in the design, direction, and duration of their projects. Mrs. López understands that there are benefits for a STEM school to participate in university research, but she is also concerned about how such research disrupts the collaboration, student creativity, and critical thinking that are essential components of Collegiate STEM's project-based learning design.

**Budget Constraints**

To meet the needs of students who have been minoritized in STEM, schools need sufficient resources, including adequate financing and access to specialized programming. A theme that cuts across all four cases in this study is that principals serving underrepresented students in STEM must often do so without all the resources they need to ensure equitable access to STEM. At Roosevelt Prep, Mr. Coleman has a growing migrant student population, but he lacks funding for an English Language Learner (ELL) instructor, and due to limited facility

space, there is nowhere to house an ELL program. As a result, the school frequently has to discourage migrant children from enrolling. Dr. Taylor, principal of Franklin Middle School, has struggled with inadequate funding from her district since a state law was enacted which exempts owner-occupied residential property from taxes for school operations. Dr. Taylor reports that "there was no backup plan, so now we are always destitute."

Like Franklin Middle School, Mrs. Young has also had to cope with inadequate district funding as she transitioned Jefferson Polytechnic into a STEM school, including insufficient resources for designing a project-based curriculum, furnishing classrooms, and providing students with access to 1:1 technology. And with approximately 99% of Jefferson Polytechnic families classified as economically disadvantaged, Mrs. Young has needed to worry about addressing food insecurity and adequate medical care for her students, needs that extend beyond the traditional reach of district funding. Mrs. Young reports that she has "had to go out and raise money for different things, find money to do so many unique things we wanted to do."

Collegiate STEM serves multiple school districts over a wide geographic area, but it does not have bus transportation, making it challenging for blue collar families to get their children to school. In addition, the school does not have adequate resources to provide for students' social emotional needs. A growing number of students at Collegiate STEM are economically disadvantaged and lack access to computer technology at home. Mrs. López, the principal of Collegiate STEM, has found it necessary to go out and solicit donations to provide needed STEM supplies for students who lack the materials they need to be successful. In addition, some students are coming to school hungry, presenting Mrs. López with challenges similar to those faced by Jefferson Polytechnic.

**Identifying and Training Highly Qualified STEM Teachers**

Three of the four cases identified difficulties in hiring and training highly qualified STEM instructors. Mr. Coleman says that "it's extremely important" to hire a diverse teaching staff to meet the needs of underrepresented students in STEM, particularly for students of color. However, it has been difficult to hire people of color for STEM positions at Roosevelt Prep because few apply. He has attempted to remedy this situation by reaching out to HBCUs and hiring programs that cater to people of color.

At Collegiate STEM, Mrs. López wants to attract more bilingual teachers to her school to meet the needs of a growing Latino population. However, she reports that whenever she has interviewed candidates with bilingual abilities, "for whatever reason, they end up not joining us." She has also found that many of her new instructors struggle with the implementation of a project-based learning design, since they cannot simply "checklist off the standards." At the high school level, she has noticed that teachers tend to gravitate toward lecturing rather than engaging students in small group work which is essential for fostering the student-led exploration, teamwork, and peer-to-peer communication that fuels STEM learning.

As Dr. Taylor transitioned Franklin Middle School from an IB school to a STEM school, she found that her teachers were overwhelmed. They didn't comprehend the core components of STEM design, which she defines as "ask, imagine, plan, create, improve, present." She says they simply didn't understand that "STEM was about problem solving." In addition, they struggled to integrate STEM learning across all academic disciplines. Many teachers also doubted that a STEM curriculum would work in an economically distressed rural community. While Dr. Taylor has been successful in helping teachers understand that STEM can work in any school, it has remained challenging to ensure that all teachers understand how to teach STEM and integrate

critical thinking and problem solving into their lessons.

**Low Parental Involvement**

Two cases reported challenges with involving parents in the education of their children. At the middle school level, Dr. Taylor reports that "the middle school is that time period where parents, for whatever reason . . ., they kind of feel like the kids don't need them anymore. So that is real difficult for us." She attributes the lack of parental involvement to factors such as parental burnout and having younger children at home that require their attention.

At the high school level, Mrs. Young has also found it challenging to involve families in activities designed to engage parents in their child's STEM learning. Because her inner city families face significant financial hardships (about 99% of Jefferson Poly families are classified as economically disadvantaged), Mrs. Young says "my parents work and they work a lot. Some of them, prior to the pandemic, were working two and three jobs." Another factor that Mrs. Young cites that is detrimental to parental involvement is the negative experiences they had when they were in school. Like Dr. Taylor, she also has parents in her school who are either caring for young children or grandchildren at home.

**Time Constraints**

In two of the cases, the principals were unable to spend as much time working with underrepresented students and their instructors as they desired. At Roosevelt Prep, Mr. Coleman has to spend much of his time in meetings with board members, business partners, and university officials, impacting the amount of time he is available to focus on ensuring that students historically underrepresented in STEM are having robust learning experiences. At Jefferson Poly, Mrs. Young also finds that the many hats worn by a principal often pull her away from visiting classrooms and interacting with students. As a principal, she indicates that "you're the

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mayor, you're the city manager, you're the HR, you're all of it." Unfortunately, the many responsibilities often constrain the time she has available to ensure that minoritized students receive equitable access to high quality teaching.

In summary, a cross-case analysis revealed a variety of barriers that principals encounter when attempting to lead meaningful change for students who have been historically underrepresented in STEM. Some of the barriers involve what I categorize as deep-seated attitudes and inequities, such as educator bias, a lack of unity around the school's mission and core values, disruptive mandates and expectations from state institutions, and the African American male educational attainment gap. Other barriers involve resource challenges such as budget constraints, finding and training highly qualified STEM teachers, low parental involvement, and leadership time constraints. The barriers to meaningful change are summarized in Table 4. All of the barriers ultimately impede the ability of principals to be responsive to the needs of students minoritized in STEM.

**Table 4**

*Barriers to Meaningful Change*

| Theme |
| --- |
| Deep-Seated Attitudes & Inequities |
| 1. Educator Bias |
| 2. Lack of Unity Around School's Mission & Core Values |
| 3. African American Male Educational Attainment Gap |
| 4. Disruptive Expectations & Mandates |
| |
| Resource Challenges |
| 1. Budget Constraints |
| 2. Identifying & Training Highly Qualified STEM Teachers |
| 3. Low Parental Involvement |
| 4. Time Constraints |

**Culturally Responsive Leadership Behaviors and Practices**

**Engages in Self-Reflection**

All four principals in this study reported that self-reflection is essential for developing the critical consciousness that is necessary for realizing their vision for creating an equitable STEM learning environment. Mr. Coleman admits that self-reflection has led him to confront the fact that although he is African American, he "had a bias towards some of [his school's] underperforming African American students." Dr. Taylor reports that she engages in self-reflection "all the time." She confesses, "Sometimes you get real frustrated when you have high poverty students . . ., and because of their environment, you're not getting the results that you expect." Self-reflection has helped her develop the patience she needs working in a high poverty school. Mrs. López acknowledges that she has made mistakes in trying to create an equitable learning environment for underrepresented students. However, she maintains that "as long as you can reflect about it, then you have the ability to change." Mrs. Young has been keeping a journal ever since she became the principal of an inner city STEM school. She says that journaling is "a way of being really reflective of my day and thinking about . . . ways to get better." In addition to daily journaling, she finds that having a coach "is a critically important next step" in her reflection process. She submits that having a coach provides a school leader with "someone that can talk to you about problems of practice, who can elevate something that maybe you're really not identifying through your reflection."

**Displays Courageous Leadership**

The principals in all four cases displayed courageous leadership in realizing their vision of equity and inclusion for students historically underrepresented in STEM. Dr. Taylor has challenged the deficit thinking of others. She has battled teachers who 'dumb down' academic

rigor for students with behavioral issues and/or those who lower their expectations for children who are not honors students. She has also confronted teachers who think that rural schools like Franklin Middle School cannot provide the quality of programming available to children who attend wealthy suburban schools. As she reports, "The first thing that teachers always say, if I take my population to a very rich school, they're gonna say, 'Well, we can't do that.'" Dr. Taylor has also been willing to fight her district to secure the funding her children deserve. One of her teachers observes:

> We have a rival school that has students that attend there from more influential families. And so historically, most of the money would go to that school. So [Dr. Taylor] had to fight for us to receive funding from the district and support, just so we could even get started with our STEM program.

Mrs. Young has also displayed courageous leadership. She has frequently challenged state testing requirements and district instructional mandates when she felt they were limiting the opportunities for minoritized students at Jefferson Polytechnic to receive the quality STEM program they deserve. Due to state testing mandates, her school district has micromanaged curriculum and instruction, going so far as to prescribe the textbook chapter students were expected to be covering on a given week in the school year. Mrs. Young believes that project-based learning is the best design for an inner city STEM school, but that requires block scheduling, which her district didn't want the school to provide. Besides pushing back against state and district expectations for the good of her students, Mrs. Young has fought to obtain the resources needed to provide a robust academic program. She remarks that "there definitely has been a need for me to go out and just keep beating the drum loudly about what we need at the school that was outside of what the district was providing."

Mr. Coleman has displayed courageous leadership in listening to the needs of students

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who have been marginalized in their STEM journey. An experience early in his career as a school administrator helped him recognize that a culturally responsive school leader must have the courage to be inclusive of student perspectives:

> I had a group of students who came and said, 'Hey, we feel underrepresented. We don't feel respected. . . .' And I had to take an honest look at this group of students and, you know, wonder why. And there was clear evidence that they definitely were not being heard at that time.

Ever since that experience, Mr. Coleman has encouraged students to stand up for themselves. He is proud that Roosevelt Prep students will "advocate for themselves and say, 'I didn't quite understand this. . . . I'd like to retake this test." It takes courage for a principal to insist that educators will be responsive to the viewpoints and lived experiences of their students.

Like Mr. Coleman, Elena López has also displayed courage in listening to students. Collegiate STEM is a charter school operated by a state university. Several university departments use the school to conduct research, often with an adverse effect on the learning environment. Mrs. López reports that many of the university's projects do not "allow for choice or voice from the kids." During one such research project, the students "rebelled at the end." Mrs. López has engaged in courageous leadership to push back against the number and length of such projects. While she acknowledges that Collegiate STEM must collaborate with university research, she insists that it not disrupt student learning.

**Fosters Positive Relationships with Students**

Developing positive relationships with students was a common theme in all four cases. Mr. Coleman says that "relationships are critical" at a diverse school such as Roosevelt Prep. Due to its rigorous STEM curriculum, he believes that students need to know they have caring adults who will support them in successfully navigating a challenging program. He spends a lot

of time walking the hallways and visiting classrooms, interacting with students and letting them know he is concerned about them. Ms. Johnson, who teaches at Roosevelt Prep, affirms that "if they [students] have that relationship, they know there's somebody out there that can support them." In addition to building a strong relationship with the students himself, Mr. Coleman expects each teacher to be someone "that students can identify with and really build strong relations with."

Mrs. Young also understands how important it is to build strong relationships with students. She says that her students "have the same needs as kids in the suburbs. They want to know that they matter." To build close relationships with her students, she says, "I treat every student, regardless of race, regardless of ethnicity, like they are mine." She also expects her teachers to cultivate strong relationships with students. Like Mr. Coleman, Mrs. Young believes that developing positive relationships with students is critically important for advancing STEM learning in a diverse school. She submits, "The relationships that they [adults in the school] have with them are most important in terms of creating an atmosphere where a student can deeply learn and access the curriculum."

To assist teachers with building strong relationships with their students, Mrs. Young begins each school year with a STEM boot camp. She remarks, "The first two weeks of school, we always had a STEM boot camp. And inside of that boot camp, we really got to know our kids. Our grade level teams did intensified work on building relationships." Close relationships between adults and students at Jefferson Polytechnic are further enhanced through advisory time, where small groups of students meet with a caring adult once or twice a week. Mrs. Young indicates that "advisory was our key time for our kids to have an identified adult who was tuned in uniquely to their needs in a smaller setting."

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To foster her connection with the student body at Franklin Middle School, Dr. Taylor regularly visits classrooms and talks to the students about their STEM projects. One of her teachers, Allyson Smith, comments that Dr. Taylor is "very involved and the students see that." Dr. Taylor also encourages project-based learning in her school because she believes it facilitates the building of positive relationships between teachers and students. She reports that "when the teachers started doing more projects, more hands-on, they got to talk to the children more, and then they started to build a relationship with the students." Dr. Taylor believes that building positive relationships with students is critical in a school with a high percentage of economically disadvantaged children. She observes, "One of the reasons why the gang problem is very bad anywhere is not only economics, but it's also a sense of belonging." In her experience, strong student-teacher relationships give students a sense of belonging, leading to greater levels of engagement and fewer behavioral disruptions in the classroom.

Mrs. López states that building relationships is one of her major strengths: "I think I'm just super friendly and talkative with all of our kids." She spends a lot of time in STEM classes, speaking with students about their projects and asking them questions to assist them in assessing their design plans. She also expects her staff to forge strong relationships with students, particularly those children who may be challenging to work with. Mrs. López remarks that she "always [tries] to tell the teachers to make connections with those . . . that you struggle with, because that will move mountains."

Like Dr. Taylor, Mrs. López maintains that building positive relationships with students fosters a strong sense of belonging. She perceives that the relationships that she and her staff have developed with students "helps all of our families and students feel like they belong." In turn, she feels that a strong sense of belonging leads to better academic outcomes for her

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students, particularly in STEM. Paula Trevino, a teacher at Collegiate STEM, agrees: "I think when you feel that warm acceptance . . ., I think that's just good practice for STEM."

**Provides Students with Voice**

The importance of providing students with an opportunity to have a voice in their schooling was stressed in all four cases in this study. Mr. Coleman believes that all STEM learners, particularly those from marginalized communities, must be given a voice in the learning process in order to succeed. At his school, he encourages students to take ownership of their education, "to learn to advocate for themselves and say, 'I didn't quite understand this. I'd like to remediate.'" He also believes that principals must get to know their students and give them an opportunity to be heard. For example, he recalls a time that he "had a group of students who came and said, 'Hey, we feel underrepresented. We don't feel respected. . . .' And there was clear evidence that they definitely were not being heard at that time."

Dr. Taylor expects her teachers to provide students with a voice in both the projects they work on and the ways they can demonstrate their learning. She reports that many of her teachers use choice boards to give students the ability to select the learning activities they are going to complete. She also indicates that when students "have presentations or projects, they [the teachers] know that the students should have a choice in how it's done." She also values the voice that students can give outside of the classroom. Several years ago, she created a student forum that meets monthly to discuss the things students would like to change around the school.

Mrs. López maintains that her "students know that they can definitely have choice and voice" in their learning. However, she expects her teachers to place parameters on student choice to ensure that the essential question(s) in each STEM project or unit are retained. Mrs. López maintains an open door policy to encourage students to voice their questions, opinions, and

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frustrations. Due to the freedom students feel in approaching their principal, they did not hesitate to come to her last year when they were upset about the length and lack of flexibility regarding a project the school's university sponsor was testing at the school.

Mrs. Young believes that minoritized students who have a voice in their learning are far more engaged in school. At the beginning of each academic year, she instructs teachers to get to know each of their students and "honor the fact that they are an individual who [is] free to express their opinion." When teachers assign STEM projects, Mrs. Young expects that students are provided "freedom of choice of how they will present their project at the end." She indicates that students take real ownership of their learning when they are given the "opportunity to express themselves differently." In addition to teachers, Mrs. Young believes that it is imperative for principals to get to know their students, too. She says, "They want to know that you're listening to them. They want to feel like they have some ownership in this space." Mrs. Young does not wait for students to come to her office door to hear their concerns. She believes that "you've got to get in there with them. You can't be a leader who is not willing to get . . . into the student organizations and find out exactly what's happening."

## Maintains High Expectations

In all four cases, the principals hold high expectations for all students. Three of the four principals promote high expectations by articulating a growth mindset. Mr. Coleman is convicted that "all students can do what we teach them and train them to do." He believes that "you just have to find what it is that they need to reach that level of success." As a mastery-based school, all students at Roosevelt Prep are expected to achieve a mastery level of 90% or above in order to pass each course. Mr. Coleman instills a growth mindset throughout the school to achieve the high expectations that he and his staff have set for students. He explains, "Having a growth

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mindset, knowing that we can influence and have a positive impact on every student on their path towards mastery, that's our ultimate goal." His school provides numerous supports, such as instructors offering regular office hours, afterschool tutoring, a special intersession term, and multiple opportunities to remediate to ensure that every student reaches mastery. Mr. Coleman boasts, "We have more power than I think we realize as educators. We just need to find a formula that works for every child."

To promote a growth mindset at Franklin Middle School, Dr. Taylor makes use of NWEA MAP data. She explains that in her school, "students know what their range is, so when we get their MAP score, they set a goal for their growth." Dr. Taylor expects her teachers to plan classroom celebrations when students reach their growth targets. She also expects academic growth to be a frequent topic of discussion in classrooms. During an interview for this study, one of her teachers confirmed that Dr. Taylor expects the faculty to speak regularly with students "about their growth and finding that intrinsic value of their growth." Dr. Taylor is convinced that giving students ownership of the data about their academic growth fuels both their motivation and engagement in STEM, leading to higher achievement. And while she values the feedback that MAP data can provide students, Dr. Taylor notes that her ultimate emphasis is not on letter grades, but about students growing in the core skills which drive STEM success such as curiosity, thinking outside-of-the-box, and collaborating with others to solve problems.

When characterizing the STEM program at Collegiate STEM, Mrs. López indicates, "We're very much a growth mindset school." She has found that fostering a growth mindset has helped her students achieve mastery of state learning standards. She explains:

> We're a standards-based or mastery-based school. So that [the growth mindset] really helps . . . because students know, even if they fail this time, as long as they can show us that they're working toward understanding and being able to fully show mastery of the

content, they can take the test again. I think that approach definitely helps us, especially when it comes to STEM and some of the more challenging areas like chemistry and physics.

Unlike Roosevelt Prep, where mastery is considered 90% or higher, the threshold for mastery at Collegiate STEM is 80% and above. Mrs. López reports that a growth mindset is especially helpful for female students, who otherwise might give up on STEM. She remarks, "As we see our girls especially move up into the older grades. . ., they know that they can take risks, and they . . . know that perfection isn't expected." She adds, "We always try to say to them that a healthy struggle is okay, it's normal." Mrs. López believes the growth mindset helps girls embrace the idea that struggling through tough courses is a natural part of the learning process, increasing the likelihood that they will persevere and be successful in their STEM trajectory.

Although Mrs. Young did not articulate a growth mindset when describing her work with teachers and students at Jefferson Poly, she has an unshakeable belief that all students can achieve at high levels. She attests:

Where we can't shortchange children—and this is any child, this could be a child that's really well fed and loved and all of those things, or a kid that's not so well fed or not so loved—we still have to have the same expectation for all of them.

Working in the inner city, Mrs. Young reports that she has a substantial number of students enter her school with preexisting achievement gaps. Nevertheless, she maintains that "if there are any gaps in mathematics capabilities . . . that kids come to us with, we still have the expectation that we're going to have rigor that's aligned to the grade level." For Mrs. Young, a key to realizing the high expectations she has for all students is engaging them in challenging experiences that demystify STEM:

In our school, they [the students] were actually doing it! They were actually having success doing . . . projects, being a part of scientific research, learning all of those aspects. We made the curriculum approachable for those kids, so it was no longer this

mystery like, 'Maybe I can't do chemistry,' or 'Physics is really, really hard.'

Mrs. Young insists that her teachers "challenge their [students'] belief system about what they're

capable of." She also expects that "every classroom is an equitable learning space that allows

every child to be exposed to and have an expectation around work that's grade level and

standards aligned." One of her staff members confirms that Mrs. Young "always felt that kids,

when challenged, would rise to the challenge."

**Secures a Culturally Responsive Curriculum**

Three of the cases indicated that the STEM curriculum must be culturally responsive,

especially for minoritized students. At Jefferson Polytechnic, Mrs. Young posits that STEM

education lends itself exceptionally well to culturally responsive topics and pedagogy. She

observes:

> We always focus on projects—project-based learning—as our key pedagogical structure, using a lot of inquiry based science. . . . So that allowed, I think, for a greater breadth of opportunity for linkages to culture. We did a whole [unit on] . . . Harlem Renaissance. And so there was the opportunity to bring in the historical narrative of what was going on, bring in the literature from that space . . ., talk about family connections, you know. Kids were given a space to talk about that in terms of historically how connected it was to their family and then go from there. We tried as much as possible to make it relevant to them. . . .

> We were very inclusive of the information that happened last summer with Mr. Floyd. We try as much as possible to keep the topics connected to the students' backgrounds and where they come from. . . . I will tell you, though, we always go for making sure that it's not a topic that we avoid. We're not walking around acting like . . . Mr. Floyd wasn't killed and there wasn't this whole bunch of social unrest. And so researching that work, you know, is key. Research is a key part of STEM that doesn't get elevated enough.

Mrs. Young has enlisted the support of UnboundEd to train teachers on how to make the

curriculum more culturally responsive. She reports that she was recently pleased to observe a

geometry class examine patterns in quilts as they discussed "the narratives of the slaves and how

they were told through quilts." It is her expectation that teachers will always be on the lookout

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for ways to tie the cultural background and/or life experiences of students to the school's STEM learning objectives.

To engage students at Roosevelt Prep, each year Mr. Coleman gives students a design challenge related to a problem in the local community. Past topics have included issues affecting people in the community such as the opioid challenge, food insecurity, and infant mortality. Mr. Coleman notes that the topic he selected for the design challenge this past year was easy to identify due to the police brutality that led to the death of George Floyd. One of his teachers confirms:

> We always try to incorporate some sort of STEM real world problem [into the design challenge], but then with the social justice challenges across the country this summer, [Mr. Coleman] decided to do a social justice focus. So we asked our kids to create a solution in some capacity, big or small, to address all those necessary components of social justice. . . . We just wanted to harness the kids' individual concerns. . . . We had students address female gender inequality in the medical fields. We had kids that looked at death penalty issues. They covered the gamut on the wide range of things that they could focus on with social justice.

Mr. Coleman says that he continually stresses the critical importance of providing a culturally responsive curriculum with his faculty. He remarks that "it's a stated expectation and something that we monitor and have conversations about, not every week, but certainly consistently." Regarding the STEM curriculum, Mr. Coleman says that he expects his teachers to be "intentional about making it relevant to the students' lives." He suggests that making cultural connections throughout the curriculum is not as difficult as some educators believe it is: "It's a lot easier than some may think to find those connections in all of the content areas that have some relation to our students' experiences."

Culturally responsive instructional practices are also important at Collegiate STEM. In a school with a significant Latino presence, Mrs. López strongly believes in the value of providing

a culturally responsive curriculum for students and ensuring that teachers utilize culturally responsive pedagogy. To achieve these objectives, she provides regular training on culturally responsive instruction to the faculty, and culturally relevant practices are frequent topics at faculty and PLC meetings. One of the teachers at Collegiate STEM believes the training Mrs. López has provided to the instructional staff ensures that "any child, whatever culture, whatever race, whatever challenges they have . . ., they are still part of that enrichment in STEM."

**Develops Strategic Partnerships with Businesses and Nonprofits**

All four cases are actively involved in developing strategic partnerships with nearby businesses and community nonprofit organizations. In addition, school-university partnerships are vital to each school in the study. Mr. Coleman and Mrs. López lead schools that are located on the campus of state universities, and Mrs. Young's school is across the street from a major university. These partnerships have provided the schools with much needed resources for effectively ministering to the needs of minoritized students in STEM, such as afterschool tutoring programs and serving as sources of role models and mentors who are female and/or people of color. Although Dr. Taylor's school is not located on or next to a university campus, she has also leveraged several universities in her area to provide STEM instructors, teacher training, and facilitate afterschool STEM clubs.

Two of the principals cautioned that leaders need to be selective when establishing strategic relationships with business and civic organizations. Dr. Taylor begins with the end in mind: "What are our objectives? What are our standards? What do we have in the community to use as a resource?" She thinks it is a mistake when principals partner with a business or nonprofit without a clear objective in mind. She insists, "When I reach out to the businesses, I'm looking for specific resources." Mrs. Young is also selective in who she engages in community

partnerships for STEM. As the gatekeeper, she "made sure that the connections that we were bringing into the school were . . . meaningful for the students, and that it led to something that could impact them."

**Enlists Role Models and Mentors**

The four principals who participated in this study actively identify opportunities for their students to interact with STEM role models and mentors. At Roosevelt Preparatory, students are placed in internships with STEM professionals in their field of interest, such as biomedical technologies, engineering design, or environmental science. Mr. Coleman believes that real world internship experiences are the best way to provide students with authentic role models and to help students form the mentoring relationships they need to be successful. Mrs. Young also makes use of internships and job shadowing experiences at Jefferson Polytechnic to provide STEM role models and mentors for students. She has partnered with businesses and other organizations in her community to provide internship and job shadowing experiences for students in STEM fields such as microbiology, genetics, and environmental science. Mrs. Young has also worked with a nearby university to host mentoring days at her school, where students interested in fields such as engineering and information technology are partnered with STEM professionals who are people of color.

At Franklin Middle School, Dr. Taylor established an intergenerational program to pair students with adult members of the local community. The adults and students meet monthly to explore topics of interest and complete STEM projects together. The intergenerational program has proven to be an invaluable source for establishing positive mentoring relationships between adults and children. To address the need for STEM role models for girls, Dr. Taylor arranged for a female physics professor from an area university to serve as a guest instructor in her school.

She states that the professor "started coming in and teaching lessons at our school to show the kids . . . that they could do it."

Mrs. López has also used role models to create a more inclusive STEM learning environment for female students in her school. To provide female role models for her students, Mrs. López partnered with Girls Who Code, which offers an afterschool coding class. She also capitalized on her school's presence on the campus of a state university to partner with Women in Science and Engineering (WISE). Through the partnership with WISE, women working on degrees in engineering and related STEM fields volunteer at Collegiate STEM to tutor students, serve as guest speakers, help teachers with STEM projects, and assist with afterschool special interest clubs.

**Fosters Meaningful Relationships with Parents and Community Members**

Three principals indicated that forming strong relationships with parents and the local community was vital to the success of their school. At Roosevelt Prep, Mr. Coleman connects with parents and the local community by hosting an annual cultural night at the school. One of his teachers describes this event as a place "where people are encouraged to represent their primary cultural backgrounds and bring in food and music." Mr. Coleman thinks that events such as the annual cultural night are especially important for creating a welcoming environment in a school "whose parents come from Asia, Africa, you know, from all over the place." According to Mr. Coleman, events like the annual cultural night provide him with a great opportunity to be "mindful of the culture and its practices" so that he can appreciate the community's values and forge a closer connection with parents and students. Another way he forges a strong bond with students and their families is by respecting the customs and values of the local Muslim community. Mr. Coleman encourages students to celebrate Eid al-Fitr and requests that his

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teachers "be mindful of the fact that [Eid] might impact some . . . students who may not be able to eat at certain times of day or may need to slip out for a couple minutes and do a quick prayer." Families are also encouraged to show off their Eid outfits at the annual cultural night.

Several years ago, Dr. Janice Taylor decided that she needed to find a way to foster a stronger bond between her school and the local community. She created a STEM advisory board made up of parents, community members, and area businesses. The advisory board helps set goals and secure resources to support student success. In addition, Dr. Taylor established an intergenerational program to connect students with the wisdom and customs of the local community. Intergenerational meetings take place once a month during the school day, and any community member who wants to participate is welcome to attend. Dr. Taylor describes the purpose of the program as follows:

> I have a program called intergenerational, and it's meant to bring the older and younger generations together. . . . I start my intergenerational program by first meeting with our students, our seventh and eighth graders, and we talk about what topics are relevant to them. . . . We take the topic that they want to talk about, we plan on activities, we bring in the community members, and we always do a STEM activity in our intergenerational meetings.

At the end of the school year, students and community members take a field trip to a local business associated with one of the adults who has participated in the intergenerational meetings. Dr. Taylor attests that the intergenerational program has strengthened the community's connection and investment in the school's STEM program.

At Jefferson Polytechnic, Mrs. Young has worked hard to create overlapping spaces for the school and community. She established a partnership with a local children's hospital to provide a health clinic in her school. However, the school health clinic is not restricted to Jefferson Poly students. Mrs. Young shares:

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There's a nurse practitioner at our school five days a week, and they set appointments, and you can go there instead of, you know, seeing your doctor at the [local hospital]. As a service to our community, we also allow community members who have children of the appropriate age to come into the school and go directly into the clinic to be seen by a nurse practitioner. So it services not only our kids, but also kids that are in the surrounding area.

Mrs. Young is also proud of the fact that Jefferson Poly operates a community resource center on its campus. In addition to the aforementioned health services that are shared with the local community, the school's community resource center provides parent engagement programs, career services, youth development activities, counseling, nutrition classes, and after-school programs for the community. The center also connects families with nonprofit organizations that provide help with food, utility bills, transportation, and rental assistance. Mrs. Young reports that Jefferson Poly's community resource center provides reciprocal benefits for the school. Besides helping the community, it has enabled the school to find people willing to interact with students as chaperones, mentors, and tutors.

**Hires for Mission**

All four cases in this study place an emphasis on recruiting a diverse and culturally responsive faculty. Mr. Coleman reports that he is "very intentional about seeking out individuals who share the belief that given enough time, and enough support and resources, all students can be academically successful." He also recognizes the importance of building a STEM teaching staff that reflects the diversity of the student population:

There is a proportion of students who, just by the nature of their environments, connect better and more quickly with those staff members who look like them. And I think we would do a disservice to our organization if we didn't seek out more staff who can fit that bill. So when students are seeing themselves as diverse and being exposed to staff who are equally diverse, I think it certainly does provide them with more confidence in becoming professionals.

Mr. Coleman says that it has often been difficult to hire people of color for STEM positions at

Roosevelt Prep because few apply. To remedy this situation, he has started reaching out to HBCUs and other institutions that cater to people of color to expand the applicant pool.

Mrs. López has also had difficulty in finding people of color for her openings at Collegiate STEM. She wants to increase the number of Hispanics on staff, but she indicates that when teaching candidates who share her ethnic and cultural heritage do apply, they tend to accept job offers elsewhere. Nevertheless, she is determined to keep trying to diversify the staff. One area where she has had great success is hiring females to teach STEM courses. At the present time, all the math and science teachers in the middle school and high school at Collegiate STEM are female, largely due to the high priority Mrs. López has placed on helping young women develop competence and confidence in their STEM abilities.

At Franklin Middle School, Dr. Taylor looks for educators who will "treat everyone with dignity and respect." Since it is her African American male population that struggles the most in STEM, she tries to hire "teachers that are going to understand that, number one, my male population is going to be the hardest to motivate and to engage." During the interview process, Dr. Taylor uses a lot of scenario-based questions to discover how a candidate might approach the challenges of working in a high poverty school.

At Jefferson Poly, Mrs. Young uses the interview process to identify people who share her inclusionary vision and core beliefs:

> All students can learn, being a teacher-led school, empowering all learners, regardless of their unique learning styles, to be successful in STEM—we incorporated that into the questions that we asked our candidates. And quite frankly, we turned down people who did not show an appreciation for those particular values.

Mrs. Young also places a priority in hiring teachers who can form positive relationships with students and work collaboratively with their peers to foster an inclusive school environment. She

considers the ability of a teaching candidate to participate in a collaborative school culture to be "a North Star in terms of how we develop our work and how we onboard, how we select people to join the community."

**Leverages Professional Development**

Each principal in this study indicated that teacher training is critically important for creating an inclusive school environment. At Roosevelt Prep, Mr. Coleman has used professional development to help his teachers and staff confront the biased perceptions they harbor towards students and staff. He recognizes that perceptions affect reality, and he does not want deficit thinking to become a hindrance to student success. He submits, "You can't support students . . ., knowing that we will provide them with the resources and the support that they need to be successful, and then not do the same for teachers, because that's where the message comes from." Mr. Coleman has also provided his instructional staff with ongoing training in mastery learning and differentiated instruction, remarking that "all students learn at different rates in different ways."

Dr. Taylor emphasizes the importance of taking a team approach to professional development. She recalls that she "had to promise my teachers when we started this STEM journey that we would work together." She adds that "you have to listen to your teachers." As Dr. Taylor led Franklin Middle School's transition from an IB school to STEM, she provided opportunities for her faculty to observe STEM education in practice to dispel any notions that it would not work in a high poverty school:

> I started taking the staff to visit different schools that were identified as STEM, because one of the first things that teachers had to do is they had to see it, to understand it, in order for them to believe that it could be done. . . . I took my teachers to actually see it. You have to take teachers to the best places where STEM is working, and it has to match your population so teachers can't say, 'Oh, our kids can't do this.'

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Dr. Taylor's ultimate goal through professional development has been empowering faculty members to deliver high quality instruction for all students. One of her teachers acknowledged that Dr. Taylor made sure "that everybody understood what STEM is and how to make it work." Another faculty member at Franklin indicated that Dr. Taylor "pushed us to go beyond the limit. She incorporated every opportunity there is for professional development."

Like Dr. Taylor, Mrs. Young recognizes that professional development must be a collaborative effort between school leaders and faculty members to be successful. She recounts how she went about building an equitable learning environment in her school:

> I was able to navigate it best by focusing on culture and empowering teachers to lead in their spaces by setting up professional development. I spent a lot of time on professional development, making sure that I was present, codesigning it with the teachers on the teams and in the departments, so that we would have this [shared] language that we could always speak about the work.

To realize her vision of an inclusive STEM culture at Jefferson Poly, Mrs. Young enlisted the services of UnboundEd, an organization that assists schools in identifying the ways that racism and bias impede students of color from having access to rigorous, grade-level instruction. In addition to the training that UnboundEd has been providing the faculty on equity-focused instructional practices, Mrs. Young has targeted professional development efforts on assisting her staff with recognizing and supporting students with adverse childhood experiences (ACEs). Mrs. Young indicates that many of her students have experienced childhood trauma, which she posits is a major barrier for inner city students as they traverse the STEM pipeline.

At Collegiate STEM, Mrs. López is concerned about teachers ignoring the unique needs of students of color. When students struggle academically, her goal is to ensure that all teachers have "strategies that are going to help them when they feel like, 'Oh, I don't know what else to

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do.'" Therefore, she has provided regular training on Response to Intervention (RtI) and differentiated instruction. To foster an equitable learning environment across classrooms and grade levels, she also provides training on incorporating STEM learning into all the academic subject areas. Mrs. López is also a strong believer in culturally responsive instruction. She has provided training on culturally relevant pedagogy for her faculty, and culturally responsive practices are frequent topics at faculty and PLC meetings. And like Mr. Coleman, she has provided professional development to help her staff address their hidden biases and deficit thinking. One of her faculty members confirms that "we have diversity training . . ., making sure that we are aware of any biases that we hold on to as teachers."

**Encourages Teachers to Reflect on Attitudes and Practices**

Two of the cases shared the importance of fostering a school climate where everyone engages in critical reflection. Dr. Taylor says that when she interacts with faculty members, "I want to see what their reflection process is." When an equity audit revealed that African American males in her school were insufficiently engaged in mathematics and science, she helped the faculty reflect on the problem. She recalls, "I had several meetings looking at what we could do. 'What kind of behaviors are you seeing with the males? Why are they being disengaged?' And how could we counter that?"

Mrs. López expects the entire school community to engage in regular self-reflection. She notes that her school has "a little motto or tagline—we want reflection, not perfection." Like Dr. Taylor, Mrs. López regularly guides her teachers through the reflection process. She observes, "With teachers, I definitely push [reflection]. . . . 'What do you need to change? How are you going to reflect and change . . . so that you make sure that you are able to teach everything that you need to teach." Mrs. López says that calling others to engage in critical reflection is "really a

big part of the way that I lead."

**Promotes an Equitable and Inclusive School Environment**

A leadership emphasis on equity and inclusion emerged in all four cases in this study. Ed Coleman is passionate about fostering an equitable learning environment at Roosevelt Preparatory. He believes that one of his most important tasks as principal is "to make sure that the expectations that we put in place will be inclusive of all students." To realize his vision, he makes frequent use of equity audits. He explains that equity audits enable the administration and instructional staff to determine if the "expectation for mastery in the classroom [is] a fair process to the point where it's not hindering an unequal amount of minorities from achieving the same goals or opportunities that everyone else is receiving." Dr. Taylor uses a similar strategy at Franklin Middle School. When a recent equity audit revealed that African American males were struggling in their STEM and reading courses, Dr. Taylor used the data as a springboard to foster rich conversations with her faculty about how to make Franklin Middle School more inclusive. The impact of such conversations is not lost on the faculty. As one of her teachers observed, "One of the biggest things is that she [Dr. Taylor] made sure that every single child on campus had access to the STEM programs that we're offering."

At the high school level, Brianna Young is passionate about providing an equitable and inclusive learning environment for all students at Jefferson Polytechnic. She believes that one of her central roles as principal is "making sure that all kids have equitable learning spaces. It just has to be. I don't care—white, black, Hispanic—I don't care, all kids deserve the absolute best period." Like Dr. Taylor and Mr. Coleman, she also makes regular use of equity audits to achieve her vision. Among other things, she looks for discrepancies in access and/or achievement among various subgroups including "African American, poverty, students with

disabilities, gifted, and students that speak a different language." She is especially proud of the fact that although her school has three specialized classrooms for students with profound behavioral and/or mental health needs, she has been able to "make sure that they have full access to the opportunities we offer inside of STEM."

While Collegiate STEM does not use equity audits on a regular basis, Mrs. López is deeply concerned "about the access portion" of learning. She admits that she used to fall into the trap of colorblind ideology, treating all students as equally as possible at the expense of racial and cultural diversity. Today, she intentionally considers the race, ethnicity, gender, and cultural background of children, recognizing that different children have different needs. She attests, "I'm not going to worry about making myself provide the exact same thing for every student, because that isn't what's fair or equal or equity." A particular focus of her vision for enhancing equity and inclusion at Collegiate STEM is actively recruiting Latino STEM instructors who understand and value the cultural heritage of the school's rapidly growing Latino population. She has also been willing to expand access to STEM learning in ways that were not initially anticipated. For example, to help female students develop more confidence in their STEM abilities, she partnered with Girls Who Code and Women in Science and Engineering to provide several afterschool opportunities for girls. She recalls that "the first year we had Girls Who Code, a young man came to me and said, 'Well, I'm just so upset. Why can't I be part of that? It's only for girls.'" Not one to exclude anyone from robust STEM learning experiences, Mrs. López decided to open up access to the program regardless of one's gender. She now has several boys participating in Girls Who Code on a regular basis.

In summary, a cross-case analysis indicated that culturally responsive leadership behaviors are regularly used by the principals in this study to provide a STEM program that is

responsive to the needs of underrepresented students. Principals form a critical consciousness by engaging in self-reflection about their leadership practices and displaying courageous leadership when confronted by attitudes, behaviors, and mandates that compromise the ability of their schools to provide high quality instruction for all students. Principals engage students who have been historically underrepresented in STEM by fostering positive relationships with students, providing students with voice, maintaining high expectations for all students, and securing a culturally responsive curriculum. Principals empower community involvement by developing strategic partnerships with businesses and nonprofits, enlisting role models and mentors for minoritized students, and fostering meaningful relationships with parents and community members. Finally, the principals in this study develop a culturally responsive teaching staff by hiring for mission, leveraging professional development, encouraging teachers to reflect on their attitudes and practices, and promoting a school environment that is equitable and inclusive. These culturally responsive leadership behaviors and practices are summarized in Table 5.

**Table 5**

*Culturally Responsive Leadership Behaviors and Practices*

| Theme |
| --- |
| The Principal Forms a Critical Consciousness<br>1. Engages in Self-Reflection<br>2. Displays Courageous Leadership<br><br>The Principal Engages Underrepresented Students<br>1. Fosters Positive Relationships with Students<br>2. Provides Students with Voice<br>3. Maintains High Expectations<br>4. Secures a Culturally Responsive Curriculum<br><br>The Principal Empowers Community Involvement<br>1. Develops Strategic Partnerships with Businesses and Nonprofits<br>2. Enlists Role Models and Mentors<br>3. Fosters Meaningful Relationships with Parents and Community Members |

**Table 5 continued**

The Principal Develops a Culturally Responsive Teaching Staff
1.  Hires for Mission
2.  Leverages Professional Development
3.  Encourages Teachers to Reflect on Attitudes and Practices
4.  Promotes an Equitable and Inclusive School Environment

## Strategies for Increasing Underrepresented Student Interest and Persistence in STEM

### Providing In-Depth STEM Experiences

Three of the cases reported that a key to increasing the interest and persistence of underrepresented students in STEM is providing opportunities for in-depth, real world STEM experiences. Mr. Coleman has found that internships often help students persist in their pursuit of a STEM career. He believes it is a no-brainer that "in any school, you want students to have an opportunity to rehearse or to try out a career they're thinking about." Regarding STEM internships, he reports, "What we find is that those students become, if nothing else, even more focused on that career." He adds, "I've seen it strengthen the students' desires to be in the careers that they've chosen and not wane a bit."

At Franklin Middle School, Dr. Taylor feels that exposing students to a variety of careers at an early age stimulates their interest in STEM, particularly for students historically underrepresented in STEM who often do not have direct exposure to STEM careers in their families or neighborhoods. She hosts Job Shadow Day at her school every February, where students are sent off campus to shadow STEM professionals in a variety of fields, depending on their area of interest. Other activities she organizes at her school have included career days and structured STEM field experiences for students. Because she believes this work is vitally important, she hired a career specialist for her school to help plan and coordinate real world

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STEM experiences for the students.

Mrs. Young says that the biggest game changer at Jefferson Polytechnic for fueling interest and persistence in STEM has been intersession. Twice a year, Mrs. Young's students enjoy a special week during which they work one-on-one with community partners on real-world STEM problems. For example, past intersessions have provided students with opportunities to work on global water challenges, program industrial robotic applications, and assess the impact of pollution on the local environment. Mrs. Young posits that principals need to do more to disrupt traditional modes of instruction:

> The educational rationale for the intersession is that we believe that in order to adequately prepare students for the 21st century, we have to expand our thinking about what the classroom truly is. So that means that we have to give kids experiences that are not only inside the traditional four walls of a classroom, but outdoors and in partner organizations working with professionals in the field.

Mrs. Young says that intersession has enabled her school to provide students with "really rich, in-depth STEM experiences where they get to experience different cultures and different activities," providing motivation to further their studies in STEM fields.

**Making STEM Fun**

Three of the principals in this study stated that the interest and persistence of underrepresented students in STEM is enhanced when the school places an emphasis on making STEM fun. Each January, Mr. Coleman offers a two-week intersession at Roosevelt Prep. During this time, Mr. Coleman says that students are "allowed to select a new kind of fun class." Students take engaging intersession electives such as digital painting, robotics, and other exploratory classes taught by STEM professionals. Mr. Coleman indicates, "We've got things like glassblowing and/or ACT prep . . ., different things that they [students] can choose that might be fun or informative." Regarding fun STEM experiences, Mr. Coleman posits that the

degree to which students "love it, now you're focused early on and completely engaged in something you want to do."

Dr. Taylor also believes that the best way to get underrepresented students interested in STEM and willing to persist through the STEM pipeline is to make STEM engaging and fun. She notes:

> We try to keep up with things that are exciting to kids. I had a teacher here who did drones—it was a hobby for him. So we added drones, we added the aerospace engineering program at the Career Center. We try to include things that students really like such as robotics.

To motivate students to persist in their coursework, Dr. Taylor opened up a game room. Students are rewarded for their academic work with time in the game room. This has especially helped her middle school boys, who are often reluctant to complete their homework. She also schedules periodic STEM nights at the school, where parents and students can participate in hands-on experiments presented by STEM professionals. She says that such experiences "show the kids that [STEM] was fun." Dr. Taylor believes that "when the students can tell you . . . 'I love coming to school on Wednesday for coding,' or 'Oh, I love my medical detective class—it makes school exciting for me,'" she can be confident that she is fostering a climate where minoritized students can persist in STEM.

At Collegiate STEM, Mrs. López has discovered that project-based learning is an effective way to make STEM fun and engaging for all students, especially those who have been minoritized in STEM. She reports that she has been "working with all of our teachers to make sure that they're incorporating . . . STEM projects within their day-to-day" instruction. She is a firm believer that project-based learning is highly motivational. She observes:

> We're introducing them [students] to project-based learning and to STEM education and what it actually looks like, what it actually feels like for students. And then once . . . the

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kids actually get to experience it, then I think they're hooked, because then they're asking, 'Well, when's our project time?'

She posits that project-based learning animates challenging subjects such as physics and chemistry, generating the interest and excitement minoritized students need to persist in STEM.

**Team Building Activities**

All four cases in this study described the impact that collaborative, team building activities have on increasing the interest and persistence of underrepresented students in STEM. At Roosevelt Prep, Mr. Coleman indicates that the robotics team has been a compelling motivator for female students. An activity that is traditionally dominated by high school boys, Mr. Coleman is proud that his robotics team is led by girls. He recounts:

> We have a nationally renowned robotics team. . . . And this might be a little bit of a sidebar, but I want to tell about them, because they are led by a team of females. The leader of the team is a young woman. And I think the top three on the team are girls. . . . That team is comprised of, at least half of the team of about 50 kids, are girls. That team works with FIRST robotics, and those are girls are extremely excited!

Mrs. López has had a similar experience at Collegiate STEM. She is particularly focused on sustaining the interest and persistence of females in STEM, remarking, "We have to really start getting girls super excited about the STEM field." Like Mr. Coleman, Mrs. López has discovered that robotics teams can be a great motivator for female students. She reports:

> Robotics isn't specifically for girls, but a large portion of our robotics team in high school is made up of girls, and it has all walks, not just white, but we have Hispanics, we have African American members, boys and girls. But we do have girls who have definitely stepped up and are confident.

Another strategy that has helped Mrs. López facilitate team building and camaraderie among the females in her school is partnering with Girls Who Code and Women in Science and Engineering (WISE) to provide a variety of afterschool clubs and activities that are particularly aimed at girls. Mrs. López believes that activities that are specifically geared toward girls

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provide her female students with a greater sense that they belong in STEM. She also contends

that girl-centric STEM activities provide her female students with a safe space to ask questions

and take risks, which enables them to persist in the STEM pipeline.

At Franklin Middle School, Dr. Taylor is especially proud of the Black Greek Letter

Academic Society that her school developed. African American males at her school frequently

struggle academically. The fraternity responds to their unique needs by creating a space where

students can experience a sense of belonging and bring out the best in each other. Fraternity

members follow a code of conduct and they must meet specific grade point and behavioral

criteria to retain membership. Dr. Taylor feels that the strong interpersonal relationships and

positive peer pressure afforded to fraternity members helps the students persevere in STEM.

Mrs. Young believes that project-based learning activities are critically important for

engaging students in the inner city. She asserts, "Because we are mostly African American, and

because we're mostly poverty, we know that project-based learning is the best strategy because it

gets kids more engaged." She submits that she is "very worried about engagement and

motivation, so we know that project-based learning is going to be the best way to handle that."

Mrs. Young believes that the teamwork and collaboration inherent in project-based learning

activities help minoritized students press on in their STEM journey. Consequently, she has made

project-based learning "the linchpin of our design structure in terms of instruction" at Jefferson

Polytechnic. Mrs. Young also suggests that project-based learning activities provide "for a

greater breadth of opportunity for linkages to culture," providing another pathway for her school

to engage the interest of minoritized populations in STEM.

In summary, a cross-case analysis identified three important ways that the principals in

this study increase the interest and persistence of underrepresented students in STEM. Three

principals described how they bolster the interest and persistence of minoritized STEM learners by providing in-depth STEM encounters such as job shadowing, internships, and intersession experiences. Three principals stated that minoritized students are more engaged in STEM when administrators work with teachers to make STEM learning fun through activities such as providing special intersession electives, hosting STEM nights, offering rewards, using engaging technology such as drones and robotics, and providing hands-on STEM projects for students. Finally, all four cases affirmed that programming which builds teamwork, collaboration, and camaraderie among minoritized students, such as girl-centric clubs and activities, are a powerful way to enhance their interest and persistence in STEM learning. These themes are summarized below in Table 6.

**Table 6**

*Strategies for Increasing Underrepresented Student Interest and Persistence*

| Theme |
| --- |
| 1. Providing In-Depth STEM Experiences |
| 2. Making STEM Fun |
| 3. Team Building Activities |

## Summary

This chapter presented a cross-case analysis of the four cases included in this study. The cross-case analysis began by examining the barriers that principals encounter when attempting to make meaningful change in their schools. Next, the analysis focused on the culturally responsive leadership behaviors and practices that the principals in this study utilized to provide a STEM program that addresses the needs of underrepresented students. The cross-case analysis concluded by exploring the ways that principals increase the interest and persistence of

underrepresented students in STEM.

The cross-case analysis revealed a variety of barriers that principals encounter when attempting to lead meaningful change for students who have been historically underrepresented in STEM. Some of the barriers involve deep-seated attitudes and inequities, such as educator bias, a lack of unity around the school's mission and core values, disruptive mandates and expectations from governmental institutions, and the African American male educational attainment gap. Other barriers comprise resource challenges such as budget constraints, finding and training highly qualified STEM teachers, low parental involvement, and leadership time constraints.

The cross-case analysis suggested four primary ways that the principals in this study engaged in culturally responsive leadership behaviors and practices in attending to the needs of students who have been minoritized in STEM. They form a critical consciousness by engaging in self-reflection about their leadership practices and displaying courageous leadership when confronted by attitudes, behaviors, and mandates that compromise the ability of their schools to provide high quality instruction for all students. Principals engage students who have been historically underrepresented in STEM by fostering positive student relationships, providing students with voice, maintaining high expectations for all students, and securing a culturally responsive curriculum. They empower community involvement in their schools by developing strategic partnerships with businesses and nonprofits, enlisting role models and mentors for minoritized students, and fostering meaningful relationships with parents and community members. Finally, the principals in this study develop a culturally responsive teaching staff in their schools by hiring for mission, leveraging professional development, encouraging teachers to reflect on their attitudes and practices, and promoting an environment in their schools that is

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equitable and inclusive.

The cross-case analysis identified three important ways that the principals in this study increase the interest and persistence of underrepresented students. The principals shared how they bolster the interest of minoritized STEM learners by providing in-depth STEM encounters such as job shadowing and internships. The principals submitted that minoritized students are more engaged in STEM when school leaders work with teachers to make STEM learning fun through activities such as special intersession electives and providing hands-on STEM projects for students. All four cases affirmed that programming which builds teamwork, collaboration, and camaraderie among minoritized students, such as girl-centric activities, are a powerful way to enhance their interest and persistence in STEM learning. The next chapter discusses implications for practice and recommendations for further research.

CHAPTER VI: DISCUSSION AND CONCLUSIONS

The purpose of this study was to investigate the leadership of principals who have experienced success in working with underrepresented students in STEM to learn how they eliminate inequitable practices and transform their schools so that all students can thrive. In addition, the study sought to identify the problems and challenges such principals face in addressing the needs of underrepresented students. An extensive literature review revealed that while equitable STEM education is critically important for technological progress and human flourishing (e.g., Egan, 2011; Erduran, 2020; Kilmartin & Pimentel, 2014; NSB, 2016; Xie & Killewald, 2012), females and URMs have been minoritized in the STEM fields (e.g., Fouad & Santana, 2017; NSB, 2018; Ong et al., 2018; Stearns et al., 2016; Xie et al., 2015). The literature review also indicated that little is known about how principals provide effective leadership for students historically underrepresented in STEM (e.g., Kilmartin & Pimentel, 2014; Sampson, 2018).

The research questions that guided the study were:

1. What problems or challenges do principals encounter in addressing the needs of underrepresented students in STEM?

2. What are the culturally responsive leadership behaviors and practices principals employ when implementing a STEM program that is responsive to the needs of underrepresented students?

3. What strategies are used by principals to increase the interest and persistence of underrepresented students in STEM?

To answer these research questions, I used a qualitative comparative case study design. A purposeful sampling strategy was employed to identify four principals who served as the cases

for this study. I collected and analyzed data from semi-structured interviews with the principals. To validate the principal interviews, some of the teachers, staff, and parents associated with the cases were also interviewed to get more information regarding the principals' work. To further validate the data, artifacts and documents relevant to each case were collected. The artifacts and documents provided additional details about each principal's background and leadership context, as well as the principal's work serving underrepresented students in STEM education. As each case was coded, broad topics were identified. These findings were reported in Chapter IV. A subsequent cross-case analysis provided the overall themes that emerged from the four cases, which were reported in Chapter V. I discuss these themes in the following section, including excerpts from the findings to illustrate each theme.

## Discussion

### Research Question 1

The first research question asked, "What problems or challenges do principals encounter in addressing the needs of underrepresented students in STEM?" The data suggests that principals must navigate a host of problems and challenges when addressing the needs of students who are underrepresented in STEM. Some of the obstacles the principals in this study encountered involve what I categorize as deep-seated attitudes and inequities, such as educator bias, disruptive expectations and mandates, a lack of unity around the school's mission and core values, and the African American male educational attainment gap. Other impediments involve resource challenges that hinder the transformation of STEM education, such as budget and time constraints, low parental involvement, and identifying and training highly qualified STEM teachers. These problems and challenges ultimately create barriers to meaningful change for females and URMs who have been minoritized in STEM.

*Deep-Seated Attitudes and Inequities*

**1. Educator Bias**. Educator bias contributes to low expectations for students who have been minoritized in STEM. This problem is illustrated by Brianna Young, principal of Jefferson Polytechnic High School, who observes that many of her teachers "automatically go to a deficit way of thinking," making stereotypical assumptions about black students growing up in the inner city. She shares that many of her teachers have "grown up in a system that is surrounded by bias, low expectations for kids in the city." Mrs. Young stresses that it is "a civil rights issue when teachers decide to not teach the core curriculum at the grade level that's expected."

**2. Disruptive Expectations & Mandates**. Despite inclusive rhetoric, federal and state institutions have a troubling tendency to advance testing mandates, curricular directives, and research expectations that are not in the best interests of minoritized students (e.g., Berliner, 2011; Farvis & Hay, 2020; Menken, 2006). Mrs. Young attests to this leadership challenge as she copes with state testing mandates and the restrictive curricular expectations of her school district that result from state testing. Mrs. Young firmly believes that project-based learning is the best way to provide STEM education for her minoritized students, but she submits that "when you have a district that's saying you've got to be on Chapter 23 by April so that you can take the state test, it becomes a challenge."

**3. Lack of Unity Around School's Mission & Core Values**. A lack of unity around the school's mission and core values means that principals must continually cope with stakeholders who are working at cross-purposes to the foundational principles and ideals that contribute to the success of all students. Khalifa (2018) acknowledges that in implementing a culturally responsive school environment, administrators often face pushback from teachers, staff, and members of the community. This barrier to responsive leadership is illustrated by the experiences

of Elena López, principal of Collegiate STEM. She notes that her institution is a growth mindset school that has moved away from tracking and ability grouping. However, she reports that she "definitely did struggle with the whole tracking [concept], because I think it got to the point where parents were expecting it. You know, 'My student is a lot smarter.'"

**4. African American Male Educational Attainment Gap**. The African American male educational attainment gap reflects the reality that oppressive socioeconomic conditions are particularly detrimental for students of color who are boys. Khalifa et al. (2016) observe that "closing the racialized achievement (opportunity) gap has been one of the central issues in education" (p. 1279) for decades. This persisting inequity is exemplified in a statement by Dr. Janice Taylor, principal of Franklin Middle School. She attests that African American males at her school are "not taking those upper level [STEM] courses when they go to the high school," perpetuating the achievement gap with their white peers.

*Resource Challenges*

Khalifa et al. (2016) posit that culturally responsive school leaders must be able "to leverage resources to . . . foster a culturally affirming school environment" (p. 1282). However, the principals in this study face a number of resource challenges as they work to create meaningful change for females and URMs who have been minoritized in STEM, such as budget and time constraints, low parental involvement, and difficulty in finding and training highly qualified STEM instructors.

**1. Budget Constraints**. The educational needs of minoritized students are often sacrificed to the insatiable demands of citizens and corporations to reduce their tax liability. As state and local governing bodies cut taxes, subsequent budget constraints compromise the ability of school leaders to provide students with appropriate instructional supports and resources. Jha

(2020) validates that "the equity of student outcomes is eroded by reducing equity of real resources across children of varied economic backgrounds" (p. 24). We can see the challenge imposed by budget constraints reflected in the situation faced by Dr. Janice Taylor. She has struggled with inadequate funding from her district ever since a state law was enacted exempting owner-occupied residential property from taxes for school operations. She reports that "there was no backup plan, so now we are always destitute." She adds that the loss of revenue makes it especially difficult to be responsive to the needs of minoritized students: "It's not because you don't think those students can learn. It is just you don't feel like you have the resources and the support" to provide for their needs.

2. **Low Parental Involvement**. Parental involvement in school plays a key role in the success of minoritized students in STEM (e.g., Atwater & Brown, 1999; Talley & Martinez Ortiz, 2017), but the data from this study suggests that school leaders often find it difficult to engage parents in their child's STEM learning. For example, at Franklin Middle School, Dr. Taylor reports that "parents, for whatever reason . . ., they kind of feel like the kids don't need them anymore. So that is real difficult for us." She attributes the lack of parental involvement to factors such as parental burnout and having younger children at home that require their attention.

Many school leaders attribute low parental involvement to apathy about their children. Khalifa (2018) describes how he initially bought into this way of thinking when he began his career as an educator:

> When they said to me, for example, that parents 'don't show up to school because they don't care about their kids' education,' I entertained the unfair 'deficit' depiction of the families because only a few showed up for parent-teacher conferences. (p. 2)

The data from the present study indicates that culturally responsive school leaders reject such deficit thinking. Brianna Young's response to low parental involvement typifies the positive

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perspective that all principals should hold: "I know one thing about our parents is that they love their kids."

**3. Identifying & Training Highly Qualified STEM Teachers**. To provide quality STEM education for all students, schools need a highly qualified cadre of STEM educators, particularly when working with diverse student populations (Nguyen & Redding, 2018). Unfortunately, it is often difficult for principals to hire and train highly qualified STEM teachers. For example, Mrs. López has attempted to attract more bilingual teachers at Collegiate STEM to meet the needs of a growing Latino population. However, she reports that whenever she has interviewed candidates with bilingual abilities, "for whatever reason, they end up not joining us." She has also found that many of her new instructors struggle with the implementation of a project-based learning design. Especially at the high school level, her teachers tend to gravitate toward lecturing rather than engaging students in small group activities centered on student-led exploration and teamwork.

**4. Time Constraints**. Effective principals focus their time on teaching and learning (e.g., Robinson et al., 2008; Shaked, 2018). Unfortunately, principals are often constrained from devoting the amount of time they desire to attend to instruction (Shaked, 2018). At Jefferson Poly, Mrs. Young validates that the many hats worn by a principal often pull her away from visiting classrooms and interacting with students. She aptly describes that as a principal, "you're the mayor, you're the city manager, you're the HR, you're all of it." Many of these responsibilities constrain the time she has available to ensure that underrepresented students receive equitable access to high quality STEM instruction.

**Research Question 2**

The second research question asked, "What are the culturally responsive leadership behaviors and practices principals employ when implementing a STEM program that is responsive to the needs of underrepresented students?" The data from this study suggest that culturally responsive principals employ four key leadership behaviors when meeting the needs of students who have been minoritized in STEM. They form a critical consciousness by engaging in self-reflection and displaying courageous leadership. They actively engage underrepresented students by securing a culturally responsive curriculum, providing students with voice, maintaining high expectations, and fostering positive relationships with students. They empower community involvement by developing strategic partnerships with businesses and local nonprofits, enlisting role models and mentors, and fostering meaningful relationships with parents and community members. Finally, they develop a culturally responsive teaching staff by hiring for mission, leveraging professional development, encouraging teachers to reflect on their attitudes and practices, and promoting an equitable and inclusive school environment.

*The Principal Forms a Critical Consciousness*

**1. The Principal Engages in Self-Reflection**. Khalifa (2018) asserts that "a first and continuing act of culturally responsive school leadership is critical self-reflection" (p. 74). The present study suggests that self-reflection is a critical aspect of leadership in a STEM-focused school. Ed Coleman fittingly captures the crucial value of self-reflection in the life of a culturally responsive school leader:

> One of the things that I really had to grapple with as a black man myself is that I . . . had a bias towards some of our underperforming African American students. And I had to reflect on how I was planning and how I was responding, even to discipline . . . how I was communicating to staff about students who were underperforming. So I think biases

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exist. Everyone has them. And to not reflect or to seek out what your biases are, so you can begin to address them, it's kind of malpractice.

Culturally responsive school leaders recognize that self-reflection is an essential step for developing the critical consciousness that is necessary to provide minoritized students with equitable access to STEM learning.

**2. The Principal Displays Courageous Leadership**. Khalifa (2011) observes that "courage is necessary for any social justice school leader, particularly one in a context serving underrepresented students" (p. 723). Such courage is epitomized in the leadership of Dr. Janice Taylor as she challenges the deficit thinking of others. She has battled teachers who 'dumb down' academic rigor for students with behavioral issues and/or those who lower their expectations for children who are not honors students. Dr. Taylor has also confronted teachers who think their rural school cannot provide the quality of programming available to children who attend wealthy suburban schools. As she reports, "The first thing that teachers always say, if I take my population to a very rich school, they're gonna say, 'Well, we can't do that.'" Dr. Taylor has also been willing to wrangle with her district to secure the funding children deserve. As one of her teachers validates:

> We have a rival school that has students that attend there from more influential families. And so historically, most of the money would go to that school. So [Dr. Taylor] had to fight for us to receive funding from the district and support, just so we could even get started with our STEM program.

Dr. Taylor's leadership demonstrates that critical consciousness is more than just developing an awareness of the bias and inequities embedded in one's own assumptions and the context in which they lead; critical consciousness "means they work in the process of pointing out inequities and taking actions that critically examine and change inequities" (Khalifa et al., 2016, p. 1290).

*The Principal Engages Underrepresented Students*

**1. The Principal Fosters Positive Relationships with Students**. Developing positive relationships with students is essential for advancing STEM learning in a diverse school. Khalifa et al. (2016) validate that "principals can influence student success by having strong relationships with students" (p. 1279). The value of forging such relationships is admirably captured in a statement by Brianna Young, principal of Jefferson Polytechnic. She says that her students "have the same needs as kids in the suburbs. They want to know that they matter." To build close relationships with her students, she adds, "I treat every student, regardless of race, regardless of ethnicity, like they are mine." Mrs. Young also expects her teachers to cultivate strong relationships with students. She submits, "The relationships that they [adults in the school] have with them are most important in terms of creating an atmosphere where a student can deeply learn and access the curriculum."

**2. The Principal Provides Students with Voice**. Providing students with voice empowers them to make meaningful decisions about their learning and become true partners in their education. Khalifa (2018) confirms that culturally responsive school leaders must "help students … position their presence, voice, and interests in all aspects of schooling and learning" (p. 100). This culturally responsive approach is exemplified in the leadership of Mrs. Young. At the beginning of each academic year, she instructs her teachers to get to know each of their students and "honor the fact that they are an individual who [is] free to express their opinion." When teachers assign STEM projects, Mrs. Young expects her teachers to provide students "freedom of choice of how they will present their project." She affirms that students take real ownership of their learning when they are given the "opportunity to express themselves

differently." She adds, "They want to know that you're listening to them. They want to feel like they have some ownership in this space."

**3. The Principal Maintains High Expectations**. Culturally responsive principals have an unshakable faith that all students can learn at high levels. Khalifa et al. (2016) affirm that "maintaining high expectations of minoritized students is central to CRSL [culturally responsive school leadership]" (p. 1295). A fitting example of what it means to maintain high expectations for students who are underrepresented in STEM is reflected in the leadership of Ed Coleman. He knows from experience that "all students can do what we teach them and train them to do." He believes that "you just have to find what it is that they need to reach that level of success." Mr. Coleman serves as the principal of a mastery-based school, where all students are expected to achieve 90% or above in order to pass each course. To help all students reach mastery, he ensures that his students are provided numerous supports such as afterschool tutoring, a special intersession term for remediation, and access to regular office hours from their instructors.

**4. The Principal Secures a Culturally Responsive Curriculum**. In culturally responsive schools, "school leaders . . . create school contexts and curriculum that responds effectively to the educational, social, political, and cultural needs of students" (Khalifa et al., 2016, p. 1278). The present study suggests that securing a culturally responsive curriculum is especially helpful for students who have been minoritized in STEM. For example, Mrs. Young posits that STEM education lends itself exceptionally well to culturally responsive topics and pedagogy:

> We always focus on projects—project-based learning—as our key pedagogical structure, using a lot of inquiry based science. . . . So that allowed, I think, for a greater breadth of opportunity for linkages to culture. We did a whole [unit on] . . . Harlem Renaissance. And so there was the opportunity to bring in the historical narrative of what was going on, bring in the literature from that space . . ., talk about family connections, you know.

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Mrs. Young has provided the faculty with extensive training on culturally relevant pedagogy, and she expects that her teachers will continually identify ways to tie the cultural background and/or life experiences of students into the school's STEM learning objectives. She was recently pleased to observe a geometry class examine patterns in quilts as they discussed "the narratives of the slaves and how they were told through quilts."

*The Principal Empowers Community Involvement*

**1. The Principal Develops Strategic Partnerships with Businesses and Nonprofits**. Culturally responsive school leaders leverage partnerships with businesses, universities, and community nonprofits to address the needs of marginalized students (Khalifa et al., 2016). Ed Coleman illustrates how a principal can facilitate strategic partnerships for the well-being of students who have been minoritized in STEM. His school has relied heavily on business and community partnerships since its inception. He has expanded these partnerships throughout his tenure to the point where Roosevelt Prep has "partnerships with over 100 different community groups and businesses." Mr. Coleman attributes his success in establishing partnerships with the business community and various nonprofit organizations to relationship building. He reflects:

> It's certainly a process of relationship building over the years. . . . We think we're doing a good job as far as connecting with community partners. It really kind of stems out of relationships we've established over the years and continuing to think outside the box about who we want to reach out to next.

The partnerships that Mr. Coleman has fostered provide marginalized students with opportunities to shadow STEM professionals and participate in internships and apprenticeships. They also supply guest speakers for STEM classes, sponsor activities such as the robotics team, and support teachers with training and technical assistance in areas such as chemistry and physics.

**2. The Principal Enlists Role Models and Mentors**. Culturally responsive school

leaders are actively engaged in identifying role models and mentors that marginalized students

can identify with. Khalifa (2018) confirms that "the presence of minoritized role models can help

to improve overall school climates" (p. 176) for underrepresented students. The present study

validates that minoritized role models and mentors are critically important for underrepresented

students in STEM.

The leadership of Elena López highlights how a culturally responsive principal can play

an active role in this area. Her primary focus has been on enlisting role models to create a more

inclusive STEM environment for female students. Mrs. López partnered with Girls Who Code,

which offers an afterschool coding class at Collegiate STEM. In addition, she capitalized on her

school's presence on a university campus to partner with Women in Science and Engineering

(WISE). Through the partnership with WISE, women working on degrees in engineering and

related STEM fields volunteer at Collegiate STEM to tutor students, serve as guest speakers,

help teachers with STEM projects, and assist with special interest clubs. To address the needs of

females who are students of color, Mrs. López has leveraged the proximity of one of the

university's student organizations called the Baja Buggy Club. She explains:

> As far as Hispanic students, the way that we've been able to approach getting them more
> engaged is that we collaborate with a team of engineering students here on our campus.
> They put together what they call a Baja Buggy Club. They make their own Baja bug, it's
> like a dune buggy. . . . With this group of kids, a lot of them are males, but we actually
> are seeing a lot more females as well. We also see a lot of students that are Hispanic and
> so that's a double whammy for us. . . . They serve as a role model, working on some of
> these projects that encourages kids at our level to think, 'Oh, I can go all the way to
> college and do stuff like that, too.'

Providing female role models and mentors who are people of color helps Mrs. López counter the

effects of the double bind, the gender and race discrimination that females of color face as they

attempt to navigate the STEM pipeline.

**3. The Principal Fosters Meaningful Relationships with Parents and Community Members**. Khalifa et al. (2016) set forth that culturally responsive school leaders "maintain a presence in, and relationships with, [the] community members they serve" (p. 1274). The value of such relationships is reflected in the STEM leadership of Dr. Janice Taylor. Several years ago, she established a STEM advisory board made up of parents and community members. The STEM advisory board helps set goals and secure resources to support the success of marginalized students. In addition, she created an intergenerational program to connect students with the wisdom and customs of the local community. Intergenerational meetings take place once a month during the school day, and any community member who wants to participate is welcome to attend. Dr. Taylor describes the purpose of the program as follows:

> I have a program called intergenerational, and it's meant to bring the older and younger generations together. . . . I start my intergenerational program by first meeting with our students, our seventh and eighth graders, and we talk about what topics are relevant to them. . . . We take the topic that they want to talk about, we plan on activities, we bring in the community members, and we always do a STEM activity in our intergenerational meetings.

The meaningful relationships that Dr. Taylor has developed with parents and community members through avenues such as the STEM advisory board and the intergenerational program create an environment where all stakeholders are invested in the success of underrepresented students in STEM.

*The Principal Develops a Culturally Responsive Teaching Staff*

**1. The Principal Hires for Mission.** Culturally responsive school leaders place "an emphasis on hiring diverse faculty" (Khalifa et al., 2016, p. 1285). A stellar example of such intentionality in hiring is depicted in Mr. Coleman's leadership at Roosevelt Prep. He asserts that

he is "very intentional about seeking out individuals who share the belief that given enough time, and enough support and resources, all students can be academically successful." Mr. Coleman also recognizes the importance of building a STEM teaching staff that reflects the diversity of the student population:

> There is a proportion of students who, just by the nature of their environments, connect better and more quickly with those staff members who look like them. And I think we would do a disservice to our organization if we didn't seek out more staff who can fit that bill. So when students are seeing themselves as diverse and being exposed to staff who are equally diverse, I think it certainly does provide them with more confidence in becoming professionals.

Since it is often difficult to hire people of color for STEM positions because few apply, Mr. Coleman has actively reached out to HBCUs and other institutions that cater to people of color to expand the diversity of the applicant pool.

**2. The Principal Leverages Professional Development.** Culturally responsive principals "lead professional developments *[sic]* to ensure their teachers and staff, and the curriculum, are continuously responsive to minoritized students" (Khalifa et al., 2016, p. 1274). Mrs. Young's leadership shows how culturally responsive principals leverage professional development to respond to the needs of students who have been minoritized in STEM. To advance her vision of an inclusive STEM culture, she has enlisted the services of UnboundEd, an organization that assists schools in identifying the ways that racism and bias impede students of color from having access to rigorous, grade-level instruction. In addition, Mrs. Young has provided training to assist teachers with recognizing and supporting students with adverse childhood experiences (ACEs). She recognizes that many of her students have experienced childhood trauma, which she considers to be a major barrier for inner city students as they traverse the STEM pipeline.

### 3. The Principal Encourages Teachers to Reflect on Attitudes and Practices.

Culturally responsive principals challenge their teachers to reflect on how their biases, assumptions, and instructional practices impede the success of marginalized students (Khalifa, 2018). Dr. Taylor capably demonstrates how a culturally responsive principal can foster a reflective mindset among the faculty in support of underrepresented students. She shares that when she interacts with faculty members, "I want to see what their reflection process is." When an equity audit at her school indicated that African American males were not engaged in mathematics and science, she helped teachers reflect on the problem. As she recalls, "I had several meetings looking at what we could do. 'What kind of behaviors are you seeing with the males? Why are they being disengaged?' And how could we counter that?"

To counter deficit thinking, Dr. Taylor likes to take her teachers to high poverty schools that have been successful in teaching STEM. She observes, "You have to take teachers to the best places where STEM is working, and it has to match your population so teachers can't say, 'Oh, our kids can't do this.'" Like Dr. Taylor, culturally responsive principals play an active role in helping teachers reflect on their assumptions and practices, "given that teachers are often unable to identify and unpack their biases" (Khalifa et al., 2016, p. 1296).

### 4. The Principal Promotes an Equitable and Inclusive School Environment.

Fostering an equitable and inclusive school environment is integral to culturally responsive leadership. One of the major ways culturally responsive principals promote equity and inclusion in their schools is by leading an "ongoing examination and discussion of equity data, which can reveal gaps in achievement or discipline, resource allocations, equity in classes such as advanced placement [or] STEM" (Khalifa, 2020, p. 5). A strong focus on equity and inclusion is characterized by Mr. Coleman's leadership. One of his essential tasks as principal is "to make

sure that the expectations that we put in place will be inclusive of all students."

To achieve his inclusionary vision, Mr. Coleman makes regular use of equity audits, which help him determine if the "expectation for mastery in the classroom [is] a fair process to the point where it's not hindering an unequal amount of minorities from achieving the same goals or opportunities that everyone else is receiving." He recounts that one of his equity audits documented that African American students were not participating in college courses at a similar rate as white students. He stresses that when "the data shows that there's a disparity . . ., we have to address it."

**Research Question 3**

Research question three asked, "What strategies are used by principals to increase the interest and persistence of underrepresented students in STEM?" The data from this study suggests that culturally responsive principals play an active role in implementing strategies designed to increase the interest and persistence of students who have been minoritized in STEM. I have categorized the strategies employed by the principals in this study into three major themes. First, culturally responsive principals provide marginalized students with in-depth STEM experiences such as STEM internships and job shadowing with STEM professionals. In addition, culturally responsive principals look for ways to make STEM learning enjoyable for students. Finally, culturally responsive principals orchestrate a variety of team building STEM activities where students can assist each other on their STEM journeys through peer tutoring, collaborative problem solving, and mutual encouragement.

*Providing In-Depth STEM Experiences*

In-depth STEM activities such as job shadowing and internships provide students who have been minoritized in STEM with extended exposure to real world STEM professionals,

something that otherwise might be lacking in their lived experience. Stone (2011) acknowledges that "even more advantaged students have little or no contact with working adults or much awareness of the range of career opportunities in STEM fields" (p. 12). Mrs. Young's work at Jefferson Polytechnic demonstrates how a culturally responsive principal can provide in-depth, real world STEM experiences for underrepresented students. She has partnered with several area hospitals and nursing programs to provide internship experiences in STEM fields such as microbiology, physiology, genetics, and medicine. She has also established a partnership with the city zoo, which provides students with hands-on work in areas such as environmental science, conservation, and animal care.

Twice a year, Mrs. Young's students enjoy a special intersession week during which they work one-on-one with community partners on real-world STEM problems. She believes that school leaders need to do more to disrupt traditional modes of instruction:

> We have to expand our thinking about what the classroom truly is. So that means that we have to give kids experiences that are not only inside the traditional four walls of a classroom, but outdoors and in partner organizations working with professionals.

Mrs. Young says that intersession has enabled her school to provide students with "really rich, in-depth STEM experiences where they get to experience different cultures and different activities," providing motivation to further their studies in STEM and visualize themselves having a meaningful and productive career in a STEM field.

### *Making STEM Fun*

Making STEM learning fun has been shown to increase the interest and persistence of students, especially for those who have been historically underrepresented in STEM (e.g., Burt & Johnson, 2018; Mosatche et al., 2013). Dr. Taylor's leadership illustrates how a culturally responsive principal can foster a climate where STEM learning is fun. She indicates:

> We try to keep up with things that are exciting to kids. I had a teacher here who did drones—it was a hobby for him. So we added drones, we added the aerospace engineering program at the Career Center. We try to include things that students really like such as robotics.

To help students persist with their STEM coursework, Dr. Taylor opened up a game room at her school. Students are rewarded for their academic work with time in the game room. She also schedules periodic STEM nights at the school, where students can participate in hands-on experiments presented by STEM professionals. She says that such experiences "show the kids that [STEM] was fun." Dr. Taylor believes that "when the students can tell you . . . 'I love coming to school on Wednesday for coding,' or 'Oh, I love my medical detective class—it makes school exciting for me,'" she can be confident that she is fostering a climate that increases the interest and persistence of minoritized students in STEM. However, it should be noted that making STEM learning enjoyable may be insufficient for getting minoritized students to choose a STEM career in the absence of other supportive strategies (Sorge et al. 2000).

### *Team Building Activities*

This study documents the positive influence of collaborative team building activities for increasing the interest and persistence of underrepresented students in STEM. Mr. Coleman aptly describes the impact that being part of a team can have on underrepresented students:

> We have a nationally renowned robotics team. . . . And this might be a little bit of a sidebar, but I want to tell about them, because they are led by a team of females. The leader of the team is a young woman. And I think the top three on the team are girls. . . . That team is comprised of, at least half of the team of about 50 kids, are girls. That team works with FIRST robotics, and those are girls are extremely excited!

Other team-building activities described by the principals in this study include the creation of girl-centric STEM clubs, the formation of a Black Greek letter fraternity, and project-based learning teams. Team-building activities are effective because they safeguard "vulnerable

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students' sense of belonging from threats within the academic environment" (Lewis et al., 2016, p. 8). In addition to fostering a sense of belonging, team building activities are powerful because they provide minoritized students with a psychological safety net where they can feel free to take risks in their STEM learning.

<div align="center">**Implications for Policy and Practice**</div>

The findings from this study suggest several ways for improving policy and practice for K-12 principals as they support underrepresented students in their STEM learning. Many principal preparation and professional development programs do not adequately address the major barriers that principals encounter in providing culturally responsive leadership for minoritized students, such as navigating through mandates that disrupt the learning process. Curricula for principal preparation courses and ongoing professional learning programs should be designed to examine key challenges to culturally responsive leadership and discuss effective strategies to address them.

This study revealed several overarching themes that highlight the culturally responsive leadership behaviors and practices that effective principals employ as they implement a STEM program that is sensitive to the needs of underrepresented students. The overall themes that emerged from this study (e.g., empowering community involvement) and their accompanying subthemes can be incorporated into principal preparation programs and professional development workshops to equip aspiring and practicing principals with a constructive framework for providing culturally responsive leadership to support the STEM learning of females and URMs who have been minoritized in STEM. The culturally responsive leadership behaviors and practices that emerged from this study could also enlighten a cluster of school improvement activities for districts committed to expanding opportunities for minoritized

students in STEM, such as redesigning principal induction programs, updating administrator evaluation instruments, and aligning goal setting priorities for district principals.

Finally, this study looked at ways that culturally responsive principals increase the interest and persistence of underrepresented students in STEM. Strategies such as providing students with in-depth STEM experiences (e.g., internships) and collaborative team building activities have been shown to engage minoritized students and give them the confidence they need to persevere in the STEM pipeline. This knowledge can be used to help inform best practices for both STEM administrators and instructors.

## Critique of the Study

The data for this study was collected at the height of the COVID-19 pandemic. As a result, the schools where the participants worked were closed to visitors. I was unable to spend time directly observing the leadership practices of the principals as they interacted with students, teachers, parents, and other stakeholders. Direct observation of the principals would have provided me with a more complete picture of their STEM leadership. I was also unable to speak with underrepresented students about their experiences, which could have given me a better understanding of the important role that culturally responsive principals play in the STEM journey of minoritized learners.

The four cases in this study were identified with the assistance of Cognia, a nonprofit organization, formerly known as AdvancED, that accredits schools throughout the United States and globally. Cognia recommended a list of principals from their STEM-certified schools who could best answer my research questions. This created a degree of selection bias, as exemplary principals working in schools that Cognia has not certified in STEM were not considered for the study. Another problem contributing to selection bias is that Cognia disproportionately

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recommended principals who were either African American or Indigenous persons. All four

cases participating in this study were people of color. They might approach leadership to

minoritized students differently. Another factor that may have contributed to selection bias was

the pandemic itself, which greatly increased the workload for school administrators. Principals

recruited for participation in the study who declined the invitation might have done so because

they had a greater commitment to the underrepresented students in their schools than those who

accepted the invitation.

## Recommendations for Future Research

The following areas are recommended for further research.

1. The principals identified for this study served in schools that had received STEM

   certification from Cognia. A comparable study should be conducted with principals who

   do not work in Cognia STEM-certified schools to see if it produces similar findings.

2. All principals who participated in this study worked in either a specialized STEM school

   or a STEM-focused school. It would be useful to investigate how principals who work in

   traditional schools are responsive to the needs of underrepresented students.

3. All principals participating in this study were people of color working in schools with

   sizeable populations of URMs. A study examining how principals provide exemplary

   leadership for URMs when they are not members of a minoritized population themselves

   would provide valuable insight into the efficaciousness of culturally responsive school

   leadership for supporting underrepresented students in STEM.

4. Three of the four cases in this study were women. The presence of a female principal

   might empower female students to be engaged in STEM for reasons other than culturally

   responsive school leadership. Therefore, qualitative research exploring how male

principals contribute to the success of female students in STEM would provide a more robust understanding of the effectiveness of culturally responsive school leadership in supporting female students in their STEM learning.

5. The data for the present study was collected from principal interviews, interviews with teachers and parents, and artifacts relevant to each case. Additional research that gleans the perspectives of underrepresented students would provide a more comprehensive understanding of how principals can support the needs of students who have been minoritized in STEM.

6. Two of the four principals who participated in this study had a STEM background. Future research should investigate if principals with a STEM background engage in leadership behaviors when working with underrepresented students that differ from principals who do not have a background in STEM.

7. While a major focus of this study was how principals are responsive to the needs of female students in STEM, several principals cited challenges in meeting the STEM needs of their male students. It has been known for decades that educators must be cognizant of the environmental factors that impact the learning of boys (e.g., Everts, 1969; Wax, 1967). Research exploring how principals can be responsive to the unique needs of male students in their STEM learning would be beneficial, particularly in furthering the journey of African American, Latino, and Native American males.

8. This study used a comparative case study methodology to explore the culturally responsive leadership behaviors and practices of four principals as they supported underrepresented students in STEM. Since there is a dearth of previous studies exploring this phenomena, additional qualitative and quantitative research examining the leadership

behaviors and practices of principals working with students who have been minoritized in STEM would contribute to an even greater understanding of the role of culturally responsive school leadership in this area.

## Conclusions

Women and URMs such as African Americans, Latinos, and Native Americans are markedly underrepresented in the STEM fields. Too many females and students of color drop out of the STEM pipeline during their middle and high school years, enabling this inequity to persist. School administrators have a moral obligation to address this problem and foster schools with the capacity to help all students thrive in STEM. This study suggests that culturally responsive school leadership is efficacious for supporting minoritized students in their STEM learning. Consequently, aspiring and practicing principals who want to transform their schools into spaces where underrepresented students can thrive will benefit from formal training and mentorship grounded in culturally responsive school leadership.

As documented in the literature review, all too often females and students of color do not have equitable access to a robust STEM education, locking them out of future careers in STEM, particularly highly paid jobs in fields such as engineering and computer science. Broadening the participation and success of students who have been minoritized in STEM is indispensable for enlarging America's technical talent pool and increasing the creativity, perspectives, and insights that are needed to drive innovation and problem-solving in the 21st century. This study provides meaningful evidence that principals who engage in culturally responsive school leadership practices have the power to increase the interest and persistence of minoritized students in STEM, fostering more vibrant communities for all.

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# APPENDIX A: CASE IDENTIFICATION FORM

| Name of Principal | School Name | School Location (city/state) | Students of color >25% | Min. 5 yrs. admin. exp. | Min. 3 yrs. at current school | Cognia Rec. |
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APPENDIX B: SCHOOL DISTRICT PERMISSION


Dear Superintendent ███,

I am a graduate student under the direction of Dr. Guy Banicki in the Department of Educational Administration and Foundations at **Illinois State University**. As part of my dissertation requirement, I am conducting a research study to identify the behaviors, skills, and practices of middle and high school principals who have provided leadership that is responsive to the needs of underrepresented students in STEM education, such as females and students of color.

Working with the Cognia STEM Certification Network, I have identified one of your principals, ██████████, as someone who has provided effective leadership for students underrepresented in STEM. I am seeking your permission to invite ██████'s participation. His participation is voluntary, and would consist of 2-3 interviews of no more than one hour each, conducted virtually via Zoom.

I have attached a brief description of the research study, as well as my Institutional Review Board approval from Illinois State University. Please feel free to contact me at any time if you have any questions or would like further information about the study.


Thank you for your consideration,

Kenneth J. Sanderson, Ed.D. Candidate
Department of Educational Administration and Foundations
Illinois State University

APPENDIX C: PARTICIPANT INVITATION

Dear ███████████,

I am a graduate student under the direction of Dr. Guy Banicki in the Department of Educational Administration and Foundations at Illinois State University. I am conducting a research study to identify the behaviors, skills, and practices of middle and high school principals who have provided leadership that is responsive to the needs of underrepresented students in STEM education, such as females and students of color.

You are being invited to participate in this study because you have been identified as someone who has provided effective leadership for students underrepresented in STEM. Your participation is voluntary. Enclosed (attached) is a consent form which provides further information about the study. If you would like to participate, please complete the form and return it to me at your earliest convenience. It is fine to return the form electronically, or if you prefer, I can provide you with a mailing address.

I look forward to hearing back from you. Please feel free to contact me at any time if you have any questions or would like further information about the study.


Thank you for your consideration,

Kenneth J. Sanderson, Ed.D. Candidate
Department of Educational Administration and Foundations
Illinois State University

APPENDIX D: LETTERS OF CONSENT


PARTICIPANT CONSENT FORM—PRINCIPAL



Dear Partner in Research,

I am a graduate student under the direction of Dr. Guy Banicki in the Department of Educational Administration and Foundations at Illinois State University. I am conducting a research study to identify the behaviors, skills, and practices of middle and high school principals who have provided leadership that is responsive to the needs of underrepresented students in STEM education, such as females and students of color. You are being invited to participate in this study because you have been identified as someone who has provided effective leadership for students underrepresented in STEM.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, it will not impact my research and all mention of you in any capacity will be removed from the study. Your responses are confidential and any information that might allow someone to identify you will not be disclosed. You will not be penalized if you choose to skip parts of the study, not participate, or withdraw from the study at any time.

If you choose to participate in this study, you will be asked to take part in up to three interviews over a three-month period, with each interview lasting no more than one hour each. The interviews will be conducted via a Zoom conference call. In addition, you will be asked to share artifacts which may include documents or photos that you believe provide examples of your accomplishments as a leader in your district. The artifacts collected will be determined in collaboration with you. Potential artifacts could include but are not limited to items such as professional development plans, school newsletters, promotional fliers, meeting agendas/minutes, and/or links to information on the school's website.

Risks of participation in this study are minimal.  Participants may become uncomfortable while being interviewed. You are able to refuse to answer any questions, quit the study at any time, and/or ask for particular answers to not be included as data. An additional risk would be a potential breach in confidentiality. If your confidentiality were breached, there is a small risk that what you stated during an interview could be viewed negatively by the district superintendent or school board. Every effort will be made to maintain confidentiality. All data will be kept in a password protected computer, and names will be replaced with pseudonyms.

The results of this study may be presented at educational conferences or published. Any information that may identify you or potentially lead to reidentification will not be released. In addition, I will not use any identifiable information from you in future research, but your deidentified information could be used for future research without additional consent from you.  Please note that when required by law or university policy, identifying information (including your signed consent form) may be seen or copied by authorized individuals.

Although there may be no direct benefit to you, a possible benefit of your participation is a greater understanding of effective practices of principals when working with students who have been historically underrepresented in STEM.

If you have any questions about the research or wish to withdraw from the study, please contact me at ███████████ or by email at ███████████, or you may contact my faculty advisor, Dr. Guy Banicki, at ███████████.

If you have any questions about your rights as a participant, or if you feel you have been placed at risk, contact the Illinois State University Research Ethics & Compliance Office at (309) 438-5527 or IRB@ilstu.edu.

Sincerely,

Kenneth J. Sanderson
Ed.D. Candidate, Illinois State University

I consent to participating in the above study. I understand that interviews may be recorded by audio for later data analysis.

Signature _____     Date _____

*You can print this form for your records.*

PARTICIPANT CONSENT FORM—TEACHER/PARENT

Dear Partner in Research,

I am a graduate student under the direction of Dr. Guy Banicki in the Department of Educational Administration and Foundations at Illinois State University. I am conducting a research study to identify the behaviors, skills, and practices of middle and high school principals who have provided leadership that is responsive to the needs of underrepresented students in STEM education, such as females and students of color. You have been invited to participate in this study because your principal suggested that you may be able to provide insight into how they provide effective leadership for students underrepresented in STEM.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, it will not impact my research and all mention of you in any capacity will be removed from the study. Your responses are confidential and any information that might allow someone to identify you will not be disclosed. You will not be penalized if you choose to skip parts of the study, not participate, or withdraw from the study at any time.

If you choose to participate in this study, you will be asked to take part in one interview which will last no more than one hour.  The interview will be conducted via a Zoom conference call.

Risks of participation in this study are minimal.  Participants may become uncomfortable while being interviewed. You are able to refuse to answer any questions, quit the study at any time, and/or ask for particular answers to not be included as data. An additional risk would be a potential breach in confidentiality. If your confidentiality were breached, there is a small risk that what you stated during an interview would be viewed negatively by the school principal. Every effort will be made to maintain confidentiality. The principal will not be informed whether or not you chose to participate in the study. In addition, all data will be kept in a password protected computer, and names will be replaced with pseudonyms.

The results of this study may be presented at educational conferences or published. Any information that may identify you or potentially lead to reidentification will not be released. In addition, I will not use any identifiable information from you in future research, but your deidentified information could be used for future research without additional consent from you.  Please note that when required by law or university policy, identifying information (including your signed consent form) may be seen or copied by authorized individuals.

Although there may be no direct benefit to you, a possible benefit of your participation is a greater understanding of effective practices of principals when working with students who have been historically underrepresented in STEM.

If you have any questions about the research or wish to withdraw from the study, please contact me at ▆▆▆▆▆▆▆ or by email at ▆▆▆▆▆▆▆, or you may contact my faculty advisor, Dr. Guy Banicki, at ▆▆▆▆▆▆.

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If you have any questions about your rights as a participant, or if you feel you have been placed at risk, contact the Illinois State University Research Ethics & Compliance Office at (309) 438-5527 or IRB@ilstu.edu.

Sincerely,

Kenneth J. Sanderson
Ed.D. Candidate, Illinois State University


I consent to participating in the above study. I understand that interviews may be recorded by audio for later data analysis.


Signature _____     Date _____

*You can print this form for your records.*

APPENDIX E: INTERVIEW GUIDES


PRINCIPAL INTERVIEW GUIDE

**Introductory Questions**

1.  Please tell me about your background.
    *   Family background, education, prior roles in schools
    *   Previous STEM training/knowledge

2.  Why did you decide to become a principal?

3.  Please tell me about your school and the community it serves.
    *   Size, demographics, cultural groups, economy, diversity

**Research Question 1: What problems or challenges do principals encounter in addressing the needs of underrepresented students in STEM?**

1.  What concerns do you have about STEM education in your school?
    *   Which students in your school have been underserved in STEM?

2.  Are there specific problems or challenges you face in diversifying your school's STEM program to address the needs of underrepresented students?

3.  How are you working to overcome these challenges?

4.  Have you encountered any barriers or resistance from stakeholders in meeting the needs of females and students of color in STEM?
    *   How do you build capacity among stakeholders that are not in full support of your STEM goals?
    *   How do you discourage deficit images of underrepresented students in STEM?

**Research Question 2: What are the culturally responsive leadership behaviors and practices principals employ when implementing a STEM program that is responsive to the needs of underrepresented students?**

1.  Do you engage in self-reflection regarding your leadership in STEM?
    *   What are some of the things that principals must reflect on regarding their STEM programs?
    *   Are you aware of any personal opinions or biases that have challenged your leadership toward underrepresented students in STEM? How do you address them?
    *   In what ways does self-reflection help you become more responsive to the needs of underrepresented students?

2.  How do you build capacity among your faculty to provide STEM instruction that is responsive to the needs of underrepresented students?
    *   Do your teachers make use of students' cultural capital when teaching STEM?

- In what ways do you help your STEM teachers improve their knowledge and skills in culturally relevant pedagogy?
- What impact has your leadership had on teacher attitudes toward underrepresented students?

3. What leadership strategies do you use to foster a school climate that promotes an inclusive environment for all students in STEM?
   - How do you promote an inclusionary vision for your STEM program?
   - How do you identify inequities that hinder underrepresented students in their STEM learning?
   - In what ways do you give underrepresented students a voice in their learning?

4. How do you engage the diverse cultural and economic backgrounds of your local school community to support a STEM program that is responsive to the needs of underrepresented students in STEM?
   - How do you make stakeholders aware of your vision for underrepresented students in STEM?
   - How do you foster strong relationships with students, parents, community leaders, and other stakeholders to garner support for your STEM program?
   - In what ways have you engaged the local community to advocate for the needs of underrepresented students in STEM?

**Research Question 3: What strategies are used by principals to increase the interest and persistence of underrepresented students in STEM?**

1. How do you personally define success for underrepresented students in STEM?
   - How do you measure the engagement of underserved students in STEM?
   - How do you determine the extent to which your STEM program is inclusive?

2. Are there particular leadership strategies that you think are important for improving the interest and persistence of underrepresented students in STEM?

3. What impact has your leadership had on the interest and persistence of underrepresented students in STEM?
   - What have been the most observable outcomes to date?

4. Please describe any promotional methods or recruiting strategies you use to encourage female students and/or students of color to participate and persist in STEM education.

**Wrap-Up**
1. Is there anything else you would like to add that we have not addressed in this interview?

2. Are there any questions you would like to ask me?

TEACHER INTERVIEW GUIDE

**Introductory Questions**
1. How long have you taught at this school?
2. How long have you worked for the principal?
3. Please tell me about your school and the community it serves.

**Research Question 1**
1. Are there specific problems or challenges your principal faces in diversifying your school's STEM program to address the needs of underrepresented students?
2. How is your principal working to overcome these challenges?

**Research Question 2**
1. How does your principal build capacity among the faculty to provide STEM instruction that is responsive to the needs of underrepresented students?
2. What leadership strategies does your principal employ to foster a school climate that promotes an inclusive environment for all students in STEM?
3. To what extent does your principal engage the diverse cultural backgrounds of the local school community to support a STEM program that is responsive to the needs of underrepresented students? Please describe.

**Research Question 3**
1. How does your principal define success for underrepresented students in STEM?
2. Are there particular leadership strategies that your principal employs to improve the interest and persistence of underrepresented students in STEM?
3. What impact has your principal's leadership had on the interest and persistence of underrepresented students in STEM?

**Wrap-Up**
1. Is there anything else you would like to add that we have not addressed in this interview?
2. Are there any questions you would like to ask me?

PARENT INTERVIEW GUIDE

**Introductory Questions**
1. Please tell me about your school and the community it serves.
2. How long have you had children attending this school?
3. How long have you known the principal?

**Research Question 1**
1. Are there specific problems or challenges your principal faces in diversifying your school's STEM program to address the needs of underrepresented students such as females and students of color (African American, Latino, Native American)?
2. How is your principal working to overcome these challenges?

**Research Question 2**
1. How does your principal foster a school climate that promotes an inclusive environment for all students in STEM?
2. To what extent does your principal engage the diverse cultural backgrounds of the local school community to support a STEM program that is responsive to the needs of underrepresented students?  Please describe.

**Research Question 3**
1. Are there particular leadership strategies that your principal employs to improve the interest and persistence of underrepresented students in STEM?
2. What impact has your principal's leadership had on the interest and persistence of underrepresented students in STEM?

**Wrap-Up**
1. Is there anything else you would like to add that we have not addressed in this interview?
2. Are there any questions you would like to ask me?