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The Development of Science Identity in Undergraduate STEM Majors: A Case Study of Urban High School Students

Charles McWilliams
University of Missouri-St. Louis, mcwilliamsca@umsl.edu

Benjamin Nims
University of Missouri-St. Louis, bdnc46@mail.umsl.edu

Kathleen Dwyer
University of Missouri-St. Louis, kd472@mail.umsl.edu

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Kathleen Dwyer

M.A., Zoology, Miami University - Oxford, 2011
M.Ed., Secondary Science Education, Southern Illinois University - Edwardsville, 2000
B.S. Biological Science, University of Illinois - Chicago, 1988

Charles McWilliams

M.S., Biology, Washington University in St. Louis, 2011
M.Ed., Secondary Education, University of Missouri-St. Louis, 2003
B.A., Biology Education, University of Northern Iowa, 1994

Benjamin Nims

M.S., Biology, University of Missouri-St. Louis, 2006
B.S. Environmental Science, St. Norbert College, 2001

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<u>Dissertation Committee</u>

Dr. Charles Granger, Ph.D., Chairperson

Dr. Keith Miller, Ph.D.

Dr. Helene Sherman, Ed.D.

Abstract

The STEM fields, science, technology, engineering, and mathematics, face a significant challenge: the underrepresentation of women and minority racial groups entering STEM degree programs and careers. Addressing this STEM gap requires more than quality curriculum and educational supports; there is a need to understand the social psychological processes that influence students' perceptions, motivation, and interest in STEM. The concept of science identity has been posed as a research perspective to understand participation and persistence in STEM. Enacting a science identity may include describing oneself as a scientist, having a high sense of self-efficacy to do scientific work, displaying an interest to do science, and engaging with and receiving validation from a scientific community of practice. The purpose of this grounded theory case study was to explore the science identities enacted by twenty-four graduates from a Midwest urban public high school (MUPHS) who have enrolled in undergraduate STEM degree programs. Data collection involved semi-structured interviews that explored four components of science identity: interest, competence, performance, and recognition. Qualitative analysis through a constructivist coding approach was applied to understand why students chose to enter and persist in a STEM degree program. Emerging themes related to experience, motivation, and persistence were examined, and salient identities both unique and shared between different gender and racial groups are identified. Five salient science identities emerged: Research Scientists, STEM-Career Focused, STEM Apprentices, STEM Humanists, and STEM Seekers. Recommendations to support gender and racial diversity in STEM programming and future avenues of research are provided.

Dedications

Kathleen Dwyer: Author 1

Heartfelt thanks to my wonderful husband Robert Lippert for his love, encouragement and neck rubs. Thank you to my children, James, Aiyanna, William and Caitlin, and my daughter-in-law Heather, for their support and motivation. Thanks to my parents for initiating and fostering my love of learning. Much respect and gratitude is extended to my wonderful collaborators, Chuck McWilliams and Benjamin Nims, for their kindness and professionalism. I would also like to thank all of the students I have had the honor of teaching. You have been inspirational, amusing, challenging, entertaining, and befuddling but never boring. I dedicate this work to you.

Charles McWilliams: Author 2

I would like to dedicate this work to my wife Roxane. Her steadfast support, encouragement, and love has sustained me through this process. To my two children Erin and Ian for their love, patience, and understanding during these past few years. I would like to thank my parents Denny and Joanie, my sister Amy, and my friend Rob for their continued support. And finally to Kathleen and Ben, thank you both for believing in me and pushing me to be my best every day.

Benjamin Nims: Author 3

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Chapter 1

Introduction

Research on motivation, or the process by which an individual initiates and carries out specific activities to achieve a set goals, has resulted in several different paradigms in education (Schunk et al., 2014). Understanding the psychological and social processes by which motivation and persistence occur provides an important analytical lens in education research. This is particularly important when fostering educational and social structures. We want to encourage structures that foster behaviors that maximize educational achievement. Modern-day theorists have proposed different ways to explore motivation. Each of these theories focuses on four common concepts: competence, value, attributions, and cognition (Cook & Artino, 2016). Examining these motivational concepts reveals factors that support student persistence in STEM-related fields. Among undergraduates who declare a STEM-related major, only about half earn a STEM-related degree (Chen, 2013). The retention rate is highest for White males and lower for female and minority students. Motivational theories aid an understanding of why some students persist while others switch to a non-STEM major or leave college without a degree.

The concept of *science identity* has been posed as a research perspective to understand participation and persistence in STEM degree programs. Identity is a multidimensional construct that is continually being developed or modified based on individual contextual social-experiences over time (Carlone, 2012). Although a specific definition is difficult to construct, generally, a science identity can be described as how one understands their abilities and desire to do or practice science. Practicing science identity may include describing oneself as a scientist, having a high sense of self-efficacy to do scientific work, displaying an interest or motivation to do science, and engaging with and receiving validation from a scientific community of practice (Brickhouse & Potter, 2001).

Educational reform requires evidence-based strategies to address the gender and racial gap. We favor strategies that are built on conceptual understandings of motivation and achievement (Cook & Artino, 2016; Williams, 2011). From this need arises an important question: why do some individuals identify as scientists and select and persist within a STEM-related career pathway and others do not? Part of the gap may be explained by the social psychological processes at play in influencing students' perceptions, motivation, and interest in science. In addition to quality curriculum, there is a need in science education to acknowledge the lived experiences, perspectives, and identities students bring into the classroom; this includes the concepts of self-efficacy, a sense of belonging, and science identity as representative of a student's affective domain (Trujillo & Tanner, 2014). The following are examples of the critical questions regarding science education posed by Carlone and Johnson (2007):

1. What are the characteristics of learners who are promoted or marginalized by teaching/learning practices?
2. How are learners taught the norms/expectations to be accepted by a community of practice?
3. How are we asking learners to engage with science?

Background of the Problem

The various fields that constitute the STEM disciplines, including science, technology, engineering, and math, face a significant challenge in regards to gender and racial diversity. In its biannual report *Women, Minorities, and Persons with Disabilities in Science and Engineering*, the National Science Foundation (2019) identifies the extent of the gender gap: of all science and engineering degrees awarded in 2016, women earned about half of bachelor's degrees, 44% of master's degrees, and 41% of doctorate degrees, which is about the same as in 2006. The disparity in 2016 was greatest in the physical and computer sciences. Whereas just over half of biology bachelor degrees were conferred to female students, only 42.4% of degrees were awarded to females in mathematics and statistics, 20.9% in engineering, 19.3% in physical sciences, and 18.7% in computer science. Among scientists and engineers, more men than women were employed full time in 2017 (12.8 million men versus 10.1 million women) and about twice as many women were employed part-time (2.9 million women versus 1.5 million men) (National Science Foundation, 2019). Further analysis that includes race and ethnicity reveals a predominant trend: the majority (56%) of bachelor's degrees in science and engineering are being earned by White students. In 2016, Hispanics or Latinos earned 13.5% of science and 10% of engineering bachelor's degrees, while Black or African American students earned 9% and 4% (respectively), and American Indians or Alaska Natives, 0.5% and 0.3%. As Museus et al. (2011) point out, these statistics are to the detriment of both gender and racial diversity in STEM and also to the greater scientific, economic, and social prosperity of the nation as a whole.

Many reasons have been suggested for the gender and diversity gap including inequities in quality educational opportunities (Estrada et al., 2016), lower expectations based on gender (Wang & Degol, 2017), racial and socioeconomic status stereotypes (Museus et al., 2011), lack of perceived relevance within STEM curricula (Kennedy & Odell, 2014), and a lack of role models in classrooms (Museus et al., 2011; Price, 2010). It is important to note that the gender and diversity gap trends are not due to an ability gap (Hyde et al., 2008), nor are they due to a lack of interest in STEM (Hill et al., 2010). Research suggests no single issue is the sole cause and that, despite these challenges, many students still choose and persist in the STEM degree pipeline (Aschbacher et al., 2010). As students encounter learning difficulties in STEM classes some may feel like they cannot be successful and decide to give up. This negative experience can produce a range of behaviors pertaining to academic focus and persistence within individual students in STEM classes (Lin-Siegler et al., 2016). Further, students in many subgroups tend not to enroll in upper level science classes or pursue STEM degree programs (National Science Foundation, 2019). There is a critical need to address both scientific literacy and interest in the STEM fields in secondary science classes for all students.

Statement of the Problem

The application of identity research has great potential to reveal social and structural inequities in educational systems (Gee, 2000). There is a need for educators to understand affective aspects of the student educational experience, including self-efficacy, sense of belonging, and science identity (Trujillo & Tanner, 2014). The lens of science identity to approach this problem has been applied to studying gender and race in several contexts including middle school (Carlone et al., 2014), middle and high school (Vincent-Ruz & Schunn, 2018), post-secondary (Robinson et al., 2018), and doctoral and post-doctoral educational settings (Carlone & Johnson, 2007; Hudson et al., 2018; Szelényi et al., 2016). Currently, there is a limited amount of qualitative research that examines science identity in undergraduate college students who are enrolled in STEM degree programs. Through qualitative interviews we hope to clarify several aspects of science identity formation in this demographic. First, what motivational factors influence a student to choose a STEM undergraduate degree? Second, how do students exhibit their science identity in an undergraduate setting? Third, to what degree do K-12 science experiences contribute to the formation of science identity? Finally, to what degree do informal science-related experiences contribute to the formation of science identity?

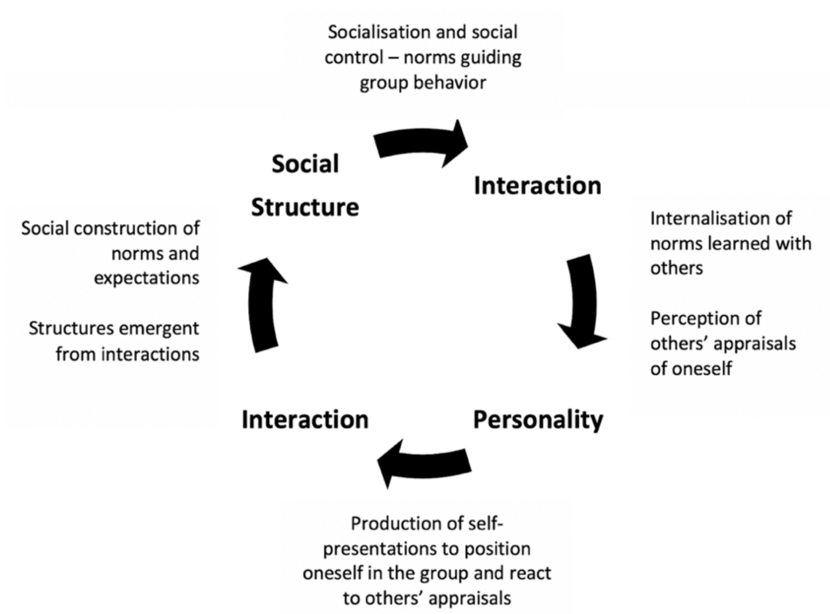
Conceptual Framework

The definition and conceptual understanding of an individual's identity is an area of social research steeped in a number of theoretical explanations (Turner, 2013). Gee (2000) proposes that one's identity is related to how one is recognized as a certain "kind of person." This definition is inherently tied to the social context by which one's identity is being enacted. Further, an individual will have multiple identities depending on each social context. Identity can be largely defined as the interaction of several components (Stets & Serpe, 2013). First, identity refers to the roles, often defined as social constructs, we play within our society. Such roles include parent, daughter, police officer, teacher, etc. Second, identity relates to the social groups we engage with and participate in including religious, political, or social groups with similar personal interests. Third, identity is constituted by an individual's unique personal characteristics that then give rise to participation within a group as mentioned above. Therefore an individual has multiple identities that may cross over or interact within different societal contexts (Burke & Stets, 2009; Gee, 2000). Understanding identity from a structural symbolic interactionist's perspective focuses on the importance of social interactions and context in identity development. Throughout life, an individual interacts with multiple social structures which provide opportunities to enact one's identity within each social structure (Stets & Serpe, 2013). These social structures may be large, such as race or ethnicity. They may be intermediate, such as within neighborhoods or educational systems. Finally they may be proximate, such as between peers or family members. These interactions shape and refine an individual's identity and give rise to multiple personal and group identities.

In educational research, studying identity can provide a framework by which to understand motivation, behavior, and participation in educational settings (Gee, 2000). This research looks at the way structure and agency shape an individual's identity as they become members of social groups. Shanahan (2009) displays the concepts of structure and agency in the context of identity research through the Personality and Social Structure Perspective (Figure 1). Not a conceptual model of identity per se, this framework provides an analytical tool to organize identity research. Here we see how agency and structure continually interact. All identity research studies arguably focus on one or more of these interactions. Agency refers to an ability to act and shape the learning environment. From this lens we can explore how an individual is engaged in the act of constructing an identity as opposed to reacting to an imposed identity. Structure refers to the normative patterns and cultural expectations within a social group.

Figure 1.1

Personality & Social Structure Perspective (Shanahan, 2009)



The concept of a science identity as a lens for educational research is relatively recent. Carlone & Johnson (2007) have provided a conceptual model by which to understand science identity (Figure 2). This model includes three dimensions to support a formal concept of science identity: competence, performance, and recognition. Competence refers to one's knowledge of scientific concepts along with the motivation to understand the world in a scientific way. Performance involves the ability to demonstrate the knowledge and skills necessary to carry out scientific practices. Recognition includes seeing oneself as a science person in addition to being recognized by others in the same identity group. This model takes into account self-efficacy, knowledge and skills, and acceptance from a community of practice as influential in the development of a science identity. When this model was applied in a research context, it revealed the influential role recognition plays in science identity for women of color who had completed STEM-education programs at the graduate level and were in different science-related careers (Carlone & Johnson, 2007). This allowed for a revised grounded model of identity to be developed, adding to the potential of this model in future research.

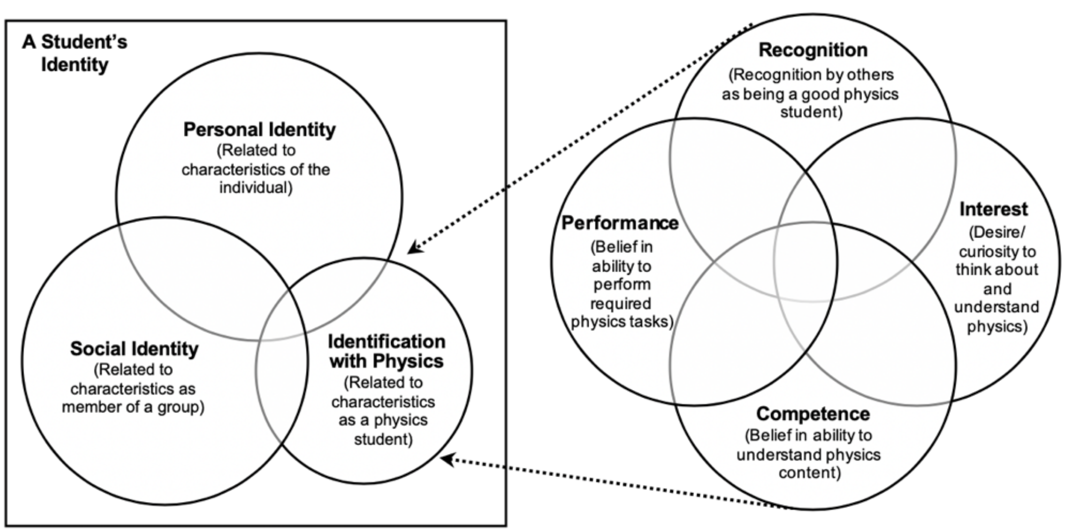
Figure 2

Model of Science Identity (Carlone & Johnson, 2007)

Carlone & Johnson's (2007) original model has been applied in different academic contexts. At the secondary level, providing students with authentic science experiences has been shown to change students' perceptions of a scientist in addition to strengthening their personal science identity; this adds support to the performance component of the science identity model (Chapman & Feldman, 2017). This model has also undergone modification. Hazari et al. (2010) applied the model in their work on understanding a "physics identity." As part of this, they included a fourth component to the original science identity framework: *interest*. This was added to understand how science identities are fostered in primary and secondary educational settings, as opposed to the graduate or professional settings where interest in science is already strong for individuals in a STEM educational tract (Figure 3). The presence of a strong physics identity correlates highly with physical science career choices; further, there are several key practices that secondary physics teachers can do to foster students' physics identities including a focus on core physics concepts, building connections between the classroom and the real world, and empowering students to pursue physics as an educational and career pathway.

Figure 3

Framework for Students' Identification with Physics (Hazari et al., 2010)



The attempt to study science identity fits squarely into the structure-agency problem within social research: to what extent is science identity shaped by individual agency, the structure of formal educational environments, and the interaction between the two? The power of these models as conceptual frameworks lies in their application as guides for future research and understanding of science identity formation. Research and understanding of science identity requires an exploration of agency, structure, and the interaction between these two factors. It must be built on a sound conceptual framework. This research continues to be relevant as science identity is a significant factor in the gender and racial gap problem within the STEM disciplines (Stets et al., 2017). Further, identity research can determine the specific factors that best support science identity formation that promotes persistence of minority students in STEM-related career pathways (Estrada et al., 2011; Hernandez et al., 2013). By analyzing past research, we can design research to help address the need for a scientifically literate populace and workforce. Fostering healthy science identities is an essential part of the science education process.

Purpose of the Study

The purpose of this case study is to explore the science identities enacted by graduates from a Midwest urban public high school (MUPHS) who have enrolled in undergraduate STEM degree programs. The STEM degree programs included were biological and physical science, technology, engineering, and mathematics. This research will explore three dimensions that support a formal concept of science identity: competence, performance, and recognition. We hypothesize that science identity plays a critical role in the motivation that transforms an individual’s interest in science into a desire to pursue and do science. Personal interviews and qualitative analysis will be used to investigate why students chose to enter a STEM field, how their science identity developed, and the reasons why students persisted (or did not) in undergraduate programs. Emerging themes related to motivation and science identity will be examined, and salient identities that are both unique and shared between female and male students and different racial groups will be identified. By clarifying our understanding of how science identity develops, we will suggest interventions for improving science literacy and engagement in STEM related high school coursework. Further, suggestions will be provided for undergraduate academic support practices to achieve better gender and racial diversity in STEM programs. Finally, recommendations for future research will be made.

Research Questions

1. What influences high school graduates of different gender and racial groups to pursue and persist in a post-secondary STEM degree program?
2. To what degree do high school graduates of different gender and racial groups who enroll in post-secondary STEM degree programs exhibit their science identity?
3. What are the salient forms of science identity among different gender and racial groups enrolled in a post-secondary STEM degree program?

Significance of the Study

Participants in this study are all graduates (2015-2019) from the same Midwest urban public high school in the United States. The participants have experienced a common science curricula and academic program. This shared academic experience allows for a distinctive case study by which to examine science identity formation and the impact on motivation and persistence in STEM degree programs. The transition from high school to college is not one that has been explored qualitatively in previous identity research. Arguably, this transition is a crucial time of identity development as students navigate new social and educational settings (Erikson, 1972). There is a need to understand the temporal components of science identity and how it changes based on different experiences and contexts. The exploration of the lived experience of undergraduates in STEM provides a valuable opportunity to study science identity, motivation, and persistence in STEM degree programs.

Definition of Terms

- Competence: Knowledge and understanding of science content
- Gender: Characteristics pertaining to masculinity and femininity, which includes biological sex and socially constructed differences
- Ethnicity: Identifying oneself as being Hispanic or not
- Performance: Demonstration of relevant science practices; using the language and tools of science
- Persistence: Ability to work toward goals while successfully navigating setbacks
- Post-secondary: Education received after high school or secondary school
- Prominence: The degree to which an identity is viewed as important or worthwhile
- Racial groups: The self-identification of belonging to one or more social groups
- Recognition: Whether one recognizes oneself and whether others recognize someone as a science person
- Salience: Indicates the degree to which one identity emerges relative to others
- Science identity: A reference to whether or not a person views themselves as a science person, whether others view them as a science person, as well as the prominence and salience of that identity
- STEM degree program: Program designed to enhance learning in the disciplines of science, technology, engineering and/or mathematics

Assumptions, Delimitations, and Limitations

Qualitative research assumes that the researcher is the primary instrument as meaning is constructed and analyzed inductively and deductively (Creswell, 2018). A pre-screening survey was sent to elicit voluntary participation in this study. Using semi-structured questions, personal interviews were used to query participants to recall their earlier experiences retrospectively. This research approach introduced several assumptions, limitations, and delimitations.

Participants were graduates from a small urban public high school that are currently enrolled in a variety of undergraduate STEM degree programs. As will be discussed in Chapter 5, using this sample of convenience limited the generalizability of this study's findings. Before interviews commenced, respondents were reminded how their identity and personal information would be kept confidential, so it was assumed they were being truthful in sharing information during the interviews. It was also assumed since the interviewees were former students in one or more of the researchers' classes while in high school, bias in their responses could emerge. The views of each participant are recognized as a product of their lived experience. We acknowledge that each individual processes these experiences through personal "filters" and thus may have been recalled incorrectly and/or influenced by personal bias (Creswell, 2018). Some respondents may have more detailed memories and their ability to articulate what they recall could be better than others' abilities.

Examples of limitations and delimitations are represented in Chapter 3 as the objectives, research questions, sampling methods, and interview procedures are described in detail. Participation was restricted to graduates who are currently enrolled in a postsecondary educational program and pursuing a course of study in a STEM field. The number of graduates from this high school is typically fewer than one hundred students each year. Graduate contact information was limited to students who voluntarily left email addresses and other contact information with their high school administrators and counselors. To increase sample size, all survey respondents who were interested in being interviewed were included. The interviewees were deliberately selected to examine students whose science identity is still in development as they are pursuing a STEM degree. Interview sessions were administered by a teacher from the high school from which the subjects graduated and conducted by each participants' former science teachers. To minimize researcher bias, participants were randomly assigned to the three different interviewers. The research questions focus on describing similarities and differences between gender and racial subgroups. Efforts to include representatives from these subgroups in the final interview sample was limited by who voluntarily responded to the survey invitation and were also willing to be interviewed. After a thorough search of the literature, Carlone & Johnson's (2007) science identity framework seemed the most appropriate to guide our research into the development of science identity.

Conclusion

There is a critical need to address both scientific literacy and interest in the STEM fields in science classes for all students. Students in many subgroups tend not to enroll in upper level science classes or pursue STEM degree programs (National Science Foundation, 2019). Educational reform requires evidence-based strategies to address this gap that are built on conceptual understandings of motivation and achievement (Cook & Artino, 2016; Williams, 2011). This research continues to be relevant as science identity is a significant factor in the gender and racial gap problem within the STEM disciplines. Further, identity research can determine the specific factors that best support science identity formation that promotes persistence of minority students in STEM-related degree programs (Estrada et al., 2011; Hernandez et al., 2013). By analyzing past research, we can design programs and curricula to help address society's need for a scientifically literate populace and workforce. Fostering healthy science identities should be an essential component of the science education process.

Chapter 2

Review of the Literature

Chapter 2 explores the factors that underlie the gender and minority gaps present in STEM education programs and careers. One contributing factor is motivation which is defined as the process of establishing goals and working towards achieving them (Schunk et al., 2014). Modern-day theorists have proposed different ways to study and explain motivation and its relationship to identity. Many leading theories, such as attribution theory (Weiner & Kukla, 1970), expectancy-value theory of achievement (Eccles, 1983), goal orientation and implicit theories of intelligence theory (Dweck & Leggett, 1988), self-determination theory (Deci & Ryan, 2000), and social cognitive theory (Bandura, 1977) share common characteristics. Each of these theories focus on four concepts: competence, value, attributions, and cognition (Cook & Artino, 2016). Examining these different theoretical frameworks provides understanding of what motivates students to take an interest in STEM and pursue coursework and careers. The chapter concludes with an examination of identity theory and its use as a research lens to understand motivation and persistence in STEM degree programs.

Search Description

A wide-ranging search for past and current literature was performed using online databases including EBSOhost, ERIC, Education Full Text, SCOPUS, and others. Online search engines such as Summon, Google, Google Scholar were utilized. Major search terms included: *identity, science identity, motivation, persistence, self-efficacy, expectancy value theory, self-determination theory, attribution theory, goal orientation and implicit theories of intelligence, social cognitive theory, STEM and gender gap, STEM and race/ethnicity gap, and STEM education.* The results of these searches were examined carefully and summarized to better understand underlying frameworks that define how science identity forms.

Review of Research

STEM and Gender

The National Science Foundation (2019) uses the term STEM to include areas such as physics, chemistry, biology, computer science, engineering, psychology, and social sciences when referring to college majors of study and careers. There is debate as to whether the U.S. educational system is preparing enough STEM workers. For several decades after World War II ended, the majority of STEM workers in the U.S. were White and male. Workers were in high demand as technology continued to evolve at a rapid pace (National Academy of Sciences, 2010). This fast-paced growth in technology eventually led to a long-held belief that the U.S. was not producing enough STEM workers when compared to other countries. While there is a lack of consensus concerning exactly how many more STEM workers will be needed in the future, an increased demand is still likely (Anft, 2013; Pierce, 2013; Smith, 2017). Employment has increased in STEM-related fields by 79% in the last 30 years, mainly in technology and computing (Funk & Parker, 2018). Regardless of the anticipated need, a great disparity in diversity among STEM workers continues to persist (Stets et al., 2017).

Despite efforts to increase the emphasis on STEM education among K-12 girls, women are not choosing to enter STEM-related degree programs and careers as frequently as men. Fewer than 30% of people who earn a doctorate in physical sciences, mathematics, or statistics are women (National Science Foundation, 2019). In 2017, men outnumbered women in STEM-related careers; nearly 72% of the STEM workforce is comprised of men, compared to 28 percent of women. Women who enter STEM-related degree programs often choose the biological and social sciences. In 2016, women earned around half of the college degrees awarded to students in the life sciences and nearly 75% of the degrees in psychology were awarded to female students (National Science Foundation, 2019). The National Science Foundation (2019) reports that engineering, physics, and computer sciences have the lowest levels of female participation. Opportunities and participation shown by women in STEM-related fields have increased, but these gains are disincentivized when overall men still earn higher wages than women in many workplaces (Hegewisch et al., 2015).

Researchers continue to explore the many factors that lead to the gender gap in STEM-related fields. Cultural and gender stereotypes posit that boys are better at mathematics and science than girls (Nosek et al., 2009). It is thought that these stereotypes can begin as early as elementary school and can persist well into adulthood (Steffens et al., 2010). Researchers have observed girls in grades 6 through 8 demonstrate less interest in math when compared with boys in math and science classes and that this fosters the development of social stereotypes (Calabrese Barton et al., 2013). A lack of encouragement and support from the parents and teachers of young girls could serve as a possible explanation for the gender stereotypes and the impact on their science identity (Cundiff et al., 2013).

While balancing work and family life continues to be a challenge for both men and women in the STEM sciences, it is women who struggle more than men (Raddon, 2002). In 2017, women were four times more likely to cite family responsibilities as a reason for not working in a STEM-related field when compared with men (National Science Foundation, 2019). Female engineers who demonstrate persistence and learn to negotiate within a male dominated profession usually have high levels of self-efficacy but are less likely to have children and husbands (Buse et al., 2013). Despite men taking on increased roles and responsibilities within the traditional family structure, women in families usually spend more time with children and housework than men (Coltrane, 2004). The careers of men often take precedence over women’s in traditional heterosexual family relationships (Stone & Lovejoy, 2004). This pattern is observed across racial, socioeconomic, and ethnic backgrounds (Leonard, 2003). Further, women report feeling their “biological clock” and having children interferes with their decision to enter STEM-related academic fields (De Welde & Laursen, 2011). This contributes to an internal discourse of requiring women to choose between pursuing a career in STEM and their families. Work-life balance issues and internal choice discourses are not unique to women in the STEM fields and family gender roles impact families in many different ways. However, universities and employers should provide “family friendly” work environments and understand how family gender roles contribute to the lack of female representation in STEM (Beddoes & Pawley, 2014).

Gender inequality, interest and motivation, gender stereotyping, lack of encouragement, work-family balance, and lack of role models are just some of the prevailing reasons why the gap continues to persist (Ceci and Williams, 2010). Many of the factors that contribute to the gender gap in STEM can be directly addressed in education. A lack of female representation in STEM careers has shown to decrease the number of role models available for younger women (Chang et al., 2008). The addition of positive role models plays a significant role in the development of motivation, self-perception, and interest. The number of female STEM teachers working in schools is greatly influenced by gender-related experiences. Whereas difficult, universities can attempt to attract, train, and develop a faculty that is gender-balanced (Sinclair, 2008). Providing more female role models in schools could increase motivation and interest for women choosing to pursue careers in the STEM fields. Legewie and DiPrete (2014) successfully reduced the gender gap 25% by focusing on the female STEM experience at school. They suggest two ways to improve female participation and performance in STEM courses: participation in gender-integrated extracurricular activities and a well-developed science and math curriculum.

Schools in both K-12 and postsecondary levels have begun investing considerable resources to improve STEM curriculum and educational programs.

Research indicates the overall performance gap between males and females has been reduced significantly on math assessments (Hyde et al., 2008). Many schools have implemented targeted interventions to encourage females to take more upper level mathematics courses along with their male peers (Buchmann & DiPrete, 2006). Colleges and universities are modifying their curriculum to increase female participation in computer science. Harvey Mudd College lowered the gender gap in computer science courses by creating tiered courses and improving the overall curriculum by adding more language and problem-based learning experiences (Klawe, 2013). This increased the level of interest in female students and improved the overall motivation and performance in male students. The need for a strong science curriculum and improved standards is supported by most people (Achieve Inc., 2012). Many states have already adopted the Next Generation Science Standards (NGSS). States who adopt the NGSS standards aim to meet the needs of diverse learners in K-12 schools by driving curriculum reform that helps teachers prepare students for the STEM disciplines (Rennie et al., 2012). The NGSS are nested within crosscutting concepts that weave scientific content with scientific practices. While reforming and improving the science curriculum is another way to decrease the gap, the novel approach of the NGSS may not be suitable for diverse, non-dominant groups (Legewie & DiPrete, 2014).

STEM and Race

The underrepresentation of both racial and ethnic minorities in STEM has been a problem of concern for several decades (Crowley, 1977). This issue persists today in both STEM degree programs and STEM careers. At the postsecondary level, minority students are less likely to earn a degree in a STEM-related field as compared to White students. The higher the level of the degree, the greater the level of the disparity; in 2016 minorities received only 22% of science and engineering bachelor's degrees, 13% of master's degrees, and 9% of doctorate degrees (National Science Foundation, 2019).

Minority students who enter college with the intent to study STEM-related subjects switch to other fields at a higher rate than White and Asian students. The rate of attrition for minority students in their first year of college is highest at selective institutions and lowest at Historically Black Colleges (HBC) (Chang et al., 2008). Colleges and universities with stricter admission standards create a competitive environment that minorities perceive as negative and disempowering (Hurtado et al. 2016). In terms of STEM careers, Blacks and African Americans, Latinos, and Native Americans are employed in STEM related fields at levels much lower than Whites and Asian Americans (National Science Foundation, 2019). Underrepresented minorities including Asian, Black and African Americans, and Hispanic only comprise 29% of those employed in STEM occupations compared to 69% of occupations held by Whites (Funk & Parker, 2018).

The academic achievement gap between White and minority students has been a persistent and pernicious challenge in public education. The past several decades have seen this gap fluctuate between narrowing and increasing (Haycock, 2001). An accurate understanding of this gap lies in focusing on the roots of systemic socioeconomic and racial inequalities in both education and in society (Museus et al., 2011; Rothstein, 2015). This achievement gap is present as early as kindergarten and continues to grow in the primary grades (Fryer & Levitt, 2004; Reardon, 2008). The National Assessment of Educational Progress (NAEP) reports that minority students in grades 4, 8 and 12 continue to perform below White students in math and science; gains in narrowing the achievement gap in math and science within the last few decades have stagnated (McFarland et al., 2018). The NAEP reports the percentage of students eligible for free or reduced lunch under the National School Lunch program as a designation of a low, mid-low, mid-high, or high poverty school. In 2015-2016, the percentage of Black and Hispanic students attending high poverty schools was greater than White students (45% and 45% versus 8%, respectively).

Research suggests no single issue is the sole cause of the achievement gap; many reasons have been suggested including inequities in quality educational opportunities (Estrada et al., 2016; Haycock, 2001; Rothstein, 2015), lack of perceived relevance within STEM curricula (Kennedy & Odell, 2014), and a lack of role models or mentors in the classroom (Price, 2010; Strayhorn, 2015). As students encounter learning difficulties in STEM classes some may feel like they cannot be successful and decide to give up. This negative experience can produce a range of behaviors pertaining to academic focus and persistence between individual students in STEM classes (Lin-Siegler et al., 2016). Students in many subgroups tend not to enroll in upper level science classes or pursue STEM degree programs (National Science Foundation, 2019).

The underrepresentation of minorities in both STEM degree programs and careers has been the focus of several large-scale initiatives involving educational researchers, policymakers, and practitioners (Museus et al., 2011; Olszewski-Kubilius et al., 2017). Museus et al. (2011) provide a comprehensive summary of the educational research focused on supporting ethnic and racial minority students in STEM; in K-12 environments these factors include parental involvement and support, culturally relevant teaching (CRT), early exposure to careers in STEM, increased interest in STEM subjects, and supporting self-efficacy in STEM domains. The support of parents towards prioritizing education overall, and STEM in particular, has shown to contribute to persistence in a STEM education tract (Aschbacher et al., 2010; Russell & Atwater, 2005). The concept of culturally responsive pedagogy focuses on the role of culture in learning, and it was first introduced as a method to focus on academic achievement while respecting African & African-American culture (Ladson-Billings, 1995). Integrating both CRT with inquiry-based STEM practices in the classroom can help bridge the minority gap in STEM disciplines (Brown, 2017; Denson et al., 2010; Rolon, 2003). Exposure to challenging coursework and increased rigor at the secondary level is a strong predictor of one's ability to persist within a postsecondary STEM degree program (Adelman, 2006). High teacher expectations and rigorous coursework help build pre-college self-efficacy and a nurtured interest in STEM at a young age, leading to persistence at the post-secondary level (Strayhorn, 2015).

At the college level, participation in academic support programs reduces the loss of minority STEM students. Minority freshmen who joined a science related club were 150% more likely to remain enrolled in a STEM program (Chang et al., 2008). Participation in undergraduate research was also strongly correlated with minority STEM retention; participants reported increased self-confidence when they practiced components of the research process: study design, data analysis, and scientific communication (Lopatto, 2010). Research programs provide students with a learning community where relationships form with peers and mentors. When measured from a goal-orientations perspective, undergraduate research opportunities and growth in scientific self-identity increases student persistence in Black and Hispanic students (Hernandez et al., 2013). In addition to academic support and opportunities for research lies the need to address the affective domain of students in STEM (Trujillo & Tanner, 2014). Identity and sense of belonging play contributing factors in the persistence of underrepresented minorities in STEM majors (Rainey et al., 2018). Finally, there is a need for better tracking of students who enroll in a STEM college track in order to better understand their progress and persistence and the unique challenges underrepresented minorities face (Estrada et al., 2016).

Motivational Theories

Attribution Theory. Attribution theory explains how people interpret outcomes by identifying responsible factors including effort, ability, task difficulty and luck (Weiner

& Kukla, 1970). These attributions can be viewed by their *locus*, *controllability*, and *stability*. Locus denotes the location of the factor: whether an internal cause such as effort, or an external cause such as task difficulty. Controllability indicates whether the factor can be altered. Stability refers to whether the factor is temporary or expected to last. Attributing causation influences responding behaviors. The degree to which these factors influence an outcome determines perception of success. A *situational attribution* ascribes blame to external factors such as the difficulty of a test. A *dispositional attribution* finds that internal factors are responsible such as poor time management (Heider, 1958). Rationalization of personal behavior tends to stress situational explanations while dispositional causes are overemphasized in others (Jones & Davis, 1965). For example, a student might blame a poor grade on the difficulty of the assignment while believing that others scored poorly because they did not study a sufficient amount of time. This differential ascription of blame for others is culturally influenced and is more pronounced in individualistic than collectivist cultures (Miller, 1984; Pilati et al., 2015).

Identification of responsible factors changes from childhood to adolescence (Kurtz-Costes et al., 2008). Before the age of five, effort is equated with ability. In the early elementary grades, effort is perceived to cause outcomes; those who exert similar effort are expected to attain similar results. By middle school, effort and ability are viewed as distinct; a person's ability to succeed can be limited by ability, regardless of effort. Distinguishing between ability and task difficulty also changes throughout development (Nicolls, 1990). The egocentric young child equates ability with difficulty; inability to complete a task means one is incapable. The older child understands levels of difficulty and recognizes that more ability is required for more difficult tasks.

Gender differences exist in the ascription of causal factors with males being more likely than females to attribute internal causes to their success (Frieze, 1975). These differences are domain specific with minimal differences noted for verbal ability (Clem at al., 2018). Female students more frequently identify effort, not ability, as the cause of success in mathematics (Frieze et al., 1982) and science (Kahle et al., 1993; Li & Adamson, 1995). While effort contributes to what females attribute their success to in mathematics and science, ability also plays a role. When content becomes more difficult, female students who believe they have less ability are more likely to give up, adopting an attitude of learned helplessness (Farmer & Vispoel, 1990).

Differences in attributions have also been noted between racial groups. African American students are more likely to identify ability as cause of academic success compared to Caucasian students (Swinton et al., 2011). African American students who attribute their success to unstable factors are less likely to report confidence of future success (Graham et al., 1996). Students can be taught to revise their beliefs of causative factors (Haynes et al., 2006). Retraining programs have altered student perception of controllability and improved academic achievement (Perry et al., 2014).

Expectancy Value Theory. Expectancy Value Theory seeks to explain whether a person will be motivated to achieve. *Ability belief* means whether a person feels they are able to complete an activity. *Expectancy beliefs* relate to whether a person feels they can accomplish an upcoming task (Eccles, 1983). While ability refers to one’s competence in the present, expectancy considers their potential in the future. These two facets are distinct but correlated (Wigfield & Eccles, 2000). Motivational choices are also influenced by *value beliefs* or the value placed on an achievement (Eccles,1983). The value ascribed to a task is based upon its perceived utility to the individual: value may be granted to work that is deemed important. Enjoyment of an activity or interest may also determine value. An additional consideration is cost and whether the task merits the required effort, the negative effects (such as stress), and it's worth compared to other choices.

Together, expectancy and value beliefs influence academic effort (Eccles,1983). A student's perceived ability to perform well on a task influences the value placed upon it. If a student expects to do well in a math class, their performance exceeds that of students who do not expect to perform well. This observation concurs with the aphorism that “whether you think you can or you cannot, you’re correct.” Expectancy value beliefs can be used to predict academic achievement (Meyer, 2019; Trautwein et al., 2012). Students placing greater value in and feeling more competent in a subject were found to earn higher grades. Expecting success and valuing a task influence behaviors associated with homework (Trautwein et al., 2006). Expectancy beliefs (possessing the competence for the assignment) and value beliefs (finding the work useful, important or interesting) predict the effort expended and quality of work completed. The relationship between expectations and values is multiplicative rather than additive (Nagengast et al., 2011; Trautwein et al., 2012). High scores can only be achieved when both expectations and values are large. While low scores in one can be offset by a high score in the other, if either expectation or value is very low, the other variable cannot overcome this.

Expectancy and value beliefs are frequently task domain specific (Trautwein et al., 2006). Examples of task domains include athleticism, mathematics ability, social behavior, etc. A student may have high expectancies and place great value in one domain, but low expectancies and value in another, even if the performance is the same in both. This domain specificity can predict the completion of homework; the greatest engagement is observed in domains where students report the highest expectancy of success and find the most value in the work (Nagengast et al., 2013). Choosing to pursue a course of study in STEM is correlated with expectancy value beliefs. Students with higher expectations and values related to STEM are more likely to choose STEM coursework at the secondary level (Caspi et al., 2019) and as a university major (Gaspard et al., 2019).

Understanding both expectancy and value beliefs has implications in addressing the gender and racial gaps in STEM. Gender differential treatment can impact students' beliefs and achievement (McKellar et al., 2019). Female students disproportionately report low math with high English expectancy value beliefs (Gaspard et al., 2019). When female students reported that teachers treated males differently, lower beliefs for expectancy and value were observed. The reduced expectancies and values were then correlated with lower grades and test scores. The impact was greatest in middle school and the negative perception persisted into high school (McKellar et al, 2019; Gaspard et al., 2020). Expectancy value beliefs differ between racial and ethnic groups, with fewer minority students rating science classes as having a high utility value (Hines, 2003). Examples of same-race peers, teachers and role models exist much more frequently for White students, reducing minority expectations for success in science courses (Cooper, 2011). STEM careers are considered a less plausible possibility by minority students as compared to Whites (Archer et al., 2007).

Interventions that address expectancy value beliefs have improved student attitudes toward STEM (Phelan et al., 2017). When students examined their self-perceptions and journaled about their beliefs and values, interest in science and persistence increased. Written utility value interventions can improve course grades as well as student attitudes toward STEM (Hecht et al., 2019). Participation in STEM-focused workshops increases both value beliefs and competency within a domain (Ball et al., 2017). Incorporation of similar strategies may help address the shortage of women and minority students in STEM fields.

Goal Orientation and Implicit Theories of Intelligence. Goal orientation theory focuses on two cognitive orientations or self-views (Diener & Dweck, 1978). Students with a *mastery orientation* focus on improving their abilities to achieve success with the practice of learning rather than the learning task itself. Holding this self-view allows students to see the process of learning as a growth opportunity (Dweck & Sorich, 1999). In contrast, students with a *performance orientation* are more concerned with accurately completing a learning task than succeeding at the process of learning itself. Failing an assignment is perceived as a negative experience and symptom of possessing low-level abilities. Eventually, students with this self-view may decide to give up or exhibit signs of apathy. Holding this self-view can be detrimental and lead to lower performance and negative self-perception (Diener & Dweck, 1978). Students with mastery orientation believe their ability can improve or change over time, but students with helpless orientation believe their ability levels are fixed and cannot change (Robins & Pals, 2002).

Closely related to goal orientation theory is the theory of implicit intelligence. This theory examines how an individual's personal beliefs about learning, or *mindset*, affect their ability to set and master goals. People with a *growth mindset* possess a mastery orientation or a willingness to both accept challenges and to seek knowledge (Dweck, 2017). A person with a growth mindset adopts an *incremental theory of intelligence*, believing that because brains are malleable, intelligence can increase. An individual with a *fixed mindset* follows an *entity theory of intelligence,* believing that a person's traits are fixed and unchangeable. Individuals with a fixed mindset adopt a performance orientation which involves learning with the objectives of earning good grades, appearing smart, and performing better than others (Simon et al., 2015). While these contrasting viewpoints, sometimes felt unconsciously, align with goal orientation theory, implicit theories of intelligence suggest mindset can be changed (Dweck and Leggett, 1988).

The theory of implicit intelligence plays a role in development and learning. Young children who demonstrate a growth mindset tend to pay more attention to their errors. This leads to a reduction in errors when engaging in subsequent tasks (Schroder et al., 2017). Children with a fixed mindset show much less resilience when faced with challenges; viewing failures as lack of ability rather than an opportunity for growth. The language used by adults during the development of a child can support the adoption of a growth or fixed mindset. When children are told that they are smart, they develop a fixed mindset that connects their intelligence to an inborn characteristic. If instead adults offer praise for specific actions, such as working through difficulty, then children associate their intelligence with behavior. Children who adopt a growth mindset are more likely to attempt challenging tasks in the future and report a greater sense of enjoyment of learning (Dweck, 2008). Parent and teacher perceptions on student mindset can influence the development of children with whom they interact (Frome & Eccles, 1998). When parents believe that their child will not be able to complete a task, the child tends to adopt that fixed mindset and their academic grades suffer as a result. Parents also influence career considerations (Jodl et al., 2001). When parents were asked to evaluate the likelihood of their child completing advanced studies and finding employment, their ratings were directly related to the values and beliefs expressed by the children. Parents who tend to have a fixed mindset often instill this same mindset in their own children (Haimovitz & Dweck, 2016).

Differences are noted between gender groups. Female students are more likely than males to adopt a fixed mindset when confronted with challenging material in math or science (Dweck, 2007). Underperformance by females may be exacerbated by the belief that females as a group are less likely to possess an innate ability to succeed in STEM subjects (Wang & Degol, 2017). Female secondary students with a growth mindset place a higher task value in math classes (Degol et al., 2018) and are more likely to choose future advanced mathematics courses (Good et al., 2012).

Educators' perception of students influences students’ perception of themselves; and this sense of competence persists even after the students have advanced to a new grade level (Reddick, 2011). Students internalize negative perceptions and then fail to move beyond an adopted fixed mindset. The mindset beliefs of STEM faculty can serve as a predictor for racial achievement gaps in STEM courses (Canning et al., 2019). When teachers have low expectations for particular racial groups, minority students may be disproportionately affected by self-reinforcement of this negative self-perception. For students who are identified as learning disabled, teachers were not found to impose a fixed mindset on these members of the school population (Gutshall, 2013). The reason for this result may be that school districts are mindful to avoid 'labeling' students, therefore the teachers are less likely to limit their perception of learning disabled students' abilities. This approach could be applied to minority students to address teachers' lowered expectations for this demographic group.

Implicit theories are effective predictors of self-regulatory behaviors and achievement (Burnette et al., 2013). Teachers can use interventions to help students assess their mindsets and improve their ability to self-regulate (Dweck, 2017). These interventions can consist of introductory lessons on the malleability of human brains and how learning works. Teaching students the skills necessary to have a growth mindset can help increase self-regulation and achievement, particularly among females and ethnic minorities (Good et al., 2003).

Self-Determination Theory. Self-determination theory emphasizes the reasons a person is motivated to do the things they do (Deci & Ryan, 2000). This focus on an underlying premise or causality is what differentiates it from other motivational theories. Self-determination theory distinguishes between *extrinsic* and *intrinsic factors* to explain how motivation affects people's choices. Extrinsic factors are external variables, separate from the individual, that affect behaviors and outcomes. Frequently this is a reward such as recognition or compensation, but it can also entail compulsion or punishment. Intrinsic factors involve what is innately interesting and desirable for the individual. Usually these behaviors satisfy some innate need or desire and lead to feelings of autonomy and satisfaction in learning. Intrinsic motivation stems from an innate need to feel competent and in control of one's own decisions.

Extrinsically motivated behaviors can lead to reduced satisfaction, less autonomy, and overall reduced performance (Deci & Ryan, 2000). For example, research on the effects of motivation extends from the classroom to the business world (Pink, 2009). Fostering intrinsic motivation increases student engagement which can increase the likelihood that students will develop self-confidence, competence, and self-efficacy (Bandura, 1977). Teachers can focus on developing their students' individuality while increasing student engagement through authentic learning and engagement (Saeed & Zyngier, 2012). To elicit intrinsic motivation, teachers can obtain student input and allow them to have autonomy over what and how material is being taught (Filak & Sheldon, 2003). Methods that involve student choice of study topics and work pace help to increase intrinsic motivation which is then a good predictor of well-being and academic success (Hall & Webb, 2014; Reeve et al., 2009). By fostering a sense of student autonomy in the classroom both engagement and academic achievement can rise (Deci & Flaste, 1995).

In light of the gender and racial gap in STEM, self-determination theory provides a useful framework for studying motivation and persistence. Support for student autonomy and active learning in STEM classrooms holds great potential for enhancing academic achievement and psychological development (Black & Deci, 2000; Lavigne & Miquelon, 2007; León et al., 2014). Further, outreach programming aimed at high school students can increase student motivation and attitudes towards STEM careers (Ortiz et al., 2018; Vennix et al., 2018). At the college level, this framework can reveal the motivation of research mentors in order to improve the role that race and ethnicity play in the mentoring relationship (Butz et al., 2018). By implementing the self-determination framework in the development of inclusion initiatives in STEM, educators can promote autonomy and competence in all students. This has further implications towards narrowing the gender and racial gap in both STEM education and careers (Moore et al., 2020).

Social Cognitive Theory. Social cognitive theory aims to incorporate the social aspect of learning as it seeks to understand motivation. The concept of *self-efficacy* was established by psychologist Albert Bandura (1977) as part of the development of social cognitive theory. This concept was developed to explain how individuals who gained skills to succeed in certain tasks differed in their perceived ability or confidence to use these techniques in a new setting. The definition of self-efficacy can therefore be described as an individual's belief that they will succeed at context-specific tasks or situations (Bandura, 1977; Bandura, 1997). Hence, while the statement "I am good at science" is a statement of confidence, a demonstration of high self-efficacy may be "I believe that I can write a quality lab report based on my experiment." This differs from other concepts such as self-esteem (the self-respect one has), self-concept (a more general, evaluative construction of self-knowledge), outcome expectancy (the value or importance one places on an activity towards meeting a desired goal), and perceived control (whether outcomes are largely due to internal or external forces/control) (Zimmerman, 2000). Ultimately, a sense of self-efficacy is less about prior accomplishments, knowledge, and skills one has obtained and more about the beliefs one has about how they will perform within a context-specific situation (Bandura, 1997; Pajares, 1996; Zimmerman, 2000).

Zimmerman (2000) summarizes four factors that contribute to a sense of self-efficacy: *personal mastery experiences*, *vicarious experiences*, *verbal persuasion*, and *physiological states*. Personal mastery experiences relate to the previous successes and failures an individual has had in regard to a specific task. Vicarious experience is when an individual identifies with another person of the same identity group (e.g. sex, gender, ethnicity, socioeconomic group, etc.) and how they perform in a specific situation. Verbal persuasion results from an individual's perception of outside expectations or the verbal praise, advice, or admonishment one receives. Finally, physiological states consist of the emotional states that arise in specific situations and how an individual reacts to these feelings.

The relationship between self-efficacy and academic performance in the STEM disciplines raises two interesting questions. The first question is how self-efficacy is related to an individual's understanding of intelligence and their internal motivation. According to Dweck (1999), this understanding may be divided into two groups: those who interpret intelligence as something that is fixed versus those that interpret intelligence as being malleable or able to be changed. There is evidence that a sense of self-efficacy is tied to perception of intelligence. For example, college students that exhibit high self-efficacy may also tend to believe intelligence is malleable, as opposed to students with low self-efficacy who understand intelligence as innate; this relationship was also found to correspond with grade point average (Komarraju & Nadler, 2013). Further, a meta-analysis spanning 12 years of research found a moderate correlation between self-efficacy and academic performance at the university level (Honicke & Broadbent, 2016). Self-efficacy may also be tied to motivation and interest. An explicit, project-based approach to STEM education in middle school showed that this method could increase interest in STEM, STEM self-efficacy, and student persistence in engaging with STEM content (Brown et al., 2016).

The second question that arises is how both internal and external expectations may influence self-efficacy. It has been found that self-efficacy may compensate for differences in a student's academic background, where individuals with a high sense of self-efficacy but with a poor academic background perform just as well as those with a low sense of self-efficacy and a high academic background (McConnell et al., 2010).

There is evidence that individuals with a higher sense of self-efficacy also set and embrace more challenging goals for themselves (Komarraju & Nadler, 2013; Zimmerman et al., 1992). When course expectations are clearly defined, student success and a higher sense of self-efficacy result. Pleiss et al. (2012) found that when students could directly identify intended course goals, they recorded higher rates of self-efficacy; in contrast, lower self-efficacy was prevalent when understanding of course goals was not in alignment with instructional goals for the course.

There is a gender and minority gap as measured by an individual's sense of self-efficacy in STEM disciplines. Controlling for course performance, Hardin & Longhurst (2015) found that women in a college-level chemistry course reported lower self-efficacy and interest in obtaining a STEM degree than men and that this sense of self-efficacy did not change substantially over the course of the semester; alternatively, men within the same course reported an increase in perceived support and interest to pursue a STEM career. This problem is not unique to the United States. In Sweden, this is evidenced by the low numbers of women in STEM careers and in contrast by the low number of men in HEED (i.e. health care and education) careers; these gaps have been attributed to women who report lower self-efficacy compared to men relating to the STEM fields (Tellhed et al., 2017). However, other factors including a lack of social belongingness accounted for the lower interest in HEED careers by men.

There is evidence that the degree to which multiple factors affect self-efficacy may differ based on gender and race. Zeldin et al. (2008) interviewed men in STEM careers to determine what factors affected their success and, hence, confidence and self-efficacy; the researchers found a high occurrence of mastery experiences and stories of personal success, in addition to a high belief in natural talent, as shared by the interviewees. Alternatively, when Zeldin & Pajares (2000) interviewed women in STEM careers it was found that verbal praise and support and seeing other women succeed in

STEM fields were perceived as greater influences on their self-efficacy. While other studies have found similar connections (Lee et al., 2014), the factors that impact self-efficacy in minority students may differ. MacPhee et al. (2013) found lower incidences of self-efficacy in women as compared to men, and this gap was even greater for students who were both minority-status and in a lower socioeconomic group. Flowers & Banda (2016) argue that the creation of a "science identity" is another crucial component, particularly for minorities, of self-efficacy in the STEM-related disciplines; they argue that minorities need more vicarious representatives in addition to academic support. Efforts to improve self-efficacy in minority students have been demonstrated in areas where unique programming, such as opportunities for undergraduate research, were provided (Carpi et al., 2017).

Identity as a Research Lens

Identity Perspectives. Identity refers to being recognized as a certain kind of person. Gee (2000) described different ways that a person can view their identities. From a *nature perspective*, identity is formed as a result of natural forces, such as genes or neurological condition. Using this perspective, a person might identify as being hyperactive or being a sibling. Both of these are conditions due to nature and not society. The significance of these identities is shaped by interactions with other identity perspectives. The possession of a gallbladder may be a natural but insignificant facet of identity, while having a twin may contribute strongly. The *institutional perspective* of identity is not obtained from nature or personal effort but as a result of position in an organization. This perspective relinquishes power for identity formation to the principles of authorities in that institution. Individuals may interpret the roles associated with an institutional identity in a positive or negative way. An active child could develop a positive identity with an athletic group but possess a less positive identity in a classroom. A *discursive perspective identity* is a trait created by an individual and verified through discourse with others. As an example, a person may believe that they are a shy person because interactions with others determined this identity. From an *affinity perspective*, identity results from membership in an affinity group: a shared allegiance to a practice or culture. The focus is not on the group members, with whom they may have little in common; instead the focus is on a common practice such as being a fan of a particular television show. Sharing this experience affects how this person views who they are. Identity is unique to each individual based upon their personal genetic makeup, experiences and roles.

Within these different perspectives, individuals develop a multitude of identities. The degree of connection with each identity varies depending on time and context (Reitzes & Mutran, 1994; Stryker & Serpe, 1994). The formation of identities is a fundamental task during adolescence (Erikson, 1972). Youth continuously explore and consider alternatives, changing identities throughout the teenage years (Klimstra, 2010). Identities continue to form and be revised in adulthood and are dependent upon environmental factors (Danielewicz, 2001).

No identity can be understood in isolation but it must be considered in relation to other identities (Jones & McWeen, 2000). In a group of young artists, an identification with an age group or an affinity for art may not be significant. If a member is much older than the other members, generational identity becomes more prominent. Context determines the interplay of identities. If an identity is considered more *salient* than other forms of identity, it is more likely that behaviors will be chosen in accordance with that identity (Stryker & Burke, 2000). For example, a more salient maternal identity predicts greater involvement in child care (Gaunt, 2008). Further, higher religious identification is associated with greater participation in religious activities (Brenner et al., 2014). The ability to express more salient identities leads to increased self-esteem and less psychological distress (Reitzes & Mutran, 1994). *Prominence* is a similar but separate concept and refers to the value an identity is given relative to other identities (Brenner et al., 2014). Identification as an inmate may be highly salient when one engages in the behaviors of the incarcerated, but this identification would not be prominent if the person does not give value to this identity.

Science Identity. Science identity refers to people's thinking of themselves as a science person (Carlone & Johnson, 2007). The intent to pursue a science related career is only one indicator of a science identity; more important is whether one sees themselves as a science person. The behaviors one adopts corresponds with their identity, so that another person should be able to confirm someone else's identity simply by observing their behavior (Stets et al., 2017). The more prominent a person's science identity, the greater the influence this identity has on their behavior, a positive feedback action. In addition to how one thinks of oneself, science identity is shaped by whether others perceive them as a science student (Stets et al., 2017). When self-perception and the views of others match, there is no discrepancy and the person's identity is validated. A difference between self-perception and the views of others produces a discrepancy. A greater value of this discrepancy is associated with a decreased likelihood that the person will pursue a science career. This association is noted whether the discrepancy value is positive or negative.

One developmental aspect of science identity is how an individual compares *who I am* to *who I want to be*. Carlone (2012) describes identity research as an ethnography of personhood. The introspective nature of identity makes it problematic to study in a quantifiable way. Much of the research on science identity applies a qualitative approach based on narrative psychology (Carlone, 2012; Shanahan, 2009). Here identity is formulated as one makes sense of their experiences and situation by creating a narrative of who they are. Researchers focus on the voice of the study participants through interviews and then analyze these narratives. Through this one gains a sense of an individual's identity-in-practice within the science learning environment. This approach has been utilized in ethnographies of minority students in both middle school and high school settings (Brickhouse et al., 2000; Brickhouse & Potter, 2001; Tan & Calabrese Barton, 2008). Such studies take an in-depth look at how different identities, including gender and racial, interact and influence each other. This approach has also been utilized at the university level in both undergraduate and graduate degree programs in STEM (Carlone & Johnson, 2007; Szelényi et al., 2016). It is at this level that participants are often able to articulate the complexities and nuances of their science experiences in education. Researchers can then uncover salient and shared identities that emerge from a group of participants. The qualitative narrative approach reveals how individual agency responds within structures consisting of socially constructed norms and expectations where science learning takes place.

Other research has taken a more quantitative approach through this agency lens. In the form of surveys, large groups of participants are asked questions regarding a range of influential factors that shape science identity. Such a large-scale approach allows data collection that reveals how specific factors, such as student interest in science, gender-biases in science, and fixed versus growth mindsets, shape individual identity within a group (Wonch Hill et al., 2017). Other studies have used a mixed-methods approach, relying on both surveys and interviews to approach science identity. Such methods can reveal not only the science identity of an individual but also how this identity may change temporally (Aschbacher et al., 2010). This approach allows a closer analysis of the factors that shape an individual's choice to persist or drop out of a STEM-related degree program. Finally, such surveys allow researchers to explore and compare both formal and informal learning environments on STEM interest and identity formation (Campbell el al., 2012).

Most research addresses both agency and structure components of identity formation. However, there are research studies that take a more diligent focus on the ways structure shapes science identity. Referencing Carlone (2012) once more, a structural analytical lens involves an analysis of the normative, group-level meanings produced by individuals in a science setting. Rather than explore *who a student is*, researchers must ask *who is a student being asked to be*. Specifically, how are the expectations and norms defined regarding how science is practiced and how one is successful within a classroom? This latter question is specific and unique to different educational contexts. Therefore, structure is one other lens by which to understand science identity formation.

When using the structure lens, the focus is on the institutional or classroom environment. What are the predetermined science identities students are being asked to accept? These identities may be explicit or discrete, and they may be perpetuated by interactions between an institution and a classroom or between students and their teacher (Archer et al., 2017). Researchers may also hone in on a specific aspect of structure. The role that curriculum plays, for example, on science identity can influence how a student sees value or applicable skills/knowledge in science; the degree to which a student feels a sense of choice or influence on curriculum also impacts identity formation (Ulriksen et al., 2017). Understanding a science identity trajectory, or how identity changes temporally and within different structures, can reveal best practices in terms of cultivating identity across different contexts (Calabrese Barton et al., 2013; Jackson & Seiler, 2013).

Finally, Shanahan (2009) argues that much of the science identity research has focused on the agency lens of identity formation to the detriment of understanding more about the role structure plays. Here there is a call for new conceptual frameworks that look more strongly at structure. For example, how are specific norms developed and established within a classroom and how are they used to guide social groups towards predefined science identities? This question can circle back to the role agency plays in identity formation. There is a need to better understand a student's sense of self-efficacy and science identity if one is trying to generate structures that support and nurture science identities that enhance science learning for all (Trujillo & Tanner, 2014).

Conclusion

Research into the role science identity plays with respect to motivation and persistence continues at the post-secondary level. Science identity has a large mediating role on the effects of science support experiences and is a strong predictor of commitment to a science career (Chemers et al., 2011). However, both women and minorities report lower scales of self-perception and science identity compared to males and Whites in different STEM programs (Hazari et al., 2013). When tied to a sense of belonging to a science community of practice, a strong science identity can be the reason women of color persist or drop out of a STEM program (Rainey et al., 2018). Science identity is one of the key indicators that an individual will enter a science occupation after graduating with a STEM-related degree (Stets et al., 2017). Finally, the lens of science identity reveals the particular importance *recognition* by a community of practice has at the post-graduate level, specifically for women and minority students, surpassing the importance of both the concepts of competence and performance (Carlone & Johnson, 2007; Szelényi et al, 2016).

Chapter 3

Methodology

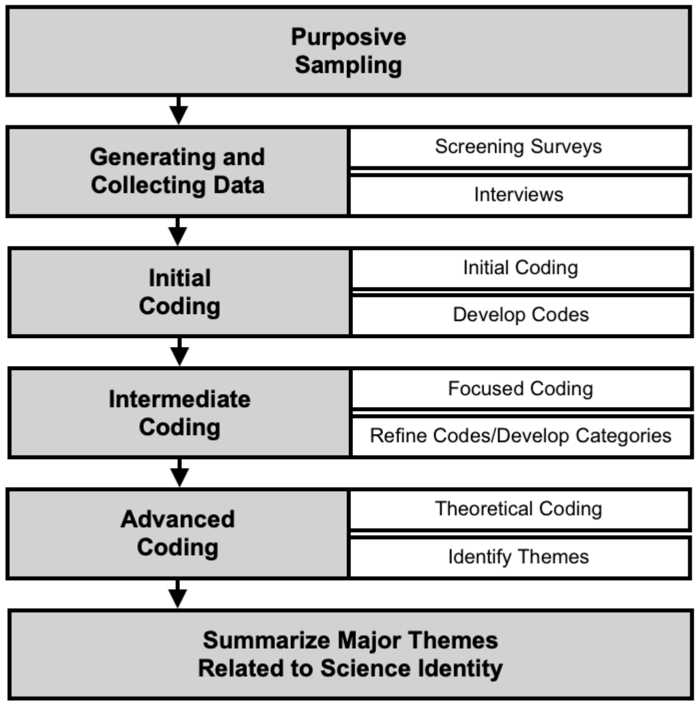
The formation of a science identity plays a role in motivation and persistence for students engaged in a STEM degree program (Graham et al., 2013; Martin-Hansen, 2018). This grounded theory case study explored the science identities enacted by graduates from a Midwestern urban public high school (MUPHS) and who have enrolled in undergraduate STEM degree programs. The research questions were as follows:

1. What influences high school graduates of different gender and racial groups to pursue and persist in a post-secondary STEM degree program?
2. To what degree do high school graduates of different gender and racial groups who enroll in post-secondary STEM degree programs exhibit their science identity?
3. What are the salient forms of science identity among different gender and racial groups enrolled in a post-secondary STEM degree program?

This chapter provides a detailed description of the methodology and research design selected for this study. Next the research setting is described and the selection process for participants. A summary of demographic characteristics of research participants is provided along with a detailed description of the data collection instrument a rationale relating to the research questions. This discussion is followed by the data collection and analysis procedures. The ethical considerations that guided the study is developed in the conclusion. An overview of the methodology sequence is provided in Figure 4.

Figure 4

Methodology Sequence



Note: Adapted from Research Design Framework (Tie et al., 2019).

Research Design

The concept of *science identity* has been posed as a research perspective to understand participation and persistence in STEM career programs. Identity is a multidimensional construct that is continually being developed or modified based on individual contextual social-experiences over time (Carlone, 2012; Gee, 2000). One developmental aspect of science identity is how an individual compares *who I am* to *who I want to be*. Carlone (2012) describes identity research as an ethnography of personhood, and the introspective nature of identity makes it problematic to study in a quantifiable way. Therefore a qualitative research methodology to answer the research questions was selected. A qualitative research design allows the researcher to understand unique individual human experiences involving different phenomena and in various social contexts. Qualitative research is a well-established methodology that seeks to describe, discover, explore, interpret, and verify how and why people behave or personally understand their experiences (Durdella, 2019). Distinct traditions utilizing a qualitative research design, including grounded theory and case studies, are well-supported in the social sciences and in educational research (Creswell & Creswell, 2018; Eisenhardt, 1989; Tie et al., 2019).

The research tradition best suited to answer the questions posed is a grounded theory case study. Grounded theory is a design approach that seeks to develop an abstract theory or explanation that is formulated inductively from data. While the foundational procedure for grounded theory was presented by Glaser & Strauss (1967), Charmaz (2006) further developed the methodology to incorporate a constructivist approach that aims to understand how a subject co-constructs meaning surrounding social phenomena via social interactions. Durdella (2019) states that “the core focus in grounded theory is in data collection and analysis --- or how to make sense of the data collected to build a model that explains patterns in the social world” (pp. 102-103). The steps to carry out a grounded theory approach involve concurrent data collection and analysis, theoretical sampling, and constant comparative data analysis (Tie et al., 2019). This approach allows the appropriate collection of data and use of an analytic process that seeks to find meaning among the relationships between different coded segments of the data. It was hypothesized that science identity plays a critical role in motivation which then transforms an individual’s interest in science into a desire to pursue and do science. Personal semi-structured interviews and qualitative analysis were used to clarify and explain why students chose to enter a STEM field, how science identity develops, and sheds light on the reasons why students persist in undergraduate programs.

While there is debate as to whether the case study approach qualifies as a research tradition (Schram, 2003), that approach allows the researcher to focus on units of analysis that are defined as bounded systems (Creswell, 1996; Merriam, 2009). While grounded theory facilitates the exploration of phenomena, case studies help the researcher set parameters that identify a specific social system in which to study the phenomenon of interest (Durdella, 2019). In addition, Merriam (2009) characterizes case studies as being *particularistic*, *descriptive*, and *heuristic*. This study was particularistic as it focuses on graduates (2015-2019) from the same urban high school and who were enrolled in post-secondary STEM degree programs. The use and analysis of semi-structured interviews allows for a rich description of the corroborating factors that shape science identity within different gender and racial demographic groups. Finally, by focusing on the formation of science identity and how students enact their identities a more nuanced understanding of science identity formation and its role in motivation and persistence, is provided thereby contributing to the current literature.

The concept of science identity as a lens for educational research is relatively recent. Carlone & Johnson (2007) have provided a conceptual model by which to understand science identity and it highlights three dimensions: competence, performance, and recognition. Another application of the case study is to help examine and refine a theory. According to Løkke and Dissing Sørensen (2014), “theory testing using case studies evaluates the explanatory power of theories and their boundaries, thus assessing external validity” (p. 73). The science identity framework as proposed by Carlone & Johnson (2007) was used to explore its applicability to a unique setting and demographic.

Participants and Sampling

All participants attended the same MUPHS with a population of 350 MUPHS students in the 2018-2019 academic year. Forty-three percent of the student body received free or reduced lunch. Demographic information reported that 59.6% White, 24.1% African American, 5.7% Hispanic, 1.7% Asian, 0.6% Native American, and 8.3%

mixed racial groups. The percentage of male and female students was approximately equal with 2% not identifying themselves as either gender. The student-to-teacher ratio was 12:1. One hundred percent of faculty met the state's department of education criteria to be classified as 'highly qualified', 17.7% received National Board Certification, and 84.3% have a master's degree or higher. There was one female and three male faculty members in the science department, and there was one female and three male faculty members in the math department. All STEM faculty were White.

This research sought to examine the factors that influence motivation, persistence, and the development of science identity. By using the only high school in one school district, the population of respondents would have a shared set of academic experiences and exposure to scientific disciplines. Thus, study participants were selected based on a convenience sample. Three units of science and three units of mathematics are required for graduation. The science sequence moves students from Physics at the freshman level, to Chemistry as sophomores, then Biology in the junior year. Elective science courses include Environmental Science, Anatomy and Physiology, Modern Physics and Science Research, as well as Advanced Placement courses for biology, chemistry and environmental science. Available math courses include Algebra I, Algebra II, Geometry, and Pre-Calculus, as well as Advanced Placement courses in calculus and statistics.

Contact information for the student subjects was provided by the guidance department for graduates between the years 2015-2019. Class sizes ranged from 70 to 85 graduates. From a larger sample of 388 graduates, 209 students were identified as having viable email addresses. The percentage of available email addresses varied widely from 14.3% for the Class of 2018 to 77.3% for the Class of 2019 and with 53.9% available overall. A summary of contact availability by graduation year is provided in Appendix A. An email invitation to participate in the study was sent in the fall of 2019. A copy of this invitation is provided in Appendix B. Graduates whose career paths were known and verified to be outside of a STEM-related field were not contacted to participate. The email invitation was sent to the remaining 186 graduates for whom contact information was provided. The body of the email identified the three researchers: all science faculty members at the school. Student participants were informed that the initial survey would ask about their formal and informal science experiences as well as their personal attitudes and beliefs about science. Anonymity of responses was assured. To encourage participation, respondents were offered a small financial incentive: a drawing for a $25 Amazon gift card.

The purpose of the screening survey was to identify graduates who had chosen to pursue a course of study related to STEM at a post-secondary institution. Respondents who chose to participate clicked on a link that sent them to an online survey. A copy of the screening survey is provided in Appendix C. The survey began by reiterating the purpose of the survey and reminding respondents that participation was voluntary. The official letter of consent was available to participants upon request (Appendix D). Survey questions asked about participants' high school courses and extracurricular activities related to STEM. Participants were asked to identify whether they were currently enrolled at a university or college, their major and minor course of study, and whether their major or minor had changed since they first enrolled. Respondents were invited to participate in an interview to learn more about their science-related background experiences and goals. The voluntary nature of participation was stated as well as assurances of anonymity. Demographic information was identified as optional and included questions about race, ethnicity, sex, and gender identification. Respondents were offered a financial incentive to encourage participation: a drawing for a $100 Amazon gift card. No additional incentives were offered for participation.

Survey responses were received from 70 of the 186 graduates who had been contacted. Twenty-eight of these respondents were eligible to participate in the semi-structured interviews. Criteria for inclusion was current enrollment in an undergraduate STEM program, previous enrollment in STEM program with a change to a non-STEM major, or an undecided major with consideration of a STEM major and enrollment in STEM classes. Majors that were considered STEM-related included life, physical and environmental sciences, computer science, engineering, and interdisciplinary majors grounded in science related coursework. In the survey responses, 22 of the 28 eligible graduates replied 'yes' when asked if they were willing to be interviewed. The remaining seven respondents replied 'maybe' when asked about participation in a subsequent interview. None of the students with a STEM major declined to participate in the interviews. Of the graduates eligible for interviews, 82% were female, 18% male; 64.3% were White, 25% Black or African American, 7% Asian and one individual did not identify their race. A summary of these demographic characteristics is provided in Table 1.

Table 1

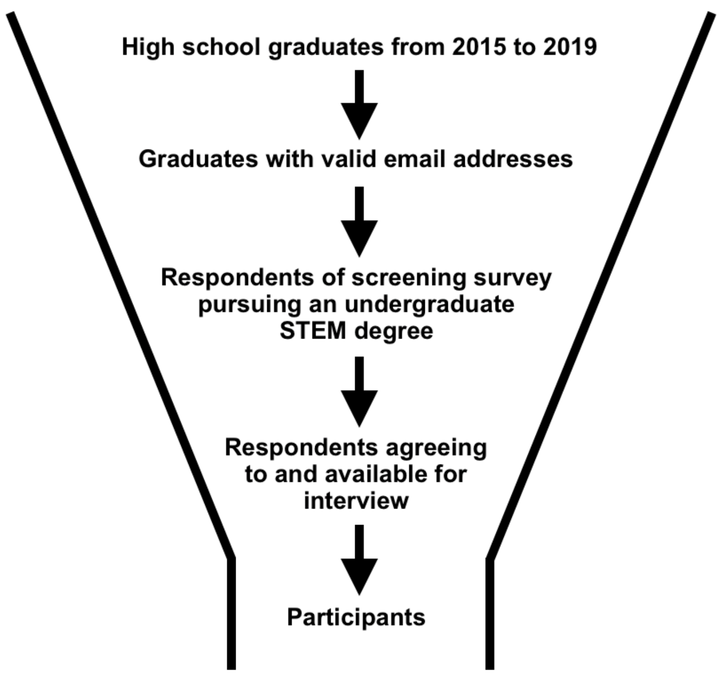
Demographic Characteristics of Respondents Selected for Interviews

Graduating Class	Class Size	Number of respondents enrolled in college	# in college, STEM major, yes/ maybe interviewed	Gender		Racial Group			
				Female	Male	Black	Asian	White	Un-declared
2019	75	19	7	6	1	3	0	3	1
2018	70	7	5	4	1	3	0	2	0
2017	79	23	9	6	3	0	2	7	0
2016	78	5	3	3	0	0	0	3	0
2015	86	4	4	4	0	1	0	3	0
TOTALS	**388**	**58**	**28**	**23**	**5**	**7**	**2**	**18**	**1**

The goal of 30 participants was set as the maximum number to use in this research as ten interviews per researcher was a reasonable number to manage. Twenty-eight respondents were eligible to participate based upon their pursuit of a STEM related major; thus none were excluded from the interviews. Using an online randomizer, each researcher was assigned eligible respondents to interview. Those selected were contacted through email to schedule a mutually agreed upon date and time for a video meeting. Interviews were successfully scheduled and conducted for 24 of the 28 eligible respondents. An overview of the sample selection procedure is provided in Figure 5.

Figure 5

Selection Procedure Model



The STEM majors identified by eligible participants included Biology (8 respondents), Chemistry (2), Environmental Science (2), Computer Science (2), Nursing (2) and Engineering (4). Two respondents were pursuing a general course of study with the intent to subsequently enroll in a medical field. One respondent wished to pursue a course of study related to sustainability but identified their major as undecided. Seven respondents changed the major they originally declared when they began their undergraduate education; six switched from one STEM discipline to another STEM discipline, while one transferred from a STEM major to a non-STEM related discipline. A pseudonym for each participant, their demographic information, and degree choices are provided in Appendix E.

Data Collection Instrument

To answer the research questions, qualitative research was selected for the collection of information. While quantitative research provides a numeric description of responses, it fails to provide the meaning behind that data (Creswell & Creswell, 2018). Understanding the exhibition and salience of STEM identity requires the depth and detail provided by qualitative analysis. One-on-one interviewing was selected rather than focus groups to ensure that the experiences of each participant were thoroughly investigated. Every participant received the same questions in a structured interview. This procedure was designed to guide answers toward the research questions. Interview questions were open ended, allowing participants to fully express their thoughts. Semi-structured interviews possess the advantage of allowing additional questions to be posed based upon the participant responses (Gray, 2004). This semi-structured format allowing questions to be added as needed to fully understand responses. The interview questions were devised from multiple quantitative and qualitative studies and later tested for face validity (see Table 2).

Table 2

Interview Questions Associated with Research Questions

Research Question	Interview Questions with supporting literature
1. What influences high school graduates of different gender and racial groups to pursue and persist in a post-secondary STEM degree program?	• What is it about science that interests you? (Trujillo & Tanner, 2014; Vincent-Ruz & Schunn, 2018) • Why did you decide to pursue science as a major? (Chemers et al., 2011; Tan et al., 2013) • When you think about life before college, what were some memorable experiences you had related to science? (Chapman & Feldman, 2017; Mills & Katzman, 2015) • When you think about your experiences at MUPHS, did you feel successful learning and doing science? In college? Has this changed? (Carlone & Johnson, 2007) • Did you have role models or supporters who helped shape your interest in science? (Hazari et al., 2013; Rosenthal et al., 2013; Trujillo & Tanner, 2014)
2. To what degree do high school graduates of different gender and racial groups who enroll in post-secondary STEM degree programs exhibit their science identity?	• Have you been academically successful in your science classes? High School? College? (Carlone & Johnson, 2007) • Do you feel that you are part of a science community? (Carlone & Johnson, 2007; Farland-Smith, 2010) • What challenges have you had to overcome? (Aschbacher et al., 2010) • What has helped you persist in science? (Aschbacher et al., 2010)
3. What are the salient forms of science identity among different gender and racial groups enrolled in a post-secondary STEM degree program?	• What is the role/purpose of science? • Why is science worth pursuing as a major/career? (Chemers et al., 2011; Tan et al., 2013) • Do you consider yourself to be a scientist? Do you feel others do? (Carlone & Johnson, 2007; Wonch Hill et al., 2017) • What are your future aspirations? (Chemers et al., 2011; Stets et al., 2017; Tan et al., 2013) • It has been suggested that there is a gender gap in STEM, as more males participate in STEM than females. What are your thoughts and experiences related to this? (Inzlicht & Ben-Zeev, 2000; Murphy et al., 2007; Schuster & Martiny, 2017) • It has been suggested that there is a minority gap in STEM, as in more white participants in STEM than minority participants. What are your thoughts and experiences related to this? (Byars-Winston & Rogers, 2019; Hazari et al., 2013)

The first research question asked: What influences high school graduates of different gender and racial groups to pursue and persist in a post-secondary STEM degree program? Five interview questions were selected to answer this research question. Participants were first asked “What is it about science that interests you?” While eligible respondents were chosen because of their enrollment in a STEM program, it cannot be assumed that personal interest was the reason for this selection; as they may have been influenced by external factors. Ascertaining personal interest in science is important because it is strongly correlated with science identity (Trujillo & Tanner, 2014; Vincent-Ruz & Schunn, 2018). The second question asked, “When you think about life before college, what were some memorable experiences you had related to science?” Science identity is influenced by participation in science experiences (Chapman, 2017). Respondents were asked “Did you have role models or supporters who helped shape your interest in science?” Interaction with STEM professionals increases consideration of a STEM career for female and minority students (Hazari, 2013; Rosenthal et al., 2013). This question aimed to identify those influential people that impacted the formation of a science identity.

The second research question asked: To what degree do high school graduates of different gender and racial groups that enroll in post-secondary STEM degree programs exhibit their science identity? The interview question “Do you feel that you are part of a science community?” allowed the respondent to explain their perceived connection and how that membership influenced their science identity (Carlone & Johnson, 2007; Farland-Smith, 2010) By asking “What challenges have you had to overcome?”, responses could reveal why some persisted in a STEM related field while others did not and to what degree science identity related to persistence (Ashbacher et al., 2010).

The third research question asked: What are the salient forms of science identity of different gender and ethnic groups enrolled in a post-secondary STEM degree program? An interview question that addressed this was: What is the role/purpose of science? Responses to this question provided an understanding of why students formed an identity that related to science. “Why is science worth pursuing as a major/career?” While identifying the value each respondent ascribed to the study of STEM, respondents might reveal how their science identity led to the pursuit of a STEM occupation (Stets et al., 2017). Respondents were asked: Do you consider yourself to be a scientist? In addition to self-identification as a scientist, probing questions revealed what it meant to that individual to be a person in science (Carlone & Johnson, 2007). The response was posed “Do you feel others do (think of you as a scientist?)? Being recognized by others as a science person leads to stronger self-identification as scientists (Carlone & Johnson, 2007). The question “What has helped you persist in science?” sought to use persistence as an indicator of the respondent’s science identity. The ability to persist is related to the prominence and salience of one’s science identity (Brenner et al. 2014). In addition to the three research questions, respondents were asked two additional questions about their thoughts and experiences related to gender and race. Being one of few females in a STEM related program can increase the salience of gender stereotypes (Inzlicht & Ben-Zeev, 2000) and decrease persistence (Murphy et al., 2007).

Establishing validity of research instruments and data are necessary components of qualitative research (Creswell & Creswell, 2018). To establish the face validity of our data collection instrument, the interview questions were given to six colleagues with doctoral degrees in education. Four were administrators and two were classroom educators. Each was provided with the three research questions as well as the interview questions designed to answer them. Using their professional expertise, these volunteers were asked whether the interview questions would elicit answers that dealt with the research questions. Responses were received from five of the six colleagues. Comments from colleagues included suggestions for rewording questions to extract better answers. For example, asking respondents if their success changed from high school to college might simply elicit a yes or no response. Asking how their success has changed provides more revealing information. Likewise, instead of asking graduates "Do you have any role models or supporters who helped shape your interest in science?", they could be asked to identify their role models or supporters. Colleagues also recognized the need to probe to ensure that responses fully revealed the connection to the research question. It was suggested that we ask the respondent to describe their thinking, elaborate what was meant, and provide examples to illuminate their reasoning. All colleagues stated that the interview questions provided a valid tool for answering the research questions.

Data Collection Procedures

Interviews were scheduled by email at a time and date mutually convenient for the participant and the researchers. Twenty-two of the twenty-four interviews took place online. Two interviews took place in the high school at the request of the participants. All interviews were recorded using Zoom, an online video conferencing platform. To assure consistency, the researchers followed a script. Each interviewer conducted an initial practice interview to gain experience with the script and to appropriately adjust their pacing and approach. The practice interview data was not included in the final study. Interviews began by thanking each respondent for their participation, reminding them that their participation is voluntary, and that they could choose to end the interview at any point. The participants were also reminded that their anonymity would be protected in the writeup of the research findings. It was explained that the interview would be recorded for transcription and coding. In addition to the video recording, notes were taken during the interview. In the event that clarification of responses was needed, participants were informed that they could be contacted in the future. The list of semi-structured questions was used to frame each interview. To elicit more complete responses we used pausing as wait time increases the depth of response, paraphrasing to ensure that the meaning of the responses was accurately noted, and probing to provide additional details or new information. Interview length ranged from 20 to 69 minutes with an average of 36 minutes. At the culmination of each interview respondents were thanked and reminded that they could contact the researchers at any time for information about this research. A copy of the interview introduction script and semi-structured interview questions are provided in Appendix F.

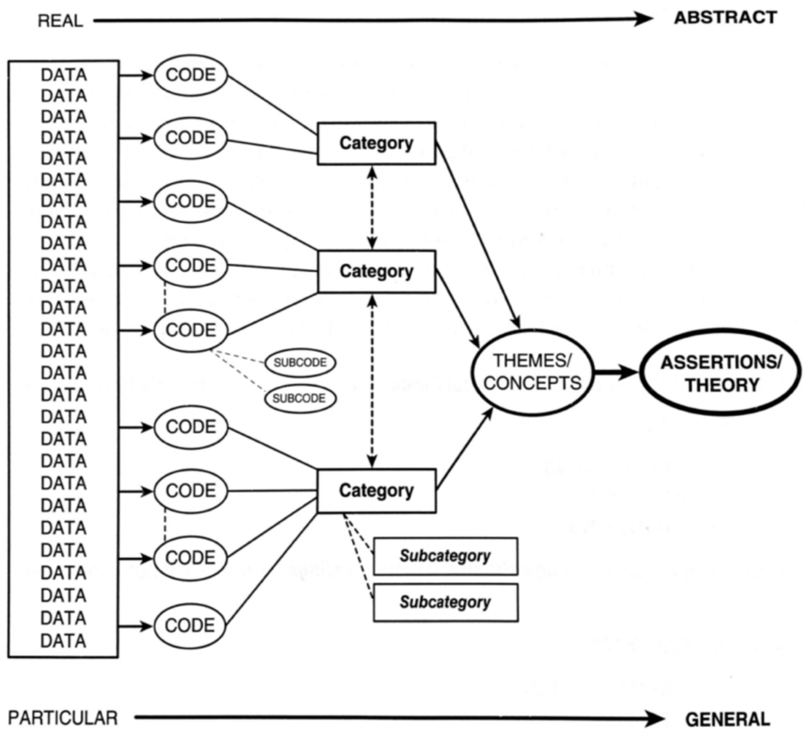
Data Analysis Procedures

All interview data was recorded using Zoom and therefore automatically transcribed using the software's built-in video-to-text feature. Each researcher reviewed the video recordings, checked the written transcripts for accuracy, and edited when necessary. Observational notes were also recorded at this time. All of the transcriptions were checked and reviewed for accuracy by the researchers. The final versions of the interview transcripts were organized by interview question, printed, and copied in order for each researcher to review, make notes, and code manually. Digital copies of each transcript were entered into a coding and qualitative data analysis software (CAQDAS) package called *Dedoose*. This software is web-based and allows users to develop codes, tag data with descriptors, and annotate and write memos to better organize and analyze data (Salmona et al, 2020). Dedoose was selected because it allowed for all three researchers to code and annotate the data synchronously or asynchronously. The software also contained built-in features to test for interrater reliability.

An iterative process was used to analyze and interpret the results of interview data inductively. We were guided by the process illustrated in Figure 6 which involved analyzing the data, defining codes that emerge from the data, sorting the codes into categories, then identifying emerging themes. We read all of the interviews independently in order to become familiar with the variations and patterns in the data. A descriptive approach was used when annotating the printed transcripts for general themes, similarities, and differences in the data.

Figure 6

*A Streamlined Codes-to-theory Model for Qualitative Inquiry (*Saldaña, 2016)



Using the preliminary codes generated from initial coding, categories can be constructed and refined to make sense of the data (Moghaddam, 2006). Using *focused coding*, the codes were redefined and sorted into categories based on emerging trends. A revised code structure was developed, aligned with each research questions, and added to Dedoose (see Appendix G – I). One interview was randomly selected to be used as practice and each researchers read, coded, and added memos in Dedoose as a training exercise. Definitions and descriptions of codes were discussed and refined during this orientation process. After completing the training exercise and reaching consensus on the meaning behind the codes and sub codes, each researcher coded three additional interviews in Dedoose. To check for intercoder agreement each researcher read excerpts of one another's coded passages and came to consensus regarding code usage (Creswell & Creswell, 2018). After confirming consistency of interpreting the coding structure, the remaining interviews were coded. The final coding applications were further tested for interrater reliability using the training center feature on Dedoose. Several reliability tests were generated using coded interview excerpts; during each test the individual saw the excerpt but not the codes that were applied to the excerpt. The code(s) most appropriately aligned with each excerpt in the test were the ones applied. Dedoose compared each of each researchers' independent answers and produced a Cohen's kappa coefficient for each code. In the majority of tests, a Cohen's kappa coefficient of .80 or greater was obtained; this level of coding consistency meets the recommended level of at least 80% agreement and is indicative of good qualitative reliability (Miles & Huberman, 1994). Disagreements in code usage were minimal, but when identified consensus was reached and necessary adjustments made. Using the data generated from focused coding, codes and categories were integrated into emerging themes using *theoretical coding.* This method results in a synthesis or abstraction of data resulting in the development of an original theory or support for existing theories (Saldaña, 2016). The completion of this process culminated in the production of salient science identities and major themes that emerged from the data.

Ethical Considerations

Consideration was given regarding the time commitment asked of the participants. The survey required approximately five minutes to complete. Although volunteering may have necessitated some inconvenience, there was no harm or known mental anguish to participants. All participation was voluntary and participants were allowed to withdraw from the study at any time. Students were not formally identified and data was securely stored on password-protected computers and will be destroyed at the completion of the study. All participants and data in our study were kept confidential. All video recordings obtained were destroyed at the conclusion of the study.

Conclusion

The purpose of this grounded theory case study was to explore the science identities enacted by graduates from a MUPHS high school and who have enrolled in undergraduate STEM degree programs. Mitigating factors that drive motivation and persistence in STEM among gender and racial groups were also explored. Recent graduates (2015-2019) were screened and selected through email communication. Semi-structured interviews were conducted with 24 participants. Interviews were recorded and transcribed using Zoom. Interview transcripts were reviewed, coded, and analyzed using the program Dedoose. Through an iterative process of coding and analysis steeped in grounded theory tradition, emergent themes and characterized salient identities that contribute to a broader theory of science identity were developed.

Chapter 4

Findings

Grounded theory is a qualitative approach that allows the derivation of a general theory or explanation for a process or sociological phenomenon (Durdella, 2019). This general theory is then built inductively based on data that is grounded in the experiences and perspectives of the study's participants. Based on the application of grounded theory and using case study methodology the science identities enacted by graduates from a Midwest urban public high school (MUPHS) and who enrolled in undergraduate STEM degree programs was explored. The research questions were as follows:

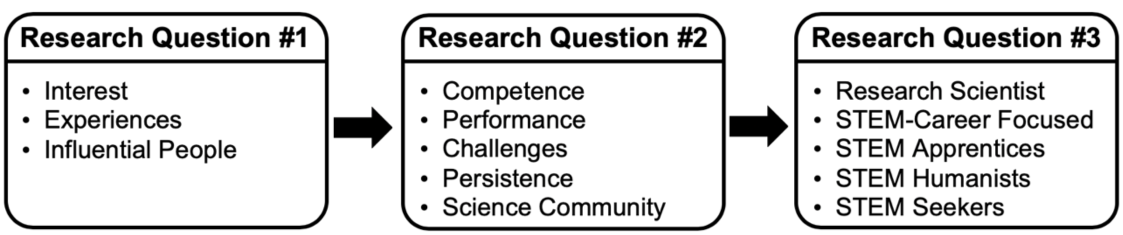
1. What influences high school graduates of different gender and racial groups to pursue and persist in a post-secondary STEM degree program?
2. To what degree do high school graduates of different gender and racial groups who enroll in post-secondary STEM degree programs exhibit their science identity?
3. What are the salient forms of science identity among different gender and racial groups enrolled in a post-secondary STEM degree program?

A sample of twenty-four college students, all graduates from the same MUPHS, were selected and interviewed to collect their lived experiences. Each semi-structured interview followed a protocol with open-ended questions where students were asked to relate their experiences and perspectives regarding STEM education. Through an iterative process of coding and analysis steeped in grounded theory tradition, emergent themes related to gender and race were identified as well as how each group expressed their identity in a post-secondary educational setting. Finally salient identities that contribute to a broader theory of science identity were categorized.

The concept of science identity involves exploring how individuals understand who they are and how that knowledge influences the person they hope to be. This understanding is often evidenced through an individual's decisions and actions. It is important to note that science identity is not static; it is fluid and often evolving. This dynamic is in constant interaction with the multiple identities each individual has, and it is further shaped within different sociological contexts. In addition, Carlone and Johnson (2007) proposed that competence, performance, and recognition all shape science identity. Hazari et al. (2010) further posit that interest also plays a role. The outline of the chapter is provided in Figure 7. Specific salient characteristics or themes related to science identity were identified based on the lived experiences of the participants. Each participant was categorized in one of five science identity groups. Appendix G displays each of the 24 participant's demographic and academic major along with their salient science identities. The salient identities were distributed as follows: four are characterized as Research Scientists, four as STEM-Career Focused, five as STEM Apprentices, five as STEM Humanists, and six as STEM Seekers.

Figure 7

Overview of Chapter 4 Findings



Data Description and Analysis

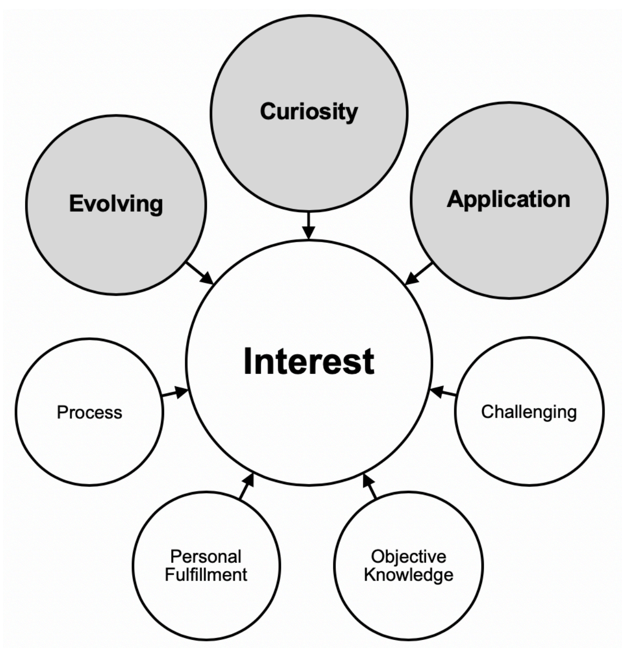
Research Question 1: What influences high school graduates of different gender and racial groups to pursue and persist in a post-secondary STEM degree program?

The factors that influenced the pursuit of a STEM degree pathway were identified. Participants described reasons for their interest in science, the experiences that fostered a connection to science, and their motivation to decide to pursue a degree in the STEM pathway. Ways in which influential people impacted the participants were also determined. Codes, frequency counts, descriptions, and examples of participant responses are provided in Appendix G.

Interest. Reasons stated for possessing an interest in science included a sense of curiosity, the desire for personal fulfillment, the ability to meaningfully apply their learning, an affinity for challenges, an appreciation for the process of science, the attainment of objective knowledge and the enjoyment of discovery. Sub codes for interest are shown in Figure 8. No distinct patterns emerged with respect to gender and minority groups related to interest.

Figure 8

Code Structure Related to Interest in Science



Note: Shading and size difference indicate increased code occurrences.

Participants commonly related their interest in science to *curiosity* about how the world works. For example a graduate, Timothy, expressed that this predisposition is natural: “The world is a very abstract and confusing place and science is a way to sort of get a grasp on that. I think it's part of human nature to try to understand things; how the world works.” Others identified more domain specific interests such as when Sasha stated, “I just like knowing more about the world. I like biology because I want to know more about what makes me work and what makes the living things around me work.” Clara’s curiosity related to humans: “I'm very fascinated by people. How they become who they are. Why they act the way they do. Why they think the way they do.” Willa sought to understand the connection between humans and the environment: “It's interesting learning how things work and how we interact with other species. I'm really interested in anthropogenic effects on species. So that's really my prime interest. I like to see how humans are either harming or helping certain species.” Instead of gaining content knowledge Alan desired to learn how the world works by acquiring a more mechanical understanding: “I like to take things apart and put them back together; I love to see how things work.” Chantel revealed that her interest in computers arose from curiosity about video games: “It was interesting to think how they work and how somebody actually made them.”

Many participants chose a STEM degree pathway because it provided *personal fulfillment* through a feeling of competence. Brandy related her academic performance to her decision to pursue a STEM major: “I decided to pursue science because that's actually the only thing I find myself good at. I got an A in physics and chemistry and biology. So, it just makes sense.” Heather related a personal connection to science: “People have their little niche, where writing is their thing or math is their thing, but science has always been my thing.” She identified the qualities that instill a sense of fulfillment: “I guess it has to do with skill. I'm better at solving equations and doing lab experiments than I am writing a paper.” Competence in science was developed later in Latoya’s academic career. She did not feel academically successful in high school, recognizing that she did not put much effort into her studies. In college she discovered, “I'm actually, like, kind of good at it, I found out, when I put the work into it.”

Some participants selected a STEM degree pathway because they were drawn to its *challenges*. Heather described how this enhanced her STEM interest:

> The rigorous courses that I was taking, the reason I took them was because they interested me and they were all STEM. I definitely liked the challenge. I feel that I focus a lot more on the classes that challenge me rather than the ones that I just sit there and we watch videos in class every day. I found that I had better grades in those classes because I was more challenged to do better in those classes.

Madeline described the tough classes she is taking in her junior year of college:

> They're really challenging for me especially when it comes to tests, rather than projects or homework. But I gain a lot of happiness when I work and things that make sense and I get the right answer. It's like, wow, I did it. And it's pretty rewarding.

Charles expressed pride in persisting through STEM courses, recognizing that his course load provided more challenge: “I've made a lot of friends outside my major … and I've learned that engineering classes are far more rigorous than business classes.” Willa recognized that it was easy for her to be academically successful in non-STEM classes, while science classes were more demanding:

> I was successful, but I felt challenged, in high school and middle school, my whole experience growing up, science was the only class that was remotely difficult to me. There's something about pushing yourself and challenging yourself to do something new you didn’t think you could, or something that doesn't come naturally or easy.

For some participants, their connection to STEM emerged from its *application*, usually in a manner that improved the life of others. Vonda stated, “There’s ways that science works that could contribute to making other people's lives better." Brandi recognized that science "was something that would be able to help other people." Timothy elaborated upon the connection to helping others:

> I want to be able to help the world. I know that's a little bit cliché, but I think that every step that we take in science there are applicable things that you can take and you can turn into ways to make people's lives easier or better. I think that that's really important; there's a lot of problems that need to be solved.

Madeline explained how her study of chemistry could be applied to social justice issues:

> I feel like I'm helping [knowledge] progress so that people who aren't as well-off financially, who don't have as much of a financial ability to acquire medical treatment, start to gain access because it's getting cheaper and cheaper to produce. I'm hoping to make an impact in that kind of world.

Some participants described an affinity for the *process of science* and how scientific thinking is used to process information. Vonda stated that science is about answering questions: "Science is a way to understand something on a really deep level, like when you're an annoying kid and you asked 'why, why, why,' you know? It seems like you could get some of those answers from science." Ruby explained, "I like asking questions and answering questions. I like the 'think process' behind it." Charles elaborated on how learning STEM subjects differ from other fields:

> Whereas English was very interpretive and very personal and history was kind of the same, it was a lot more just memory based rather than, like in math, I can derive an equation. If I don't remember it in history, I can't derive history. There's no step process to get what happened. I like the way that a brain takes in that information.

The *objective nature of science* was identified as a source of appeal. Timothy explained that science "is about trying to reach an understanding, trying to find the truth and most importantly being objective and not letting your own biases get in the way." Karter described the appeal of a specific answer to a problem: "I like that it's very technical and especially with the math part of it, you have an end result. It's not vague; it's a specific number." Yuri expressed that subjectivity of other subjects made them less appealing. There's usually an objective truth to science where other topics don't have objectivity. With STEM, you know, you can calculate an answer, like if I'm trying to find out the Gibbs free energy in a chemistry equation, I can come to the correct answer. And if there's a problem, I can track back to where I went wrong. With art history or English or sociology or anything like that, it's very personalized to whoever's teaching it. But with science it's usually just pure truth and that's what I like about it.

Participants also found value in the nature of *discovery* in science. Grace said, "Science is always changing. You're always learning new things. So I think that's what I like most about it." Teagan stated:

> One thing about science that interests me is how rapidly it's developing every day. It's something that isn't just a standstill subject that you learn everything and you're done. It's always changing. And it's always growing and there's so many discoveries to be made in it.

Faith explained how the novelty of science led to its preference over other fields: "I think it's the continuous learning aspect. I did think about previous majors, like business, and a lot of it just involves doing something over and over again. I don't really enjoy monotonous work. I like being able to learn continuously." Brandy explained in a similar way: "Science was always interesting to me. It just never got boring. It seemed like with other subjects like English or History, there is nothing more that I could learn. Science is always different. It's always new. It's always something to learn."

Experiences. The second interview question asked participants to think about their lives before college and identify memorable experiences related to science.

Participants identified formal and informal experiences that were part of a class as well as memorable experiences outside of school. Most formal experiences were reported by representative numbers of White and minority participants, but more females had engaged in science research experiences. Informal experiences were reported by fewer minority males and not at all by Black females.

The most frequent response was the memory of a *class-based lab*. Among the participants, three quarters described at least one memorable classroom activity. Latoya explained that these types of experiences stood out: “I usually remembered experiments or activities we did in science courses, more so than I remember what I learned in math or history.” Ruby identified the reason lab experiences were important to her: “I think doing the hands-on projects really kept everyone’s attention and made it real, and not just like a theoretical thing that I have to learn for school, but that I can really see how to apply it.” Charles recognized that labs provided a connection to math and a deeper understanding of the content:

> I knew math was a strong suit pretty early on, but I didn't really start appreciating it until I got to high school, when we were doing more experiments and getting a little bit more in depth than learning just the basics, like ‘gravity is a thing’. I think most of my appreciation and memories of the science field was from high school experiments.

Many participants stated that anatomy classes were particularly memorable. For Rebecca, it engaged her enough to spark her interest in science: “I've always liked science, but I hadn't really given it the time of day until my senior year when I was in the Human Body class. I got really interested in how the body works.” Clara stated that she loved dissection and that it provided a better learning experience: “It was very memorable for me because it really humanized death and you kind of appreciated the stuff in the body. Instead of looking at it in a textbook you were watching it being removed." Grace credited this course with inspiring her career trajectory:

> Human Body senior year, that's what led me to picking up my emphasis in biotechnology. Because that's what I really liked. The medical side of it just seems so fascinating and I really enjoyed all of that. And so I said, "I'm going to go to med school!"

Chantel, who is currently studying computer science, liked the labs that provided an opportunity to use technology: "We took pictures with the camera and had to Photoshop the pictures that we took. The teacher also taught us a little bit of coding and we also made websites." Some lab activities stood out because they left graphic images in their minds. Grace said of her chemistry class, "I remember all the labs and the Bunsen burners and the different colors and solutions and stuff. I remember when the teacher poured acid on the cow eyeball and said, 'this is what happens if you don't wear your goggles.'"

Many of the recollected memories described problem solving activities. Six participants talked about a paper rocket lab from their freshman physics course. They expressed that it was fun and challenging. Alan acknowledged that he became engrossed in the competitive nature of this activity:

> It was a really hyped up thing because it was a project that went over the course of two months. I remember me and my lab partner, we had the top record for the furthest feet for a rocket. So I got into this competition that was going on. That was really nice.

Another memorable challenge from the freshman physics course was a roller coaster experiment. Alan described how difficulties did not detract from the appeal of this experience: "We would get into groups and we put together the roller coasters, but there would always be a problem or a hick there that needed to be fixed or rearranged in it."

Grace also remembered how the roller coaster lab did not always work as expected. She laughingly recalled, “I asked my dad for so much help on that thing,” and she asserted its impression: “That's what I remember from physics.” Latoya recalled a challenge presented in her Human Body class:

> We had like a broken limb made out of cardboard. It was a paper towel roll with something else in there and a stick to represent the bone. We had to build something to keep it sturdy so that the person could use it. I thought that was fun because it was like we were doctors trying to figure something out.”

Six of the participants enrolled in Science Research class when they attended high school. Students in this course complete an authentic research project on a topic they find interesting. All six former Science Research students described memorable experiences in this course. Alan said that the research class “was like an early college experience.” Willa asserted that the course provided “really good learning about how to put together a project and how to go through the scientific method. That’s not stressed enough, I think.” Olivia described why this course cemented her decision to pursue science:

> My research project was the catalyst. I had been interested in science, and I felt that research is a good way to get more out of science than just reading about it, more actually interacting with it. Before then, I was only in 10th grade, so I had never even really done anything in a lab because I took chemistry at the same time. So it was my first time really doing lab work. I was experiencing new things. I thought I might as well take this opportunity and it really changed everything for me.”

Students enrolled in Science Research work with scientists to help them design and conduct their experiment. Alan valued the connections he made at a local university and expressed that visiting different universities was influential. Faith recalled the professionals she worked with for her Science Research project:

> I was trying to find a different material that would be easier to make solar panels out of, and it would make it cheaper for regular people to buy it. [My teacher] and I worked with the professor for a couple months in the chemistry lab at the university.

Sasha described how her high school Science Research class made her feel capable of conducting research at the collegiate level:

> I did the independent research class in high school and that gave me the opportunity to do an independent research project through the university. I got to work in their lab. It was very interesting. And I think that it kind of helped me to decide I really like this research. And now at the high school level, I'm seeing, okay, this is how research is done at the college level and then go on to do that in a college.

Alan developed a deeper connection to science when he shared his lessons with younger students and developed his research project through meeting with college professors.

> I got to work with a lot of people outside of high school, I went to the elementary school and did a lot of experiments there. And then I went to the university as well. I got to see the NAO robot that I wanted to work with, which is a $12,000 robot. There were a lot of different experiences like that in the research class.

Other memorable experiences were part of a class but did not take place in school. Adelia remembered being on a boat with her middle school class and learning about how scientists work out in the field. Grace remembered going to Dauphin Island and “all the things we learned on that expedition.” Latoya described how that middle school field expeditions furthered her awareness of science topics:

> I remember the eight-mile hike. And we were by the river looking at salamanders. I don't like outdoors; that is just not me. But that actually was my favorite part of the trip, looking around just seeing things. We were picking up rocks and like finding animals; and we were testing stuff in the water. I never would have even known about all that because I don't go outside. But our school always got us outside and using classroom stuff in the real world.

Uri remembered his anatomy class trip to a university's cadaver lab, recalling that the visit left a strong impression: "That was very interesting. I thought it would kind of spook me. I mean, obviously it's a bit weird, but going into it was very fascinating too." The trip was remembered for more than the lab component. Uri stated, "Being on an actual university campus and to actually be inside an actual laboratory, that was quite memorable." Timothy visited a nuclear reactor with his Chemistry class. He stated that this experience reinforced his interest and confidence in science: "It sort of went beyond just the math and just the science and it went into making it realistic and making it seem like something that was achievable." Teagan agreed that this field trip exposed her to the possibility of a STEM related career:

> Going to the nuclear energy plant with my chemistry class was a big one for me. I think just like being able to actually see science in application. And meet the people who are pursuing science as a career outside of an educational realm. We see science teachers, but sometimes it's hard to picture going into science in a way that's not as an educator. I think that was an interesting thing for me to see. People pursuing nuclear energy research and application of nuclear energy. And just being able to go out into the world and have experiential learning is something that sticks really well in my brain. So that really solidified it for me.

After-school clubs also provided informal science experiences. Jacyln remembered trips as part of a nature club and experiments that were conducted throughout the year: “That was super interesting. I think that's gotten me into science.” Ruby also recognized middle school Adventure Club trips as “one of my favorite things! We would go on a float trip and conduct our own study of the water. That always really interested me, how you could just go on a float trip and have fun and learn.” Alan acknowledged the significance of an after-school robotics club. He remembered participating in competitions from middle to high school and credited it with his pursuit of a mechanical engineering degree: “That was the early on thing that deciphered what my major would be in the future.” Heather recalled her participation in two extracurricular science contests: Science Bowl and the Science Academic Challenge. She learned additional science content outside of class to compete successfully at these competitions.

Some extracurricular activities took place as summer programs. Sonia attended an aquarium’s summer camp in which participants learned oceanography, completed lab experiments, and took a final trip to Florida. Heather completed a summer program with the state conservation agency. She expressed how much she enjoyed this experience: “I did field work with them, and that was super fun. The program is really awesome. It was like a field trip but for the whole summer.” While she does not intend to pursue a career related to this summer experience, she felt that it increased her awareness of STEM career possibilities:

> It was stuff that you could actually do in real life, and like make a career out of it. So I found that really interesting. While I wouldn't necessarily want to go out and count bees every day in my job or my career, it was still awesome … to be able to figure out a type of career that is STEM-related. Because we didn't really get introduced to different jobs at that point in my life.

The interviews also described *informal experiences* that were not part of school but increased consideration of a STEM career pathway. Karter liked learning about science at the local science museum, Grace discussed family trips to an ecology center, and Sasha talked about visits to a botanical institution. These trips were selected as memorable experiences which furthered their knowledge of science. Charles recalled activities he did at home:

> I had a fascination with machines and putting stuff together. I remember there were a handful of DIY-like experiments I would do at my house where I would take, you know, like popsicle sticks and string and make like a small crossbow or like a little small project I would do all the time at home and I wanted to try to do that on a bigger scale.

Uri remembered doing STEM-related activities building rockets with his father. In middle school they explored Arduino and Raspberry Pi. In high school his Uri's father fostered his connection to STEM when they worked together to fix used computers. Timothy felt that advances in space science provided memories that persisted from an early age:

> I was always really interested in the Mars rovers. The thing that I can remember from my early childhood is, I can't remember which one it was that landed with the balloons, but it came out of the sky and it had these big airbags that crashed onto the ground and bounced around on the surface of Mars.

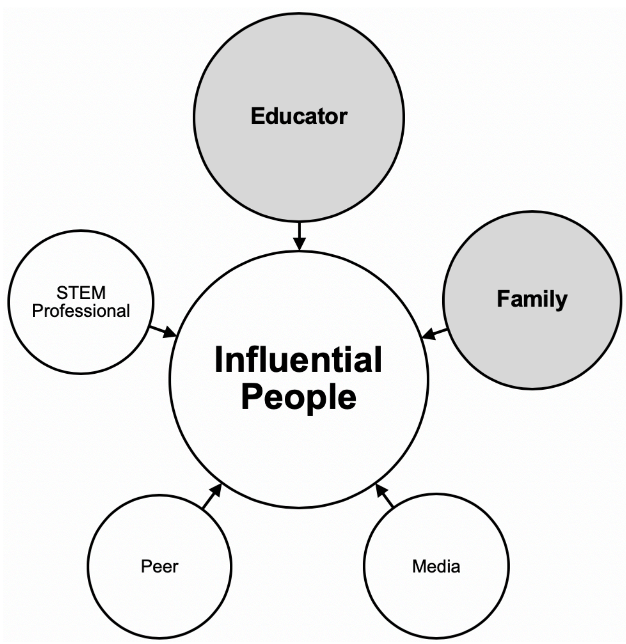
Madeline found the ability to reinforce her science knowledge through everyday experiences. She stated that she engaged with science:

> ... just doing random things with friends and siblings. 'Cause I kind of do that now, whenever I'm with friends we will be doing some stuff like throwing snowballs at each other and we'll, you know, some of my other friends are also studying STEM. I have a roommate in physics and I just mention things like, well, can you calculate the initial velocity versus the final velocity of the snowball when it lands and, you know, they just laugh and it's really funny.

Influential People. When asked whether they had any role models or supporters who helped shape their interest in science, participants identified influential people in five categories: educators, family members, STEM professionals, peers, and the media (Figure 9). Male and female participants reported equally on the influence of passionate teachers, good teaching practices and enjoyable instruction. More female than male participants described the influence of additional assistance and personal connections. Differences in influence of teachers was not noted for different racial groups.

Figure 9

Code Structure Related to Influential People in Science



Note: Shading and size difference indicate increased code occurrences.

Three quarters of the participants identified at least one *educator* who influenced their selection of a STEM degree program. Jaclyn asserted, “I definitely feel like the whole [high school] science department got me more into science.” Madeline agreed that her high school teachers were “so inspiring it was really easy to like whatever we were studying. Because they all made it really fun and they're all wonderful with these different personalities and every time I went to class I got really into it." Ruby felt that her high school teachers paved the way to STEM:

> Physics was like the first class that really got me into science. Before I thought I didn't even like it at all. But the way that it was taught really opened my mind up to what science actually is about. And that just kind of opened the door to science for me.

Several teachers were recognized for their passion. Heather described one teacher's influence:

> Without taking her class, without her passion for chemistry, I would never have thought about my majoring in chemistry. I was always interested in it when I was in middle school, but sophomore year completely changed my outlook and what I was interested in, what I could see myself doing actually and what I could actually stand taking classes during college.

Clara said that she learned more from her science teacher who made class enjoyable:

> He was so funny and he made everything interesting. He made learning fun and he made it an enjoyable thing. It was a classroom where people were encouraged to enjoy it instead of just sitting there and taking notes. I appreciated his style of teaching.

Inspiration often came from teachers that were perceived to use good teaching practices. Chantel praised the efficacy and influence of one high school teacher: "He actually broke it down. It was pretty easy if you paid attention. I actually remember stuff that I learned in the class. When I took his classes they made me say 'yeah, this is what I want to do.'" Uri explained how good teaching promoted affinity for the subject:

> I had to retake chemistry because I did not do very well at my previous high school. I remember really enjoying [my new chemistry teacher's] teaching method. I say this in a very nice way, but she reminded me of Ms. Frizzle from

> Magic School Bus. Like in a very sweet way, she fostered that interest of chemistry and she made me love chemistry more.

Madeline liked the teaching style of her physics teacher:

> He would always answer every question we asked with another question. I thought that was crazy. It drove me insane. I just wanted an answer, but actually, him asking another question is actually good for us to think about what you know will be the answer, how will we get to the answer. You realize, oh, this isn't so hard. You just got to think about it.

Clara described a time when a high school teacher helped her find the answer to a question:

> I have a specific memory. We were talking about the digestive tract during the first unit. We're talking about the mouth and I was like, "Huh, what's the uvula for?" Like, we weren't talking about the uvula, but he's like, "I don't know." And he flipped over to the internet, and he looked it up. And he was like, "oh, so it looks like it blocks off your nasal cavity when you swallow. That's awesome." And then we just moved on with the lecture. And I like that. I appreciated him taking the time to address my curiosity and encourage it.

She then described a very different experience with a college teacher:

> We were talking about the integumentary system during the very first unit. We were talking about scar tissue and how it forms. And I asked, "So how would a scar gel work? You know, those products that say they get rid of stretch marks and stuff, how would they work?" And he was like, "I don't know. Moving on." Okay, I have Google, I can look it up myself. But it felt discouraging. He just was kind of like, "I don't know. Let's go back to what we're talking about." So it was kind of, it was a little discouraging after being encouraged to ask questions before.

Influential teachers were frequently noted for providing extra assistance. Ruby said of her high school teachers, “I had a lot of additional help which was always great. And it made me think that science was probably the thing that I was interested in the most.” Sasha talked about how her Advanced Placement science teachers provided tutoring sessions after school. She explained that “having those people support me very hands on along the way was really helpful; making me confident in my ability to do biology and chemistry.”

Teachers were respected for being knowledgeable in their content area. Sonia described the influence of her environmental science teacher:

> I feel like he was the biggest supporter of my science career. He was just always there for me to ask questions, he knew a lot about the topics that I was interested in. So I could have good conversations with him about whatever I was interested in. I really feel like his classes taught me the most, and the most stuck with me from his classes.

Karter appreciated an instructor’s willingness to engage in intellectual discourse:

> After class talking about random stuff that's science-related, that really just piqued my interest. It's those sort of things that I really enjoyed talking about. I'd say the more I talked about it, the more I kind of got sucked into it, the more interesting it seemed.

Influential educators made a personal connection by supporting students' socioemotional needs. Rebecca explained how a middle school teacher provided support:

> I really liked him a lot because he was just very understanding with the students. And it was a middle school which is like a weird time where nobody understands themselves. And he was just always nice and friendly and he made me enjoy going to science, just because of who he was.

Vonda praised her college for providing an environment where students and teachers frequently interacted. She developed a more personal relationship with her professors when attending office hours:

> When I go to office hours, sometimes it is to talk about assignments but sometimes I just ask for advice about life and career-related things. So I get that sort of direct interaction of having these professors tell me how they got where they are and how they feel about it now.

In addition to educators, many participants stated that *family* members helped shape their interest in science. Participants of both genders reported familial influence. Every African American participant identified a family member who influenced their STEM career pathway. Alan's interest in science was fostered from an early age by participating in science related activities with his grandfather: "He is the main reason why I like science so much, because he would always work with me in areas with just physics or like astronomy and stuff like that." In addition to learning together about science topics, Alan's grandfather offered a spacesuit as an incentive. This motivated him to pursue engineering, believing that one day he might go into space in a similar suit. Latoya is pursuing the same career as her mother and credited her with being "the reason I did nursing. She is why I do everything, why I get good grades, she's what motivates me and pushes me all the time." Others stated that an influential family member was a scientist but in a different field from the one they were pursuing. Uri is studying medicine while his father works with technology, but Uri asserted, "My father definitely was a role model in science." While Olivia is pursuing botany and medicine, she looks up to her grandfather who is a chemical engineer. She recognized his accomplishments and felt that this familial connection reinforced her capacity to be successful:

> He was always really excited because all of my siblings quit working on science and he thought I was the kid who would be the one sibling to go into STEM. He's a big role model and he's really smart. He's really successful, he's got his Ph.D., so I can do it too, I got those genetics.

Some parents were not scientists but in fields that used science. Both of Teagan's parents are physical therapists which she did not see as a science field, saying "they're not technically scientists." She explained their influence: "My parents are both healers and I'm kind of seeing myself going into that in some way or another, whether it's like environmental healing or with humans. I guess my parents would be role models for me in that way." While Vonda's mother does not have a science career, she recognized her as a role model for a different reason: "She has always valued science and scientific thinking and has, I would say, been like an unofficial scientist her whole life who has really encouraged my interest in that subject." A few parents directed their child toward a STEM career even though they had careers in other fields. Chantel described her mother's influence:

> She was the only one I really told about it, when I was picking out my major. She was the one I told that I was interested in it. Then she just pushed me to do it. Not really a role model, but she was the one that just pushed me to go for it.

Fewer participants identified *STEM professionals* who influenced their career path, but half of Black participants discussed these experiences. Both males and females described interactions with scientists through summer programs, lab visits and conferences. Brandy was directed toward STEM through childhood experiences with medical professionals. Several family members had illnesses and extended hospitalizations: her mother had hip surgery, a nephew lost his hearing from meningitis, and an aunt had breast cancer. She felt that she was constantly visiting others in the hospital. Brandy observed that nurses spent more time with the family than doctors, which cemented her decision to pursue nursing. When her younger sister was hospitalized for an extended period, she stated, “That’s what pushed me to actually choose nursing.”

Peers were mentioned less frequently than educators and family members, but some participants described the influence of fellow students. Karter said that he enjoyed “just talking with other students who also enjoy talking about chemistry. It's pretty interesting, especially when you're talking to people that know a bit more about it.” Although he commutes to college, he confessed that he is rarely home because he enjoys these conversations: “I have a lot of time to talk with people and being around other people that also know about [science] kind of piques your interest and makes you more and more interested.” Madeline described encouragement from peers to persist through tough classes: “I've talked to upperclassmen and they're like, wow, don't worry I failed tests all the time, and I realize I'm not the only one.” Charles praised the design of courses for his major. At his university, students join a cohort that enrolls in the same classes. They form study groups and work together outside of class providing assistance and encouragement:

> I ended up meeting three or four other individuals that I became pretty close with and they've been a huge help. They are a crutch that I can lean on in case I don't get something. They are motivation for when I'm not doing well and I don't think I'm built for this major.

He found inspiration from one successful peer, confessing, “There is a little bit of competitiveness between us. He added, “That helps inspire us.” Charles described how this peer successfully completed a heavy course load of tough engineering classes and was pursuing two major degrees. He expressed how this individual motivated him: “Seeing him put in all that work, it's like, well, now I gotta step up my game. I can't look like a slouch next to this guy.”

Some participants recognized the influence of the media. Teagan said, “I think the media has been a big impact in the importance of science and my understanding of the importance of science.” She talked about how certain people used social media to promote science:

> I feel like there's a lot of influential people right now that I follow that are really relaying the importance of [science]. If I see their name, I'll click on it and read because I'm interested in those people and what they're doing. Greta Thunberg right now is a big one. She was just up here recently and we did a climate strike which was really cool.

Uri looked up to the physicist Richard Feynman. He described him as “kind of kooky guy. He was a little crazy, but he was funny. He made theoretical physics very wacky but in like an understandable way.” Clara related to media that was presented to her in class: We watched the John Oliver episode about science. He made it very clear. He said “I understand that there are people out there who don't think evolution is real. But this is why we have so much evidence to support it.” And he was very straightforward. He was no nonsense, but he was also really funny.

Research Question 2: To what degree do high school graduates of different gender and racial groups who enroll in post-secondary STEM degree programs exhibit their science identity?

This research question explored the degree to which science identity was exhibited as participants demonstrated competence and performance in their studies. Patterns were identified that described the ways participants persisted in the face of challenges. Ways in which the participants participated in a science community were also investigated. Codes, frequency counts, descriptions, and examples of participant responses are provided in Appendix H.

Competence. Many of the interview participants indicated they felt competent and academically successful in their high school and college math and science courses. When asked if she felt academically successful in high school science classes Madeline said, “Yes I did, I guess, based on the grades that were reflected in my transcript.” The majority of responses were coded as formal learning experiences where participants described typical classroom-related academic experiences. Most participants reported positive experiences when learning about specific topics or subjects. Charles recollected feeling successful when taking math and physics courses and said, “I like the comfort in it. It just clicked and it was never something I had to really wrap my mind around … There was also a level of comfort just knowing that this is my niche … what I'm good at.” There were no clear patterns that emerged between different gender and ethnic groups. Participants who intend to pursue graduate school after completing their undergraduate degree spoke about their competence in greater detail. Willa said:

> I don't think I was ever disappointed in my grades in [science] classes. Yeah, it was just something where I did have to actually work for something and not just get to skate by like previously. So, I really did feel academically successful. I'd say there's some feeling of reward in return.

Participants recalled the value of grades when describing competence in science classes, however some referred to benefits beyond grades. Amani said, “I guess success is like learning something that I can use in the future.” While referring to her high school learning experiences Adelia said, “I honestly don't remember specifically what I learned. But I know it’s definitely in there and it's helped me to prepare for being a biology major.” Jaclyn echoed similar experiences and said, “… there are multiple examples in my biology courses where the things [teacher] taught were applied directly to what we're learning right now. I was able to remember those and I didn't have to study them as much.” Olivia conveyed her competence in science when she said, “I realized I was pretty good at math … it made me realize, I really like STEM and math in general." Overall, a positive sense of accomplishment and competence in math and science was a consistent theme among all of the participants.

Performance. Participants shared their experiences related to practicing scientific skills in both formal and informal settings, in doing classroom-based labs, in performing their own science research, and by communicating scientifically. Participants who were enrolled in Science Research in high school and are planning to attend graduate school provided in-depth descriptions about demonstrating their research and communication skills.

Developing and practicing scientific skills began at an early age for many participants. Vonda recalled:

> When I was a fairly young kid, like, you know, between the ages of say like 8 to 12-ish, I would keep, basically, like naturalist journals. They were basically field notes where I would describe things that I saw, like, "oh, I saw this cool bird," or I would try to identify things later with guides and I'd also take samples or draw a picture … kind of like an early naturalist. And I sort of later realized that that's what that was. And I was like, "oh yeah, I guess that was like doing science at an early time."

Other participants recalled experiences with family members where they had the chance to practice science skills outside of the classroom. Uri said, "I had a hand-me-down computer because [father] got a lot of spare parts. Instead of just fixing it outright he would teach me how to fix the computers. It was a father-son bonding activity, but we built computers together." Participants also emphasized the importance school-related field trips had on being able to demonstrate performance. Grace referred to a middle school field experience when she said, "… going to [an aquatic research facility]. We did a lot of it in the labs and everything. We did touch on a little bit of engineering … Then we did a bunch of cleaning the water because after the oil spill." Uri was able to practice science skills on a visit to a research lab. He stated:

> We went to … this was AP Biology, for the record … we went to [university] on their campus and we conducted an actual polymerase chain reaction experiment. You know, on an actual university campus and to actually be inside an actual laboratory, that was also quite memorable.

While in middle school, Sasha had the opportunity to work in a plant research facility as part of a summer program. She said, "There was a free summer program. It was a week long ... work in the lab ... learn lab technique kind of stuff. So that was really cool. And I think that really sent me into wanting to do more lab stuff." Other participants vividly recalled positive experiences related to specific labs and experiments in school. Jaclyn said, "I remember experiments with rocks and geology or weird science experiments we had to do. Making bread get moldy, like I did in sixth grade." Timothy conveyed the labs he did high school provided him with an understanding of the fundamentals of lab work. Grace shared having the opportunity to design her own labs:

> In Biology we did those labs. I remember we did the liver lab and that made me never want to go near liver again and that was gross. But then we did the enzyme lab with the laundry detergent and so now I only buy [name brand] detergent."

In some cases the high school experiences students shared aligned with their STEM degree pathway. Charles, a Mechanical Engineering major, said:

> One of my biggest moments was the rocket ship or the paper rockets that we did in physics that was always a lot of fun. All of the experiments we did in physics, just being able to get a tangible look at it and then, part of me just liked the structure of all the different math and sciences, where it's very much a cause and effect, and there was a nice smooth transition between that.

Being able to ask questions and perform independent research was another theme related to demonstrating performance. Opportunities occurred as early as middle school and continued through high school. Willa stated:

> We would do individual projects, or you'd have a partner, and on each trip you were supposed to design and plan an experiment. And I mean as best as you can get middle schoolers to do that. It was like we would be on a float trip and we would test turbidity or pH or dissolved nitrogen or [I mean] dissolved oxygen and nitrogen levels throughout different lengths. We would do trials at different parts of the river or so. Or we would do soil, we would just make up random testing and I think we did some transects and whatnot. Yeah, I took Science Research in high school as well. I almost didn't even think to include that part. That was really fun for a class and really interesting solely because of going to the conferences and the exposure to other parts of science that I just wouldn't have figured.

Other participants recalled their experiences doing authentic science research. Vonda recalled:

> ... doing real research experience and lab experience and field experience. I had the amazing opportunity to go with one of my professors to Dominica, it's a tiny Caribbean island, and do research with him. One of the things we were doing were these pollination tests that involved bagging some flowers and leaving some open …

A number of participants shared experiences related to communicating scientifically. Alan developed a deeper connection to science when he communicated with others as part of Science Research. He shared insights about his project with younger students and developed his research through meeting with college professors. These experiences fostered his enjoyment of and connection to STEM: “The project we did for the end of Science Research gave me a lot of experience with public speaking.

We presented our projects at the [local science competition]. It gave us a lot of experience and it was great.” Vonda shared her insights about the importance communication plays in her studies when she said:

> I'm doing a thesis right now for the Biology Department and learning how to talk about it to people who don't know anything about the subject in a way that makes them care or interested is a challenge. Because obviously, I want to talk about it and for it to be a fun thing to share with people. I'm also very interested in science communication and being better about…I guess democratizing science knowledge a little bit more. So, I want to have that practice and if I can practice it even just with my friends here or with my family at home, that's good.

Charles extends this idea to the importance of communication in engineering and the benefits it has on society. He said:

> A lot of things that engineers understand will have to be explained to other people who don't quite understand the small details. [Aside] “If I put the weight here and I build it in this way, you're actually going to have a huge problem right there and that's going to be a big issue.” So being able to distribute that information, I'd say that's a big part of science. That's a part of just understanding, here's how that reacts with this and here's why that's wrong and here's why that can be dangerous. It's our job to communicate that with construction teams and with the public with anybody who might be impacted.

Academic and Personal Challenges. In terms of academic and personal challenges, there were no distinct patterns that emerged with respect to gender and minority groups. Participants described challenges related to learning specific subjects in math or science in high school. Willa said, “Chemistry, I'm terrible at. That was always a challenge for me. It just bothers my soul. So that's always so hard.” Other challenges focused on individual experiences in college. These included struggling to maintain a sleep schedule, sustaining focus, financial stress, time management, and keeping up with the demands of an increased workload. Ruby raised additional challenges:

> Yeah, I think I didn’t feel like I learned things as in-depth as I did in high school, probably because of the faster pace and the different teaching style. It seems more like I knew it for the test, but I didn’t necessarily understand it … Learning from a textbook was difficult, because we really didn’t use textbooks a whole lot in high school. I wasn’t super used to having to ask for clarification on a lot things and ask a lot of questions and go to office hours.

The most common challenge participants faced was learning time management and study skills. Seven participants shared in-depth descriptions of their struggles. Heather said, “... also taught me a lot of time management, like when I have basically learned to plan out my homework for the whole week and then prioritize and get as much done like at the beginning of the week.” Madeline said:

> In college, it's like, “oh, no,” you have to actually study and simulate the kind of thing a test is going to be like when you're studying. Because that's kind of, you know, you get more practice doing the same thing over and over and on the test here and to be ready because you studied as if it were a test. And I didn't really realize that until my freshman year of college.

Grace commented on being a science major and the contrast between her non-science peers:

> Just like how much work it is and how difficult it is, especially because my roommates are business and education and everything so they don't really have to do the same things that I have to do. So, they may want to go out all the time and it's like, I can't, I have a test. They'll just study the night before for a test where I have to study all week for the test. Yeah, [science] is completely different. So that's been really hard.

Several participants commented on not having the study skills needed to be successful in college. Olivia shared, “I've had to learn how to study. I never had to study much in high school. So when I got to college, I was like, okay, I really gotta actually work for this.”

Persistence. When asked “what helps you persist in science,” participants provided a range of responses. Of the nine codes used for this question, academic support, grit, and personal mastery were coded most frequently across all gender and minority groups (Figure 10). Emerging themes across these codes were analyzed and presented according to shared characteristics.

Figure 10

Code Structure Related to Persistence in Science

Note: Shading and size difference indicate increased code occurrences.

Academic and *peer support* were coded when participants referenced accessing formal or informal supports like tutoring, office hours, etc. White participants reported these supports more frequently than minorities. Teacher support in high school and college was important for many participants. They shared experiences about going to office hours to talk about assignments and get advice about life and careers. Grace said:

> That really just kind of made me realize the connection that I do have with my professors here, especially being such a small department. They all have open door policies, so if the door is open you can just go in and talk to them and ask them questions and everything.

Participants referred to accessing support from family and campus resources. Rebecca said, “I have the support with my brother being down here. He also helped me. And then [university] offers the [tutoring center], which is nice, which is just grad students and older students helping … It's just like a tutoring center.” The responses from participants who took Science Research while in high school, particularly White females, received more peer support codes. Having classmates and friends that are really good at science has been helpful for Teagan. She said, “So, having peers around me that are very into science and understand it really well, has definitely helped me persist and helps me get through and understand concepts that were harder.” Four participants shared stories about peer mentors or teachers who acted as mentors. Sasha was aided by a mentor program during her first year as an undergraduate. She said:

> I was a mentee my first year and I found it really helpful to have somebody older than me to kind of guide me and be like, okay, like what science classes are good to take and what, you know, how do I get through these classes and how do I go to office hours, all that stuff.

Charles praised the design of courses for his major. Students join a cohort and enroll in the same classes. They form study groups and work together outside of class providing assistance and encouragement:

> I ended up meeting three or four other individuals that I became pretty close with and they've been a huge help. They are a crutch that I can lean on in case I don't

> get something. They are a motivation when I'm not doing well and I don't think I'm built for this major.

Academic support also included *verbal persuasion* which was coded when participants shared descriptions of receiving verbal encouragement, praise, or admonishment from others. Vonda stated she had a "very supportive community of friends [and family] who provide some external encouragement…giving a little, you know, "you can do it!" For Latoya, her high school principal's words of encouragement stuck with her as she moved on to college. She said:

> [Principal] was always like my role model for everything in high school, like he helped me with literally everything. He always pushed me. He's like, "Latoya, you gotta do it. You just do it. Like it's going to be better." And once you put in the work, afterwards, he was always right.

Participants recalled experiences where *quality teaching* supported their ability to persist. Ruby was influenced by the enthusiasm and passion her teachers brought to the classroom. Many participants expressed gratitude for having "good teachers" who took time to build relationships and help them understand difficult material. Recalling a learning experience Grace said, "[Teacher] also went through presentations and really explained the concepts to me. So, I definitely understood it better." Rebecca said, "I think part of it is because as I get into higher level science classes, I get better professors who make it more interesting."

Six females and one male participant described being inspired by others who succeeded in specific tasks. These "I see you doing it, so I can too" descriptions were coded as *vicarious experience.* Participants related to older students, teachers, and STEM professionals. Willa observed her peers succeed in the classroom: "So my first semester I remember just barely scraping by and very distraught because it was the first time I ever had below a 3.5. I didn't understand. So, I [started] paying attention to how other people were studying.” Adelia observed her professor do research:

> I think, just seeing and hearing about the research that my professors have done and they talk about the stuff they've done in their past and in graduate school and what research they're currently doing. And I was just think [sic] like, wow, that's really cool like I want that to be me someday. And just the research I hear about in general, not even just from my professors. But, you know, they'll tell us about stuff they've heard about or [what] their colleagues have done, and I'm just, it just keeps me going, because I just think it's really cool.

Amani reflected on her experiences in an internship program during high school: “I got to observe a nurse and I got to see a spinal tap on a preemie/newborn and a circumcision and just doing that for year, allowed me to see, hey, I could do something like this every day”.

Participants described using their goals, coded as *grit*, and internal drive to succeed, coded as *passion*, to persevere through challenges. Grace stated, “I feel like it's just my own personal stubbornness (laughs), in all honesty.” When asked if persevering represented an external standard of credibility, she elaborated:

> I do think so, especially in chemical engineering where we started with over 300 and by sophomore year, so many of them, like we're down to, I think it's technically 32 but a couple of them are out on co-ops right now. So, we're down to like 30 and it's the beginning of junior year, it's like halfway through. And all those people have dropped. And so, it's really just like, you know, ‘last man standing’ kind of a thing. And I think all the professors kind of look at it the same way, like, you know, they don't really care to get to know you until after you've passed your first major course or whatever. And then they actually know your name and start keeping up with you and stuff.

Heather described having to push through to complete homework and study for exams and said it helped her to have “the mindset that if I get something done now, then I won't have to do it later.” Many participants shared feeling a sense or reward for struggling through a difficult problem. Madeline described getting right answers on her homework as a “dopamine rush.” Similar to other participants who plan to pursue a graduate degree, Willa emphasized the importance goals and internal drive had on her ability to persevere:

> I think just realizing that it is something I truly want to do and its what interests me most. If I thought about any other major, I wouldn't foresee fulfillment in my future. I wouldn't be happy working in an office or just … there's so much I would rather do and that's with science. So, I guess that’s what always keeps me going.

Many participants described their love for science and learning as a source of internal strength. *Passion* is what drives Clara to overcome her challenges. When asked how she perseveres, she said, “Passion, I guess, because I like it so much. I'm happy to pull through even in the harder stuff that I'm not as interested in. The prospect of achieving knowledge and getting the grade makes me want to try harder.” Brandy remarked how science is always changing and her interest is what drives her to continue learning. She said, “It's just never gotten boring. [laughing] Like, it's still something that's interesting until this day. I don't think science will ever not be interesting to me. Just reading anything that is scientific is interesting to me.”

Participants sometimes described having a *fear of failure.* This was coded more frequently among females, those who did not take Science Research while in high school, and those who plan to enter a STEM career after graduation. When asked how she succeeds when she is challenged, Chantel said, “I know that if I don't do that, basically I'm wasting a whole bunch of money. Yeah, basically that’s it. Because I know that even though I’m taking out all these loans, I know that it's gonna pay back.”

Financial fears were not the only worry for participants. Amani mentioned taking longer if she makes mistakes and has to start over. Vonda shared her challenges with self-confidence and overcoming failure:

> I guess another challenge, just getting over feeling that imposter syndrome basically. Like, you have one setback and you're like, “Oh, well actually, you know, maybe I'm actually not cut out for this.” And that's very hard and scary for me, and it takes overcoming the anxiety to just cold send somebody an email and ask them for help.

Karter demonstrated his sense of optimism when facing the possibility of failure in his courses: “I mean, I'm kind of worried about it. But I'm hoping it's going to turn out okay. I just gotta not fail any classes. I mean, for now, I'm surviving. And I am all right with that.”

Personal mastery experiences, defined as the belief in achieving success based on previous success and/or failures, was coded most frequently amongst female and White participants. Participants who took science research in high school described learning from failure. Willa said, “You're gonna fail more times than you're going to succeed.” Madeline acknowledged the role failure played in her learning:

> And I think about the fact that I've had issues with classes in the past and then gotten through them and then still received good grades. Um, so yeah. It doesn't worry me when I, you know, do badly. But it was a lot harder to deal with that kind of thing in high school, because I, I guess I'm not used to being bad at things sometimes I'm, like, um, so I guess its kind of easier to look at what I did wrong and how I did it wrong. Because over time, I've kind of realized, everyone makes mistakes. It's not the end of the world to get a C on a test, it's not, you know, it's okay.

Sasha echoed this idea as it related to completing her science research project while in high school: “’Okay, like this is going to fail a bunch of times until we finally get it to work.

And then we're going to have to slightly change that again, you know. It's a lot of trial and error.” Participants also described learning from successes. Adelia said, “Whenever I did well in a class that reassured me I could do it.” Sasha stated, “You learn your basic study skills for your intro classes and then you go on to an upper level class you're like ‘okay like I'm really doing this.’ I really got to learn how to work on my own.”

Science Community. Participants were asked if they felt part of a scientific community and were encouraged to elaborate on their response. A definition of a scientific community was intentionally not provided. For participants who indicated they were part of a scientific community, their responses were coded as learning science, doing science, and feeling surrounded by a scientific community.

The majority of participants who responded they felt like they were members of a scientific community were coded as learning science. Very few differences emerged between participants of differing gender or minority groups for this code. Participants who identified as taking Science Research in high school were coded frequently as learning science. Several participants defined a scientific community as the group of students they were learning science with as part of a class or program/major. Jaclyn said, “There's a lot of my peers in the same programs as me.” Madeline echoed how she felt about being in a science community due to the fact she and her peers were in a similar program. She elaborated on the benefits of being in this community:

> Definitely my engineering program … my class specifically. We're all kind of connected because we share our answers [and] how we got things on specific homework assignments and we all, you know, figure out what we did wrong for ourselves and we help each other, figure out the right answer to things. We work on projects together, um, yeah, do a lot of science together.

Grace defined being part of a scientific community as being competent in science: “I feel like I'm a part of a science community. Not necessarily because of the courses I've taken but just because of my knowledge of science … just because I do understand that stuff." Teagan described getting the chance to attend seminar presentations with her roommate as being involved in a science community. She said, "Pretty regularly… [her roommate] doing a seminar lecture series through [university], she's getting like only a couple credits for it because it's only once a week. But it's been really interesting and that's kind of its own community." Other participants defined a science community as being part of a classroom-based lab in which they learned about science. Heather said, "My labs, for sure. Everyone in labs, like chemistry or biology labs, like everybody helps each other out." Being part of extra-curricular clubs emerged as a theme. When asked if he was part of a scientific community Uri said, "Yeah, I think so. I'm in clubs in my college that are STEM-based … like I'm in Engineering Club and I'm in Chemistry Club and stuff like that. But also I work in laboratories often." When asked about her involvement in clubs, Adelia said she was once part of one and saw herself as part of a science community:

> So, we have a marine science club, which I was a part of. We have a lot of the science discipline areas that are kind of connected and they do events together. They have like research seminars and stuff like that. So yeah, I do feel like it as a community.

Participants in minority groups did not report being involved in science clubs or groups outside of classes and labs. Alan, a Black student, said, "I was a part of [local science organization] back in high school. I was a leader for it in fact. I think I was in it for seven or six years." Despite Alan's involvement in science-related clubs in high school, he has not yet engaged in outside activities in college. He said, "I've been so busy with all the other work, but there are a lot of engineering based clubs here… the rocket team design… a Mars rover design.. the drone design team. I just haven't had the opportunity yet to join." Karter, a White student, said, "I joined Aero Design and I feel like that's probably one of the first steps to actually kind of getting myself involved in the practice of aerospace engineering."

Some participants who responded as members of a scientific community were coded as doing or practicing science. These participants responded by highlighting their involvement in labs, group projects, or independent research as evidence of what it means to be part of a scientific community. Sasha stated:

> I'm helping lead this team that's doing my project and my co-leaders project. And so I like that collaborative element of it, (for) our project one experiment takes a week long to do, so just out of necessity we need a lot of people on the team.

Timothy described working collaboratively with the global scientific community:

> Oh, yeah. And this is one of my favorite examples from [university]. And I think we did it a little bit at [high school] also. The genetic database that has millions and millions of sequences of genes and you can just look at anybody can go online and look at them and compare them to their own results. I was at [university] one of the biology labs that we did, we used that [sic] and we compared it to our own bacteria genome that we had sequenced as part of an experiment. And it was an actual collaboration. I mean, it wasn't like we were like, contributing anything I guess technically, but I felt like I was actually collaborating with other scientists, because I was using data that had already been collecting [sic] and comparing it to my own data and drawing conclusions from that.

When asked if she felt part of a scientific community, Olivia highlighted being involved in her own research:

> Oh, for sure. Um, yeah, I mean, like I'm working in a lab. Again, I'm surrounded by like postdoc students and grad students and professors who are all doing research, and specifically helping me or giving me papers to read or just being there. So, I can ask questions. Um, I know, like so many professors that are

> involved in research. There's also a lot of students that are involved in research. So definitely.

Very few participants who felt like they were members of a scientific community were coded as feeling surrounded by science. These were participants who incorporated the culture or the physical surroundings they were immersed in as their definition of what a science community is. Teagan stated:

> [University] is a very big science school. The most well-funded programs are the biology, chemistry, environmental science programs. And so, I think generally being on this campus, it's a very science-oriented feel even if you're not studying science. There's lots of science-related events and lots of exposure to science constantly. So, I think just being on this campus is like its own science-related community in a way.

Uri said, “I try to surround myself with other like-minded people, naturally, like other people do that and they are also scientifically-oriented. So, that might, you know, be true once I start going further into my education.”

Six females and one male participant did not feel like they were members of a scientific community yet. Of these participants most described the availability of programs but reported being too busy with other commitments to become involved. Rebecca said, “I feel like I could be more involved with, on campus, with science clubs and things like that.” Grace said, “I mean, there's clubs and stuff but I don’t feel that's really like a community or like my degree or my major whatever. It's definitely different, but I don't really feel like it's a different science community.” Faith, a Black first year student, didn’t really feel like she was in a science community yet. She stated:

> Actually, I'm in the process of making a club for STEM that's for people of color, because there's not a big community for people of color here, which must be expected. I knew that before coming here. But it really bothers a lot of people,

which, you know, rightfully so. So, we're in the process of getting people who are POC's within the community to come and talk to the others who are considering STEM careers, so they have someone to look up to or talk to if they're considering being within that field. But I don't really feel like I'm in that community yet because, again, I haven't really taken a science class yet. I'm probably going to have to take chemistry at some point. So, we will be in that community soon.

Research Question 3: What are the salient forms of science identity among different gender and racial groups enrolled in a post-secondary STEM degree program?

This research question explored the salient forms of science identity exhibited by participants. We recognize that while science identity is fluid and dynamic, participants demonstrated salient attributes that characterize shared themes. These themes were used to develop five salient science identities: Research Scientist, STEM-Career Focused, STEM Apprentice, STEM Humanist, and STEM Seeker (Table 3). Each identity group and the ways individuals exhibit their identity as they navigate a STEM degree program was explored. Codes, frequency counts, descriptions, and examples of participant responses are provided in Appendix I.

Table 3

Salient Science Identities of Students in STEM Degree Programs

Research Scientists	STEM-Career Focused	STEM Apprentices	STEM Humanists	STEM Seekers
Madeline Sasha Vonda Willa	Chantel Charles Grace Timothy	Adelia Alan Rebecca Karter Olivia	Amani Brandy Latoya Teagan Uri	Faith Clara Sonia Heather Jacyln Ruby

Research Scientists. Four participants were identified who exhibit a salient research scientist identity: Willa, Sasha, Vonda, and Madeline. These participants see science as a process by which to study and understand the natural world. They are also inherently interested in science. What specifically delineates this group are each student's experiences with and pursuit of scientific research opportunities. For Willa, a White female, this started in middle school as part of a district-sponsored summer field studies program that taught research skills in an ecological context. Willa stated:

> I did field study with [two middle school teachers], so I started that the summer before seventh grade and I remember being really mad. My dad signed me up for science camp. I was like, “I don't want to go to science camp.” I was so mad. I hated science. And then I had so much fun. And so then I did it the next summer … So I ended up doing that all through high school and it just ended up working out that way. And then I just, I got really interested in doing field research and that's what I wanted to go into.

Willa continued exploring scientific research in high school as part of a formal class. It is this exposure to the scientific research process that led Willa to pursue a major in biology with a focus on ecology. She has taken advantage of field research opportunities in college and is currently seeking an assistantship position in a research lab. She relates a significant lesson that other research scientists learned from these experiences: how to persist through failure.

> So that [high school research project] was a really cool project and then ultimately it showed me the biggest lesson is that projects don’t always work out how you want them to. Because I had everything on the Vernier LabQuest and the data just couldn't transfer to my computer, and I lost my data. But it was a big…it showed me a lot that projects will fail. And then when I did an independent research [project in college], I've done two independent research projects, and in

> both of them my data was either non-existent or, well, yes it was still data, but it didn't do anything to my hypothesis. So it taught me how to learn, okay, you're gonna fail more times than you're going to succeed.

The other three participants shared similar experiences in research in high school and college. These experiences align strongly with their personal interests. Sasha, a White female molecular biology major, is currently working in a lab on both personal research projects and as a mentor to other participants. She mentioned:

> I like that, especially with research, I like that I can study something and be, maybe it's a little bit narcissistic, but, be the first one to discover something or, you know, the first one to ask a novel question.

Vonda, a White female interested in conservation biology, connected her excitement for research with a sense of obligation:

> So yeah, on the one hand, I definitely feel like it's a way to, you know, contribute. Like, I see it as something that, doing something because it makes you individually happy is a good reason to do something, but if it can also help other people that's even better. And yeah, I see addressing this huge existential crisis of ecological disaster and climate change as a fairly worthwhile thing to be doing right now. And because I feel able to do it, you know, it seems like the best way for me personally to contribute.

For Madeline, a White female studying biomedical engineering, experiences in authentic scientific research did not happen until early in her college career. She stated:

> There's the head of the engineering department, [professor's name] and I, we kind of bonded, I guess, freshman year. And there's this internship she was kind of getting everyone in the department to apply for and I applied for it. And there was only one position offered and I got it. We just had to submit a resume and

> cover letter. And I was like, wow, this is pretty cool. I should definitely take this opportunity and, yeah, do this kind of system processing work.

Madeline's participation with this research continued after the initial internship ended. In each case, these participants were excited to share their research experiences in depth. It is these research experiences that participants described as influencing their desire to continue research and to enter graduate school in the future.

One aspect of science identity is recognition: when a community of practice recognizes an individual for demonstrating the attributes that qualify one as a member of that community. This idea can also be applied to the individual and how they recognize themselves as a member of a community of practice. Each of these participants reported that they see themselves as scientists. Drawing largely on these research experiences, they attribute this view to practicing scientific habits of mind (i.e. critical thinking, conclusions based on evidence), asking scientific questions, and carrying out the scientific method in order to investigate natural phenomena. Vonda said, "I do research and I try and think about things scientifically and I think that makes me a scientist." When asked if she saw herself as a scientist, Willa shared:

> I'd like to think so, sure. I think it's almost kind of hard if you don't. I think in my head it's ingrained that you have to have a Ph.D. to do so, but I would like to think so. I've done several projects and … I'm in the process of getting into a lab, I hope … Honestly, I would consider it just because of doing research. Granted I'm not published, nothing like that. But, low end, I can do grunt work. I collected spiders for a graduate student's research, so I'm like a grunt scientist here.

It is not only research experiences that shape a student's science identity, but it is also the act of learning science and being part of a community of learners. Sasha stated:

> I mean, I am in a lab and I'm conducting my own research. So I think part of that, like, I don't know, makes me feel more like a scientist. But even if I wasn't doing

> that, I feel like, even if you're just taking science classes and, you know, like even if you're taking lab classes or just learning about more science, I would still classify that as a scientist or someone who's interested in going into science. So, yeah: I guess both in my role as a researcher and in my role as learning, taking science classes.

STEM-Career Focused. Participants shared different views on what makes someone a scientist. Sometimes this definition did not align with their STEM-education pathway and how they viewed themselves as a person with interests and goals within the STEM disciplines. Their interview responses revealed a theme that we characterize as STEM-Career Focused. Participants with this salient identity include Grace and Charles who are both in engineering tracks, and Chantel and Timothy who are both studying computer science. When asked if they see themselves as scientists, there was a mix of responses. Chantel, a Black female, answered:

> I don't. I just, when I see a scientist, I just see people researching data and stuff and I don't really do that. I just find a way to, I have to make this program. I just code, like that. I don't see myself as doing research.

Similar to other participants in this study, Chantel's definition of a scientist was someone who performs experiments and collects data through research. Alternatively, other participants defined a scientist as one who has accumulated enough knowledge and earned a degree. Grace, a White female, posited:

> I feel like biologists and things like that tend to be more like scientists, whereas an engineer is more of looking at the big picture, more of "mathy" stuff like the plans. I don't know. I feel like after…, that's hard. I just, I feel like a student right now. I don't feel like an actual scientist. I feel like I'm in the process of becoming one just like I'm in the process of getting my degree. So I think maybe once I get that, then I'll feel like one.

Timothy, a White male, was congruent with what other participants answered in that a scientist is merely someone who thinks scientifically and applies the scientific method: “I think anybody who knows and understands and practices science is a scientist. And so I would call myself a scientist.” Charles, an Asian male, related a more nuanced understanding of his science identity to one that comes closer to a STEM or engineering identity:

> And so it's hard not to think of what I'm doing as engineering because that is my end goal and it would be disheartening to think that everything I've been doing to get to that point hasn't been engineering. And so part of it is, yes, I think of myself as an engineer. Everyone is very quick to use the phrase engineer, but no one's really quick to use the phrase scientists or science. So it's a lot easier to picture what I'm doing is strictly engineering rather than something in the science field.

For this group science is a means to not only understand the natural world but to then disseminate new findings to drive innovation and change. Charles stated, “I would say the purpose of science is to better understand and gain information from the inputs around us.” He went on to state:

> ...and the purpose of science is getting this information out for the public to understand [and] not just for other scientists. So I think it's possible that if the information was handed up, handled correctly, anybody could take in that information and use it to do something new with it, whereas, instead of keeping that information within the science community to create something new. It's more of getting the public to understand why something is the way it is and giving them the opportunity to do something with it.

Similarly, Grace commented on the need for science to spark innovation:

> I think it's really just to keep pushing forward. You know, like we can't be at a standstill. I feel like humans as a population, changing and innovating and stuff. I

> think it's really boring when we're all just sitting around. I think science, a lot of times that innovation really helps things, and helps people, helps the environment, and I think people just really like learning and really being able to apply that and then a lot of times that is applied to help, if that makes sense. Trying to think of like all the environmental stuff and then also like medical stuff.

The final aspect of the STEM-Career Focused group is the alignment between their interest in STEM and their career goals. Like all students we interviewed, this group is inherently curious and interested in STEM disciplines. They are also keenly aware of the job prospects that STEM opens up. Grace stated why she is interested in a chemical engineering major:

> I find the whole thing interesting. So it's like something that's interesting to me and it's just a very secure job that I know is really going to set me up for success with a future family and being able to take care of my family when they're old and everything. And then I know I'm always going to have a job. And so I'm looking at more of the career aspect and less of the helping aspect, I guess.

Chantel related a similar perspective about why she is pursuing a computer science degree:

> Well, for one thing, it's also, it’s really in the market, like people are really looking for [computer programmers]. And also, um just, I guess people just like it, I guess. It's just the technology is evolving every, every year. So you have to keep up or you're going to get left behind.

From this alignment between interest and career goals comes a drive or personal responsibility to pursue STEM. This idea was expressed in two ways. First, understanding the scientific method and the knowledge it produces helps broaden an individual. Timothy elaborated on this point:

> You know, if you want science to be done in the world you have…, I feel like it's up to each of us to do something about it. And so even if somebody doesn't become a scientist or researcher having a sort of grasp of science, it is a transferable skill that will be useful in whatever field you go into.

Second, in understanding a topic or becoming a specialist in a STEM discipline there is a need to educate others. Charles related this idea:

> It's worth majoring in for anyone who's curious. I'm personally very curious. I like to learn new concepts and new ideas. And in the end someone has to do it. But, you know, someone has to ask the question "why" and figure out, like, why is this doing this and why, you know, how can this relate to this. So that we can interpret it and translate it to something that someone who hasn't gone through all the education can still digest the same information. It's like the translator between the reasons why and the public. We are the middleman that kind of like feeds that information along.

STEM Apprentices. As previously stated, two commonalities between all participants is an inherent interest in science and their enrollment in a post-secondary STEM degree track. For the STEM Apprentices, it is a focus on being a student of science, varying degrees of involvement in a science community, and fluid career-goals that demonstrate a science identity that is still taking shape as they navigate through college. The following students as representative of a STEM Apprentice: Adelia, Alan, Olivia, Rebecca, and Karter.

When participants were asked if they see themselves as a scientist, the predominant answer was "not yet." Adelia is a White female majoring in biology and stated:

> Um, I don't think so. Not yet. I feel like I'm still working towards it. I don't really consider myself a scientist yet. I guess, like if I conducted my own research all

> the way through and knew what I wanted to do from point A to point B, all the way until the very end, and like if I knew exactly what I was looking for and how I go about finding it. But I know that I have a lot of a lot of learning to do (laughs). A lot of experience to gain.

This sentiment was shared by Alan, a Black male and mechanical engineering major: “I’d say I consider myself becoming a scientist, not all the way up there. I still feel like there's a lot of things I need to learn. But I definitely would consider myself one day.” Both Adelia and Alan related the challenges associated with rigorous coursework. In Alan’s case, keeping up with his studies has prevented him from engaging in opportunities to explore and engage with the on-campus science community. Interestingly, Olivia, a White female and plant biology major, has held an assistantship position in a plant sciences lab. She responded similarly to Adelia and Alan:

> No, not yet. Um, I don't think I have enough knowledge, like at this point, I couldn't really do any research on my own and like I don't have the knowledge to really come up with a lot of my own projects and figure things out. I don't do my own research. Like I work in a lab, but I just do what people tell me to do. And I don't necessarily have the background knowledge to fully understand everything that's going on. But I think like when I can do that, when I can formulate a project and I can get started, then I’ll be a scientist.

This idea of requiring more knowledge as prerequisite to becoming a scientist was a common theme. Rebecca and Karter provided additional nuance to this view. Rebecca stated that certain habits of mind, such as thinking critically and basing conclusions on evidence, were reasons why she considers herself a scientist; however, in regard to involvement in a science community she stated:

> I feel like I could be more involved with, on campus, with science clubs and things like that. But like I'm in a sorority. And within that all the girls who are

> science majors, they communicate with each other and help each other out. So I would say I am through my sorority, but not through [college]. I mean, I guess a science community could even be like my lecture class. But I wouldn't, I wouldn't necessarily consider that a community because we all just kind of sit and listen. There's no group interaction.

Karter is a White male currently studying aerospace engineering. He, like many, struggled with the question of whether he considers himself a scientist:

> I guess if you think about it like, not yet really. I'm pretty much just kind of starting out, but I would say that I guess even deciding to start it in the first place you could also kind of say yes, because I'm pursuing a career path to become, in a sense, a scientist. So I guess I think that you could say one who pursues to become a scientist is almost already a scientist. Does that make sense? I mean, I think in a literal sense I'm not yet a scientist. But metaphorically speaking I kind of already am.

When pressed as to what would be necessary to call himself a scientist, Karter responded:

> At the point of which I can feasibly, you know, look at something and easily understand it, especially with aeronautics. Or the point at which I can be in a group and do research on something, or research on something that's unknown, pretty much. I feel like at that point I would really consider myself a scientist.

For the participants who exhibit as STEM Apprentices, there is a sense that career goals are fluid. Unlike the STEM-Career Focused, these individuals related less specific career goals and identified several areas of potential interest. They shared possibilities that range from graduate school to different careers, but they often were vague on specifics and commitment. Nonetheless this group still shared an unwavering sense that they will stick with STEM. Adelia was asked if she considered leaving STEM in spite of the academic challenges she struggled with. Adelia responded:

> Um, no. I always wanted to pursue science. If I was going to switch majors, because it was really hard, I would have done some things like environmental studies or some other kind of science. Yeah, I've definitely known that I always want to stick with science.

As a freshman, Karter also voiced concern that the rigorous course load and timeline for completion would be challenging. When asked whether he would pursue a STEM major, even if engineering does not work out, he replied:

> Oh, definitely. Right now, for me, if engineering didn't work out I'm probably going to go into a chemistry major because, I don’t know, it's all just so interesting because there's so much we don't know which really interests me and I really want to just know more and more about it. Now, don't get me wrong, it can be a real pain sometimes. And I have had my nights trying to figure stuff out, just sitting there, you know, for hours trying to figure out just one problem. But it is fun in the long run.

STEM Humanists. When asked what the purpose of science is, participants' responses can be organized under one of three themes: to study and understand the natural world, to provide knowledge by which to support innovation and change, and to help improve people’s lives. It is this last theme that was exhibited unanimously amongst the group categorized as STEM Humanists. This identity group includes three Black female students pursuing a degree in nursing or pre-med: Amani, Brandy, and Latoya. It also includes Uri, a White male who is interested in transferring from a general studies program to pre-med, and Teagan, a white female who is beginning an interdisciplinary major with a focus on environmental sustainability.

The notion that science should be used as a means to improve the human condition was mentioned by each of the STEM Humanists. This purpose aligns with each participant's interest in STEM. Brandy feels that science is worth pursuing and stated:

> Because it's always changing. Like there's not anything you can really get tired of as far as science is. Because it's so much that we don't know. Exploring science is just..., is always interesting and is worth it because it can help many people. I feel like science tries to make the world better, so it is worth pursuing.

Specifically, it is through medical and healthcare advances that ultimately make pursuing science worthwhile, as Amani stated:

> I feel like the purpose of science is for us to not only discover what's in the world, but also to help people individually, overall and society, find different cures for things. Just kind of discover unknown things as well as helping people.

Uri was more philosophical in his response:

> I think that science is supposed to maximize happiness and reduce suffering which I think all educational endeavors usually boil down to … It's slowly trying to make it so that life is more durable and not only that, but more valuable, more special to live.

Teagan also emphasized this idea of science being both the pursuit and application of scientific knowledge to improve the world around us:

> I think it’s worth it because science is a tool, and science is one of the most valuable tools in this present day. The world is dying and so I think if more people go into environmental science or health studies, then that's just better chances of us turning things around. But I also feel like science is one of the most important ways that we can, or one of the most valuable tools for helping others medically. I

> think a lot of the advances in science have been helping people live longer and live more comfortably. And so that really interests me.

While the participants who exhibit this identity suggest science is a tool to improve the human condition, they do not necessarily see themselves as scientists. Like all participants, identifying as a scientist ultimately depends on how each individual defines what a scientist is or is not. These different definitions can be characterized into three themes: the act of pursuing scientific knowledge/experiences (i.e. taking classes), the attainment of scientific knowledge/experiences (i.e. earning a degree or doing research), or practicing different scientific habits of mind (i.e. critical thinking, conclusions based on evidence). To the first theme, Latoya grappled with her personal definition but does consider herself a scientist:

> Maybe a low scale scientist because, I mean, I do experiments every Tuesday. Like, that's pretty 'scientist' of me. I don't know, what makes a scientist? I guess someone who studies science which, that's what I do. I feel like I could…, I am a scientist. Like, I study science. Yeah.

However, Amani and Brandy did not view themselves as scientists. Specifically, Amani stated:

> I don't really see nurses as scientists. No, I see them as like assistant scientists, like an assistant. I don't know. But there's many different nursing fields that are unknown to me, but I'm sure there are scientist nurses.

Brandy offered a similar view; when asked what would be necessary for her to view herself as a scientist, she elaborated:

> I feel like if you take an answer like a question that you've been studying for a really long time. Well, it doesn't have to be necessarily a long time but at least you looked into something worth studying. And I haven't done that yet. I haven't took it upon myself to study anything, necessarily.

Uri shares this sentiment when asked if he considers himself a scientist. Earlier in the interview, Uri identified numerous experiences both personally and academically where he performed as a scientist. These instances involved lab experiences and opportunities to demonstrate scientific habits of mind. However, his definition of a scientist is more rigid:

> I think there's a professional component to being a scientist. Like if I saw a fire and I extinguished it that wouldn't make me a firefighter. Or if I intervened and prevented a crime, that wouldn't make me a police officer. There's a certain element of training and practically following the scientific model and going through your principal investigator and making sure that everything is going through the proper channels. Right? But there's no academic purpose to any of the stuff I would be doing [individually pursuing personal interests] except for just maybe touching up on skills or seeing what I can do with my own tools. So, yeah, I think there's a professional component to that that's missing … But I'm not hired by any laboratory. I'm not paid by anybody. I'm not even in an academic setting yet, doing any of that stuff.

These responses indicate a perceived difference between having an interest in science and being a practitioner of science.

Ultimately, the STEM Humanist views science as a worthy pursuit to help society. Instead of a health care track, Teagan is pursuing this through the lens of human health, social justice, and environmental science. How she views herself as a science person demonstrates how a science identity is nested within the multiple identities we all exhibit. When asked if she views herself as a scientist, she stated:

> Hmmm. That's hard, because I would say no. But that's because I consider myself a lot of things. So maybe I wouldn't consider myself a scientist firstly and most foremost … I'm interested in a lot of different things like art and activism

> and science. I think if I were to introduce myself to someone, I wouldn't call myself a scientist, even though I am interested in science.

How this understanding coincides with a STEM Humanist identity is provided by an earlier excerpt in Teagan's interview:

> I think medical advances and using science to help the environment and to help humans interact with the environment in a better way is what interests me the most. With population growth and how unhealthily our population is growing. I think I would be really be interested in … bringing sex ed and family planning to communities that don't have it, where lots of children are being born. And then also helping women start businesses, which I guess is not science so much, but it's more interdisciplinary. I think health science and tying health science into environmental science interests me.

STEM Seekers. Whereas each participant related an interest in pursuing a STEM degree program, a number of students experienced difficulties along the journey. Some met unforeseen challenges that required a change in their post-secondary plans. Others are still exploring how science fits into their identity and what type of person they want to be as they work to solidify educational and career goals that align with personal interests. For the STEM Seekers, their science identity is one still in flux as other salient identities take prominence. We characterize the following students as STEM Seekers: Sonia, Ruby, Clara, Heather, Jaclyn and Faith.

Participants in the STEM Seeker group share similar views to other participants regarding what qualifies as being a scientist. They were almost unanimous in their view that they do not see themselves as scientists. The reasons for this vary. For Sonia, a White female currently studying forestry at a local community college, her perspective is shaped by her role as a mother and as a nontraditional student. She stated:

> Science is worth pursuing as a career because we have a duty to understand our world and act in it as part of it and not as something separate, because we need to take care of our planet and take care of the world around us. So by pursuing science as a major you can further your understanding of how to act effectively in your environment.

Sonia's perspective is elucidated further by her response to whether she considers herself a scientist:

> Um, maybe not in my everyday life. But there are times where I probably am. Like when I'm out in my garden or when I'm getting messy with paint with [my child], or things of that nature, or like sometimes I'll make [them] play dough out of things I have in the house. And in those little ways we probably are scientists, but I wouldn't consider myself a scientist as a whole.

In other cases, there is a clash between the academic setting and the personal identities that are taking shape. Ruby, an Asian female, was formerly a physics major who recently transferred to a new university to study philosophy. Citing academic challenges, she grappled with this course change and how this impacts her science identity: "Um, I don't know, I don't know if I really consider myself anything yet. I'm definitely a lover and appreciator of science." Similarly, Clara, a White female, was in a program in radiologic technology and recently switched to general studies at a community college. Despite personal challenges, she took a light-hearted perspective as she stated:

> I consider myself a science enthusiast. [Laughing] I really…, I really love science and I want so badly to do more and to understand more. But where my life is at right now, I don't know if it's something that I have the time or money or anything to pursue actively. Yeah, as much as I want to say "yes, I'm a scientist," I think it's [more] like I love science. I'm a science student. I hope maybe someday I

> could be a scientist. But right now I'm just like, yeah…[laughing] a science enthusiast.

For others in the STEM Seekers group, participants are newly entering their degree program. While previous experiences have shaped their interest in science, and thus their science identity, there is clearly an open mind to continue exploring alternative interests that may foster other identities. Sonia, a White female, developed a passion for chemistry in high school due to the challenge and personal success she achieved; while she is pursuing a chemistry major she is also open to other academic majors. Her notion of a scientist is one who has actively contributed to the field:

> I realized that like, by my definition, like a scientist would be somebody who's currently studying to make a difference, but I feel like I'm just stuck studying what everybody else has discovered. Like I don't, I don't know, I don't do anything as an individual yet.

Other participants expressed more explicitly that being a scientist is not foremost in terms of their science identity. Jaclyn, a female freshman studying biology, states:

> Um, because I feel like my main goal right now isn't science. I feel like my main goal is to learn right now. And I feel like, yeah, you could be learning to be a scientist at the same time, but I feel like my attention is not focused completely on science and a lot of it is focused on the other things I have to learn right now … And I don't know if I would label myself a scientist based on what I do and what I want to do, you know?

Recognition as a scientist consists of both an external and internal component. Some participants stated that being recognized externally by others as a scientist was not a priority or important to their identity. Faith, a Black female, is majoring in environmental science and hopes to apply scientific knowledge within a nonprofit or humanitarian context. When asked if she wants to be seen as a scientist she related:

> Um, I mean, not necessarily. They don't have to think of me as a science person. I always feel like whether I do work for a nonprofit or in science it's to help other people. It's not for me to receive gratitude, per se. So it's fine I'm not seen as a science person...like, it's okay. Like, I don't like some aspects of science and I…, you know, a lot of it doesn't click with me and I understand why people don't see me that way. But yeah, I don't really need peer gratification if that's…, I can say that.

The common thread among the STEM Seekers is that a science identity is continually taking shape as individuals continue to understand who they are and who they want to become.

Chapter 5

Discussion

The call for more diversity in STEM disciplines has been identified as a significant challenge in education (Gibbs, 2014; Museus et al., 2011). There is a lack of gender and racial representation in STEM post-secondary and doctoral degree programs and in the STEM workforce (National Science Foundation, 2019). Understanding the motivational factors that, along with rigorous curriculum and support, shape an individual's interest in pursuing STEM is a crucial step in providing quality STEM education for underrepresented groups. Educational reform requires evidence-based strategies to address this gap that are built on conceptual understandings of motivation and achievement (Cook & Artino, 2016; Williams, 2011). Previous research focusing on the learner's affective domain has explored how self-efficacy, a sense of belonging, and science identity provide leverage points to address inequities in STEM education (Kim et al., 2018, Rainey et al., 2018; Trujillo & Tanner, 2014). Carlone & Johnson's (2007) conceptual framework positions competence, performance, and recognition as significant factors that shape science identity; Hazari et al. (2010) later included interest as an additional factor. Understanding these causal factors and how they interact with racial, ethnic, and gender identities is imperative in addressing the STEM diversity gap.

Chapter 5 summarizes the findings of the three research questions in this grounded theory case study. All gender and racial groups shared a variety of factors that shape science identity, and specific nuances within competence, performance, and recognition are discussed. The implications of these findings with current research and within the conceptual framework are explored and the limitations are identified. The chapter concludes with a discussion of the implications for educational practice and recommendations for future research.

Summary of Findings

Research Question 1: What influences high school graduates of different gender and racial groups to pursue and persist in a post-secondary STEM degree program?

The first research question considered the factors that influence the pursuit of a STEM degree program. Participants were asked what it was about science that interested them. Their responses indicated several reasons for possessing an interest in science, including a sense of curiosity, the desire for personal fulfillment, the ability to meaningfully apply their learning, an affinity for challenges, an appreciation for the process of science, the attainment of objective knowledge and the enjoyment of discovery. Participants who indicated the desire to challenge themselves were predominantly White and female. While Black and Asian participants discussed challenges encountered in their educational programs this was not reported to be a motivational factor. An appreciation for the process of science was stated most frequently by participants who were White and female. More males than females expressed an affinity for science because it provided an objective view of knowledge, while no Black participants stated that objectivity was influential. Most Black participants identified discovery as an appealing facet of science, describing the desire to avoid monotony and be exposed to new information. No distinct patterns emerged with respect to gender and minority groups for curiosity or the ability to apply science knowledge.

Participants were asked to identify memorable pre-college STEM experiences. The responses were classified as either formal or informal experiences indicating whether each was a class-related experience or took place outside of required academic work. Overall, it was noted that participants had rich experiences which resonated with them. Almost every respondent described classroom activities, usually labs, and field trips taken as part of a science class. All Black and Asian participants identified these formal experiences. Positive academic experiences significantly influenced minority students based on the frequency of examples provided. No informal experiences were reported by Black participants.

Participants were asked to identify any role models or supporters that influenced them to pursue a STEM degree pathway. Educators were frequently reported as influential, followed by family members. Fewer participants mentioned STEM professionals, peers, and the media. No distinct patterns emerged with respect to gender and racial groups related to influencers. Both White and minority participants described influential educators who encouraged the pursuit of a STEM career pathway. Both White and minority participants mentioned parents or other family members who exposed them to STEM related experiences and/or encouraged them to pursue their STEM interests.

Research Question 2: To what degree do high school graduates of different gender and racial groups who enroll in post-secondary STEM degree programs exhibit their science identity?

This research question explored the degree to which science identity was exhibited as participants demonstrated competence and performance in their studies. Participants were asked to describe experiences related to learning and doing science. No distinct patterns emerged between gender groups and minor differences were noted among racial groups. Participants described how they demonstrated competence in both formal and informal learning settings. The majority of participants shared experiences related to classroom-based learning. Evidence of competence was reflected in earning high grades in math and science. Some participants shared experiences related to informal learning experiences which are defined as experiences taking place outside of a traditional classroom setting (e.g. field trips, summer programs, at home experiments, etc.). In two instances, White female students recalled being guided by their parents to pursue summer programs. Notably absent were any informal learning descriptions from Black participants. It is unknown if Black students were encouraged to pursue informal learning experiences by their parents. Participants described the extent in which they exhibited performance by recalling their experiences doing classroom-based labs, performing their own science research, and by communicating scientifically. Most participant responses focused on recent and past experiences with classroom-based labs. This was not unexpected since participants were still taking classes at the time they were interviewed. While a few participants shared experiences related to the importance of practicing science communication, most did not.

Participants were asked to describe any challenges they faced and how they persisted. No distinct patterns emerged between gender and racial groups. The most frequently cited challenge was adapting to life as a college student. Most noted the need to develop more effective study skills and time management habits. Participants described the importance of academic support, peer support, and verbal persuasion to overcome their challenges related to study habits. Utilizing university support systems, working in groups, relying on the assistance of mentors, and gaining support from family were mentioned as examples of academic support. Grit and passion were coded most frequently as explanations for why students were able to persevere. Student interest, mainly curiosity and application, may point to the source of these two characteristics. Both learning from failure and success, coded as personal mastery experience, played an important role in overcoming challenges. In general, a sense of optimism was noted among participants when they described their experiences related to personal mastery. This sense of optimism may indicate these students exhibit a growth-minded perspective. Notable were the participants who took Science Research in high school. These participants described the prominent role failure played in science. Learning from trial and error was viewed as part of the process of science. Fear of failure, quality teaching, and vicarious experience were mentioned by a few participants as a way they persist in science, but no distinct patterns were observed.

Lastly, this research question investigated the ways in which participants exhibited their science identity by participating in a science community. Participants were asked whether they felt part of a scientific community and to explain why they felt this way. No distinct patterns emerged between gender and racial groups. When participants were asked if they felt part of a scientific community, a definition was not provided. This required each participant to formulate and discuss their understanding of what a science community consists of and to what extent they were or were not participating. Most participants described being part of a community as a group of students learning and doing science. Responses included being involved in classes, study groups, science clubs, and seminars. A few participants described being surrounded by a scientific community that consists of their respective campuses. Of five participants who did not feel part of a science community, three were female and in the STEM Seekers identity group. One first-year female Black student did not feel part of a scientific community yet and was planning to start a science club for minority students on campus.

Research Question 3: What are the salient forms of science identity among different gender and racial groups enrolled in a post-secondary STEM degree program?

This research question explored how participants viewed themselves in terms of being a science person and the salient themes that emerged as part of their science identity. How each participant viewed themselves as a science person did not correlate with gender but did seem to correlate with race. When participants were asked if they saw themselves as a scientist, a definition was not provided. This required each participant to formulate and discuss their understanding of who is a scientist and what a scientist does. The responses were categorized into three themes: the act of pursuing scientific knowledge/experiences (i.e. taking classes and labs), the attainment of scientific knowledge/experiences (i.e. earning a degree or doing research), or practicing different scientific habits of mind (i.e. critical thinking, conclusions based on evidence, etc.). Out of 24 students, eight students identified as being a scientist, 14 stated no, and two were undecided. The ratio of White participants that said yes versus no was approximately 50:50. Out of nine minority participants, only two identified themselves as being a scientist based on the pursuit of knowledge and none identified as a scientist based on research experiences. In our view this is demonstrative of the limited definition all students, and particularly minority students, have in terms of what makes one a scientist.

The major salient themes were organized into five representative identities that largely did not exhibit gender or racial patterns, although two exceptions are noted. Those students in the group classified as Research Scientists all shared experiences of participating in scientific research and they expressed interest in conducting research in the future. All were White females, three of whom were in biology and one who was in an engineering program. The STEM-Career Focused verbalized strong interests and goals in a specific career track. This included one Black female and one White male in computer science and one White female and one White male in engineering. STEM Apprentices prioritized the need to continue learning and related ambiguous career goals. Included were three White females in life science tracks and one Black male and one White male in engineering programs. STEM Humanists stated a fundamental interest in improving health and helping people. Participants included three Black females who were enrolled in nursing programs, one White male interested in entering a pre-medical track, and one White female with an interest in connecting health and environmental science. STEM Seekers related disrupted educational paths and/or expressed open-ended commitment to educational and career goals in STEM. This included two Black females and one White female in life science, one White female in chemistry, and one Asian female previously in physics.

Two patterns regarding salient identities and demographic groups are worth noting. The first is the four White females designated as Research Scientists, three of whom are studying biology. This aligns with the national trend where women hold the majority of biology degrees, and it alludes to the trend of an increasing number of women holding academic doctoral positions in STEM disciplines (National Science Foundation, 2019). The lack of males and Blacks in this category was interesting although this may be due to the small number of both demographic groups represented in the sample. The second pattern regarding salient identities is the three Black females as STEM Humanists enrolled in nursing programs. Nationally Blacks are underrepresented in the STEM workforce, but their highest representation is in the health-related fields (Funk & Parker, 2018). There was only one female Black student in computer science and one female Black student and one female of color in environmental science identified in the sample population. Out of 24 students, there was only one male Black student studying engineering. The results were consistent with the national trend that Blacks are not pursuing many STEM degree programs (National Science Foundation, 2019).

Integration of Findings with Current Research

Prior studies have utilized quantitative (Hazari et al., 2010), qualitative (Tan & Calabrese Barton, 2008), and mixed methods (Aschbacher et al., 2010) to understand the nature of science identity. Such studies have occurred within many STEM contexts from elementary school through doctoral research programs. This case study is the first to take a strictly qualitative approach to examine the factors that influence science identity in a sample of graduates from the same urban public high school as they navigate a post-secondary STEM degree program. It is also one of the few to explore differences in science identity in gender and racial demographic groups (Chapman & Feldman, 2017). Carlone and Johnson (2007) were the first to propose a conceptual framework for science identity which included competence, performance, and recognition, and this model was modified by Hazari et al. (2010) to include science interest. Our findings both support and add new emphasis to different components of this model.

In Carlone and Johnson's (2007) exploration of science identity in women of color in STEM-graduate programs and careers, the primary factor of recognition was found to have an overwhelming influence on each participant's identity. In their revised model they concluded that competence and performance do not predict the science identity one develops. However, science identity is something that is continually shaped throughout adolescence and young adulthood and this development interacts with the gender, racial, and other identities within each individual. Our findings suggest that the relative importance of each factor (i.e. competence, performance, and recognition) is largely dependent on the research context. In students in undergraduate STEM programs, competence and performance played a considerable role in participants' interest in pursuing STEM. Their choice and persistence in STEM can further be broken down into specific factors that both build self-efficacy and motivation. Whether participants viewed themselves as scientists was largely influenced by factors within the domains of competence and performance. These findings support Flowers and Banda's (2016) assertion that the cultivation of self-efficacy and science identity are critical leverage points to address the STEM diversity gap. Understanding the extent to which participants embrace a science identity, along with the challenges faced by underrepresented minorities, are necessary next steps in fostering diverse STEM educational environments (Trujillo & Tanner, 2014).

Delimitations

Several delimitations accompanied this research. The size of the participant group was limited to the graduates of one public urban high school. This group was chosen because of the availability of student contact information, a sample of convenience. They were also chosen because they shared a similar secondary science curriculum: taking the same core science classes from the same science faculty in the same sequence. Participation was only offered to those who had graduated within the past five years, thus were still in the process of pursuing a STEM-related degree.

Limitations

The limitations included the limited number of participants due to minimal responses to the original call for participation. Missing contact information was aggressively sought and the original email invitation sent twice. A small financial incentive was offered to maximize participant numbers. From the screening survey 28 STEM degree seeking candidates were identified who agreed to complete the interview. In subsequent communications the inability to a mutually agreeable time for interviews with potential participants limited the study to 24 respondents. Because of time limitations each participant was only interviewed once and no longitudinal data was collected. Follow-up questions would have provided an opportunity to corroborate answers and to examine changes over time.

A significant limitation was the researchers' association with the participants. As their former teachers, a personal relationship had been developed with them. While another person could have conducted the interview, it was believed that fewer respondents would have agreed to participate. When contact was made to schedule the interview time participants were eager to reconnect with their past teachers. To minimize researcher bias, participants were randomly assigned to interviewers and a script was written for the structure of the interview to consciously strive for objectivity. In addition to the potential bias as interviewers, it was recognized that participants may also have been biased as respondents. The answers given may have been influenced by their desire not to offend their previous instructors. To limit this concern, readers used a prepared introduction before each interview to encourage candid responses. Responses were limited to the experiences that participants remembered. It is possible that their STEM-degree trajectory was influenced by factors that were not recalled during the interview. To collect as much information as possible, participants were invited to contact the researchers if they wished to add any information. Only the science identity of those pursuing a STEM degree were observed but it would have been interesting to examine the science identity of those pursuing a degree in another field or not currently enrolled at an educational institution.

The case study research design was utilized because this methodology allowed the examination of different facets of participants' experiences in depth. A limitation of this type of research is the inability to generalize the findings to a larger population. General applicability was not a goal, but by examining the experiences of the participants it was hoped a significant contribution to an understanding of science identity development could be made.

Implications for Practice

The findings suggest there are many ways to increase student interest in science and participation in STEM degree pathways. In order to foster the development of science identity in students, schools need to design a robust science program. A well-developed science curriculum, taught by qualified and engaging educators, can lead to increased student competence and performance in STEM. The curriculum must also include active learning experiences that provide opportunities to practice science skills and science communication. Supporting the development of both competence and performance increases student self-efficacy. Fabio & Fabio (2011) suggests a positive correlation exists between higher levels of self-efficacy and increased persistence. Science educators have a stronger influence when they cultivate positive relationships with students and their students' parents. Schools can also expose students to a wide variety of formal and informal learning experiences. While this is important for all students, it is particularly important for students in underrepresented gender and racial groups. Additional support may be necessary to negate the barriers that prevent students from participating in meaningful informal learning activities. While programming in high school may have guided some of the participants to understand the variety of STEM career opportunities, one participant commented about feeling her choice of available STEM careers was limited. Highlighting the diversity of careers that are available within the STEM fields can benefit all students. Overall, development of the ability of students to improve competence and performance in science can lead to increased science self-efficacy, persistence, and interest.

One way to address the underrepresentation of gender and racial groups in STEM degree programs is to use lay theory interventions. Lay theories are the commonplace explanations people use to explain how people behave in certain situations. These psychological interventions consist of teaching students how it is common to experience challenges during the transition from high school to college. Such interventions in high school have been shown to reduce achievement gaps (Yeager et al., 2015). An example of this would be to invite former students who are enrolled in college to share experiences with current high school students. This mitigates the misconception that college is only meant for some racial groups. Interventions like these can also improve the sense of belonging in racial and ethnic minority groups and first generation college students who often experience adversity as college freshmen (Walton & Cohen, 2011).

The transition from high school to college is difficult for most students (Fromme et al., 2008). Support from social networks such as family members, mentors, or fellow students, increases persistence (Engstrom & Tinto, 2008). The need to strengthen existing programs that support struggling students in undergraduate programs is suggested. Academic support systems such as tutoring centers, mentor programs, and a diverse offering of extracurricular clubs and activities encourages student persistence. Findings suggest students who are more involved in science-related activities not only demonstrate increased persistence, but also an increased sense of belonging to a science community.

Recommendations for Further Research

The science identities enacted by graduates from a Midwest urban public high school (MUPHS) and who have enrolled in undergraduate STEM degree programs was explored. Findings suggest several avenues for future research. First, a case study with high school systems with different student demographics and population sizes (e.g. public, private, urban, rural, career-focused) could be repeated. For example, conducting a similar study in a STEM-focused high school would provide a unique perspective. The participant sample consisted of undergraduates who entered into a STEM degree pathway. Adjusting the sample to include undergraduate STEM and non-STEM majors would enable researchers an opportunity to explore how science identity compares between different programs. Second, students who were interviewed were once former students of the interviewers. Findings suggest educators exhibit a strong influence on student interest and motivation to pursue STEM degree pathways. Follow-up interviews would lead to increased understanding of how the act of being interviewed impacts student motivation to persist in science. Third, findings suggest competence and performance play an important role in how undergraduate students exhibit their science identities. A longitudinal study where students are interviewed multiple times over an extended period is recommended. This approach may shed light on how science identity shifts over time. Also, it may help to identify when recognition begins to play a larger role in graduates of STEM degree programs.

Conclusion

In this chapter, the need in the United States for educational strategies that address diversity gaps in STEM was reiterated. The Carlone & Johnson (2007) model of science identity development, framed by performance, competence and recognition, with the addition of science interest by Hazari et al. (2010), was reviewed. Using this framework, the influence of experiences, people, and interest in science was discussed. Five themes categorize participants' science identity: Research Scientist, STEM-Career Focused, STEM Apprentice, STEM Humanist, and STEM Seeker. Both gender and racial groups exhibited a variety of salient science identities. The patterns of both White females as more likely to display a Research Science identity and Black females a STEM Humanist identity were revealed. Limitations of a small sample population and the recognition of future research extensions were acknowledged. Fostering healthy science identities must be part of the science education process.

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Appendix A

Screening Survey Participants

Graduating Class	Class Size	Number of email addresses available	Addresses available as percent of class	Number of emails sent	Number of survey responses	Survey response rate
2019	75	58	77.3%	50	20	40.00%
2018	70	10	14.3%	10	7	70.00%
2017	79	56	70.8%	55	23	41.82%
2016	78	28	35.9%	28	9	32.14%
2015	86	57	66.3%	43	11	25.58%
TOTALS	**388**	**209**	**53.9%**	**186**	**70**	**37.63%**

Appendix B

Email Invitation

Invitation to Participate (sent via email)

Hello [name of school] alumnus!

We hope that you are faring well in your life after high school. The [name of school] science teachers, Kathleen Dwyer, Chuck McWilliams and Ben Nims, are doctoral students at the University of Missouri - St. Louis. We are asking for your help with our dissertation research.

For our study, we will be conducting research about formal/informal science experiences and personal attitudes/beliefs about science. We are asking [name of school] graduates to complete a short online survey. All responses will be kept confidential. Each survey respondent will be entered into a random drawing to receive a $25 Amazon gift card as an incentive.

We hope that you will take a few minutes to help us by answering the questions linked here. <insert survey monkey link>

Thank you in advance. We appreciate your help and look forward to hearing from you!

Best,
Benjamin Nims
Kathleen Dwyer
Charles McWilliams

Appendix C

Screening Survey (on Survey Monkey)

Pt. 1 Description of Study and Informed Consent.

1. You are invited to participate in a voluntary research study conducted by Kathleen Dwyer, Charles McWilliams, and Benjamin Nims, and it is under the supervision of Dr. Charles Granger. The purpose of this research is to study the factors that lead to the formation of a science identity and how this influences high school graduates to pursue and persist in a post-secondary STEM degree program.

2. a) Your participation will involve the following:
   - Completion of an online survey with questions about your prior educational experiences and other background information.
   - An interview with one of the investigators including questions about your formal/informal science experiences and your personal attitudes/beliefs about science.
   - All interviews will be conducted face-to-face in a semi-private setting with limited distractions, or via video conferencing, as agreed upon by the participant and the investigator.
   - All interviews will be recorded for transcription and qualitative analysis. If necessary, a follow-up interview will be scheduled.
   - Your identity and personal information will remain confidential in the report of findings from this research.

   Approximately 400 total participants will take part in the survey and a sample of up to 30 participants will be selected to be interviewed.

   b) The amount of time involved in your participation will be approximately five minutes for the survey and approximately one hour for those selected to be interviewed. Follow-up interviews will take approximately 30 minutes. Each survey respondent will be entered into a random drawing to receive a $25 Amazon gift card as an incentive. Each interview participant will be entered into a random drawing to receive a $100 Amazon gift card as an incentive.

3. There are no known risks associated with this research.

4. There are no direct benefits for you participating in this study, however your participation will shed insight into how science identity develops and help inform initiatives aimed at improving science literacy and engagement in STEM related coursework at the high school level.

5. Your participation is voluntary and you may choose not to participate in this research study or withdraw your consent at any time. If you choose to withdraw from the study, you can contact any of the Investigators (Kathleen Dwyer: [email address] Charles McWilliams: [email address]; Benjamin Nims: [email address]). You may choose not to answer any questions that you do not

want to answer. You will NOT be penalized in any way should you choose not to participate or to withdraw.

6. We will do everything we can to protect your privacy. As part of this effort, your identity will not be revealed in any publication that may result from this study. In rare instances, a researcher's study must undergo an audit or program evaluation by an oversight agency (such as the Office for Human Research Protection) that would lead to disclosure of your data as well as any other information collected by the researcher.

7. If you have any questions or concerns regarding this study, or if any problems arise, you may contact any of the Investigators or the faculty advisor (Dr. Charles Granger: [email address];). You may also ask questions or state concerns regarding your rights as a research participant to the Office of Research at [phone number].

By starting the survey, you are verifying that you have read the description of the study and informed consent and that you agree to participate. You also understand that your participation in this study is strictly voluntary and you may withdraw at any time. Please answer the following questions honestly and to the best of your ability. Questions pertaining to STEM refer to any disciplines related to science, technology, engineering, and math. By completing this survey you are agreeing to allow your data to be used in our research.

Pt. 2 Survey Questions.

1. Name (Last, First)

2. What year did you graduate from [name of school]? (pull down menu)

3. In which grade did you first enroll as a student at [name of school]? (pull down menu)

4. Which science courses did you complete in high school? Select all that apply (checkboxes).
   o Chemistry
   o Physics
   o Biology
   o Exploring Environmental Sustainability
   o The Human Body (Anatomy and Physiology)
   o AP Biology
   o AP Chemistry
   o AP Environmental Science
   o Modern Physics
   o Science Research
   o Other ____________________

5. During your time at [name of school], did you participate in any of the following activities? Select all that apply (checkboxes).
   o Adventure Club

- o Science Bowl
- o Middle School Summer Field Experience
- o SIFT
- o TERF
- o STARS
- o WYSE
- o Science Debate
- o JSEHS
- o Honors Science Fair
- o Other STEM-related after-school activities _______________
- o Other STEM-related summer activities _________________

6. Where are you currently enrolled as a student? (fill in the blank)

7. What is your current major? (fill in the blank)

8. What is your current minor (if any)? (fill in the blank)

9. Has your major and/or minor changed since you first enrolled as an undergraduate? (yes/no)

    a. If yes, please indicate which major you changed from (fill in the blank)

10. What are your plans upon graduating with your undergraduate degree (checkboxes).
    - o Enter a STEM-related career
    - o Enter a non-STEM-related career
    - o Enter graduate school
    - o Other _______________

11. OPTIONAL: Demographic and Personal Information (checkboxes)

Are you Hispanic or Latino?
- o Yes
- o No

Ethnicity (select one or more):
- o American Indian or Alaskan Native
- o Asian
- o Black or African American
- o Native Hawaiian or Other Pacific Islander
- o White

Sex:
- o Male
- o Female

Gender:
- o If you would like the opportunity, we invite you to share more about your gender identity below _______________________ (fill in the blank)

Pt. 3 Optional Interview Participation.

Part of our study includes interviewing students to learn more about their science-related background experiences and goals. Respondents who are interviewed will be entered into a random drawing for a $100 Amazon gift card. Interviews will take place during the first semester of the 2019-2020 school year at a mutually agreed upon date and time. Interviews will be recorded for later analysis. All participants in our study will remain confidential as reported in our findings and all data will be kept confidential on password-protected computers. All recordings obtained will be destroyed at the conclusion of the study. We do not anticipate any harm or inconvenience to participants. All participation is voluntary and participants may withdraw from the study at any time.

Would you be willing to be interviewed? (yes/maybe/no)

If you selected “yes” or “maybe” above, please provide us with this additional information.

1. What is the best day and time to reach you? (fill in the blank)

2. What email address would you prefer we use to contact you? (fill in the blank)

3. What phone number may we use to contact you? (fill in the blank)

Appendix D

Letter of Informed Consent

College of Education
One University Boulevard
St. Louis, Missouri 63121-4499
Telephone: [phone number]
Email: [email address]

Informed Consent for Participation in Research Activities

The development of science identity in undergraduate STEM majors: A case study of urban high school students

Participant ________________________ HSC Approval Number _________

Principal Investigators Kathleen Dwyer, Charles McWilliams, and Benjamin Nims

PI's Phone Numbers Dwyer: [phone number]; McWilliams: [phone number]; Nims: [phone number]

Summary of the Study

1. You are invited to participate in a voluntary research study conducted by Kathleen Dwyer, Charles McWilliams, and Benjamin Nims, and it is under the supervision of Dr. Charles Granger. The purpose of this research is to study the factors that lead to the formation of a science identity and how this influences high school graduates to pursue and persist in a post-secondary STEM degree program.
2. a) Your participation will involve the following:
    - Completion of an online survey with questions about your prior educational experiences and other background information.
    - An interview with one of the investigators including questions about your formal/informal science experiences and your personal attitudes/beliefs about science.
    - All interviews will be conducted face-to-face in a semi-private setting with limited distractions, or via video conferencing, as agreed upon by the participant and the investigator.
    - All interviews will be recorded for transcription and qualitative analysis. If necessary, a follow-up interview will be scheduled.
    - Your identity and personal information will remain confidential in the report of findings from this research.

Approximately 400 total participants will take part in the survey and a sample of up to 30 participants will be selected to be interviewed.

b) The amount of time involved in your participation will be approximately five minutes for the survey and approximately one hour for those selected to be interviewed. Follow-up interviews will take approximately 30 minutes. Each survey respondent will be entered into a random drawing to receive a $25

Amazon gift card as an incentive. Each interview participant will be entered into a random drawing to receive a $100 Amazon gift card as an incentive.

3. There are no known risks associated with this research.
4. There are no direct benefits for you participating in this study, however your participation will shed insight into how science identity develops and help inform initiatives aimed at improving science literacy and engagement in STEM related coursework at the high school level.
5. Your participation is voluntary and you may choose not to participate in this research study or withdraw your consent at any time. If you choose to withdraw from the study, you can contact any of the Investigators (Kathleen Dwyer: [email address];; Charles McWilliams: [email address]; Benjamin Nims: [email address])You may choose not to answer any questions that you do not want to answer. You will NOT be penalized in any way should you choose not to participate or to withdraw.
6. We will do everything we can to protect your privacy. As part of this effort, your identity will not be revealed in any publication that may result from this study. In rare instances, a researcher's study must undergo an audit or program evaluation by an oversight agency (such as the Office for Human Research Protection) that would lead to disclosure of your data as well as any other information collected by the researcher.
7. If you have any questions or concerns regarding this study, or if any problems arise, you may contact any of the Investigators or the faculty advisor (Dr. Charles Granger: [email address]; You may also ask questions or state concerns regarding your rights as a research participant to the Office of Research at [phone number];.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I hereby consent to my participation in the research described above.

____________________________ __________

Participant’s Signature **Date**

____________________________ __________

Investigator’s Signature **Date**

Appendix E

Participant Demographics and Courses of Study

Pseudonym	Grad. Year	Gender	Race	Courses of Study
Sonia	2015	Female	White	Major: Forestry Minor: Horticulture
Adelia	2016	Female	White	Major: Biology and Psychology Previous Major: Marine Science
Vonda	2016	Female	White	Major: Biology and French
Charles	2017	Male	Asian	Major: Mechanical Engineering
Clara	2017	Female	White	Major: General Studies; preparing for Radiologic Technology Original Major: Psychology
Grace	2017	Female	White	Major: Chemical Engineering Minor: Biotechnology
Madeline	2017	Female	White	Major: Biomedical Engineering Minor: Mathematics
Ruby	2017	Female	Asian	Major: Philosophy Minor: Math, Criminology Original Major: Physics
Sasha	2017	Female	White	Major: Molecular Biology
Timothy	2017	Male	White	Major: Computer Science Original Major: Biomedical Engineering
Uri	2017	Male	White	Major: General Studies with intent to transfer to: Biomedical Engineering
Willa	2017	Female	White	Major: Biology with emphasis on ecology, conservation, evolution
Alan	2018	Male	Black	Major: Mechanical Engineering Minor: Art
Chantel	2018	Female	Black	Major: Computer Science Minor: Art
Rebecca	2018	Female	White	Major: Microbiology and Biotechnology Minor: Criminology

Pseudonym	Grad. Year	Gender	Race	Courses of Study
Amani	2019	Female	Black	Major: Biology; Pre-Nursing Minor: Spanish
Brandy	2019	Female	Black	Major: Nursing
Faith	2019	Female	Black	Major: Undecided, Sustainability focus
Heather	2019	Female	White	Major: Chemistry
Jaclyn	2019	Female	Un-declared	Major: Behavioral Biology Minor: Comparative Literature Original Major: Biology
Karter	2019	Male	White	Major: Aerospace Engineering Original Major: Mechanical Engineering
Latoya	2019	Female	Black	Major: Nursing
Olivia	2019	Female	White	Major: Plant Science: Pre-medical Minor: Linguistics Original Major: Biology
Teagan	2019	Female	White	Major: Interdisciplinary, focus on sustainability and education Minor: Spanish

Appendix F

Semi-Structured Interview Protocol

Read the following to participants:

For the participants who volunteer to complete the pre-screening survey and who are randomly selected to be interviewed, we will adhere to the following protocols:

- Participants will meet with one of the researchers at an agreed upon time and date.
- Interviews will be conducted either face-to-face or via video conferencing using Zoom.
- Each participant will be provided an informed consent waiver before beginning the interview.
- Participants will be verbally reminded that their participation is voluntary and that they may choose to end the interview at any point.
- Participants will be verbally reminded that their school and personal identity will remain confidential in the writeup of findings.
- Interviews will be recorded for transcription and coding.
- Notes will be taken by the researcher(s) during the interview
- Researcher(s) will use a list of semi-structured questions.
- Participants will be informed that they may be contacted in the future if clarification of responses is needed.

Semi-Structured Interview Questions

1. What is it about science that interests you? Why did you decide to pursue your major?
2. When you think about your life before college, what were some memorable experiences you had related to science?

3. When you think about your experiences at MUPHS, did you feel successful learning/doing science? In college? Has this changed?
4. Have you been academically successful in your science classes? In high school? College? Has this changed?
5. Did you have role models or supporters who helped shape your interest in science?
6. What is the role/purpose of science?
7. Why is science worth pursuing as a major/career?
8. Do you consider yourself a scientist? Do you feel others do?
9. Do you feel that you are part of a science community?
10. What challenges have you had to overcome?
11. What has helped you persist in science?
12. So, it has been suggested that there is a gender gap in STEM, as in more males participate in STEM than females. What are your thoughts on this? What has been your experience with this?
13. It has also been suggested that there is a minority gap in STEM with more white participants in STEM than minority participants. What are your thoughts on this? What has been your experience with this?
14. What are your future aspirations?

Appendix G

Code structure and counts for Research Question 1: What influences high school graduates of different gender and racial groups to pursue and persist in a post-secondary STEM degree pathway?

Codes	Count	Code Description	Example
Experience: Competence			
Formal	41	Classroom-based learning science knowledge	*"… there are multiple examples in my science courses where the things I learned were applied directly to what we're learning right now."*
Informal	21	Outside of classroom-based learning science knowledge	*"…being out on the boat and learning about the kind of field research that they do…"*
Experience: Performance			
Class-based Labs	29	Curriculum-guided and/or traditional science experiences	*"… I love the labs we did in class, like we do all types of experiments … we did one with UV rays and sunscreen."*
Research	16	Independent and/or team-based inquiry research experiences	*"… I did an independent study while I was down there and I did it on barred owl vocalizations."*
Communication	8	Presenting, discussing, etc.	*"I'm doing a thesis right now for the Biology Department, and learning how to talk about it to people who don't know anything about the subject in a way that makes them care or interested is a challenge"*
Practicing Science Skills	4	Practicing or applying science skills outside of a class-based lab or research	*"… and on each trip you were supposed to design and plan an experiment."*
Influential People			
Educator	35	Teachers, professors, etc.	*"…I was really close to [science teacher]. She is a good person and she would help me make connections with people and encourage me to do science programs."*
Family	19	Family relatives	*"…Um, probably my grandpa. He's a chemical engineer … I think he's a big role model and he's really smart. He's really successful, so, he's got his PhD, so I can do it too… I got those genetics."*
STEM Professionals	7	Working professionals in STEM	*"…So, I meet with physician assistants, nurses, surgeons, doctors, everybody from pediatrics to psychiatry to neurosurgery, everyone. And I mentioned my interest in being a PA or being a physician and they gave me their old books."*
Peer	6	Friends and classmates	*"…[student] is my roommate in college. She's an influential person in my life because she's very actively taking lots of science classes."*
Media	2	TV, internet social media etc.	*"…the media has also been a big impact in the importance of science and my understanding of the importance of science."*

Codes	Count	Code Description	Example
Interest			
Application	49	A tool or discipline used to solve problems	*"… [science] can also help other people … I see addressing this huge existential crisis of ecological disaster and climate change as a fairly worthwhile thing."*
Curiosity	40	Interested in discovery and learning more about the topic	*"…I had a fascination with machines and putting stuff together and doing DIY experiments at home."*
Evolving	19	Science is always changing, new knowledge is being generated, it is not stagnant	*"I've always kind of wanted to be the next generation or part of the next generation that's going to keep improving on to what we already have and doing research and making new findings.'"*
Process	11	Provides a framework to learn more about a phenomenon or how things work	*"…part of me did like just the structure of all the different math and sciences, where it's very much a cause and effect…"*
Challenging	10	Like the challenge of trying to figure something out	*"It was kind of naturally fun for me to figure out why I didn't get it right. It was just reassuring that there is a right answer, even if I don't think there is a right answer."*
Individual Fulfillment	7	When a student enjoys doing science; it brings them happiness or satisfaction	*"… doing [science] because it makes you individually happy is a good reason to do something."*
Objective Knowledge	6	It is not ambiguous; it is real/concrete based on data and evidence; not subjective	*"… there's usually an objective truth to science where other topics don't have objectivity."*

Appendix H

Code structure and counts for Research Question 2: To what degree do high school graduates of different gender and racial groups who enroll in post-secondary STEM degree programs exhibit their science identity?

Codes	Count	Code Description	Example
Experience: Competence			
Formal	41	Classroom-based learning science knowledge	*"… there are multiple examples in my science courses where the things I learned were applied directly to what we're learning right now."*
Informal	21	Outside of classroom-based learning science knowledge	*"…being out on the boat and learning about the kind of field research that they do…"*
Experience: Performance			
Class-based Labs	29	Curriculum-guided and/or traditional science experiences	*"… I love the labs we did in class, like we do all types of experiments … we did one with UV rays and sunscreen."*
Research	16	Independent and/or team-based inquiry research experiences	*"… I did an independent study while I was down there and I did it on barred owl vocalizations."*
Communication	8	Presenting, discussing, etc.	*"I'm doing a thesis right now for the Biology Department, and learning how to talk about it to people who don't know anything about the subject in a way that makes them care or interested is a challenge"*
Practicing Science Skills	4	Practicing or applying science skills outside of a class-based lab or research	*"… and on each trip you were supposed to design and plan an experiment."*
Persistence			
Academic Support	24	Accessed formal or informal supports like tutoring, office hours, peers, etc.	*"I learned a lot about going to office hours and just getting help from the professor."*
Grit	23	Using goals to persevere	*"When I have homework, it's not time to shut down. It's time to really push through it and get it done."*
Personal Mastery Experiences	17	Belief in achieving based previous success	*"Whenever I did well in a case that reassured me I could do it …"*
Passion	14	Internal drive to succeed	*"I think it's just like owning the title of being a chemical engineer and like that's what I really want to do."*
Fear of Failure	9	Not willing to accept the consequences of failing	*"I mean, I'm kind of worried about it. But I'm hoping I'm it's going to turn out okay. I just gotta not fail any classes. I mean, for now, I'm surviving."*
Vicarious Experience	8	I see others (with whom I identify with) succeeding, therefore I can too	*"Another thing that's helpful is learning from some of those same role models about what their challenges were …"*
Quality of Teaching	4	Effective Teaching	*"…I think it was because the way that he taught."*
Peer Support	2	Study groups/partners	*"…it's relying on people around me ... relying on my friends and relying on my family for that support."*
Verbal Persuasion	2	The verbal encouragement, praise, or admonishment one receives from others	*"… [family] giving a little, you know, 'you can do it!' like…it's okay."*

Codes	Count	Code Description	Example
Recognition: Science Community Participation			
+ Learning Science	24	Peer groups, clubs, science student peer group/academic group	*"I'm in clubs in my college that are STEM-based … like I'm in engineering club and I'm in chemistry club and stuff like that. But also, I work in laboratories often."*
+ Doing Science	9	Class labs or Research labs	*"... tomorrow I'm going to a club and it's aero design and right now we're building a plane."*
No	8	Not part of a science community	*"…I haven't seen myself really within that community yet."*
+ Feels Surrounded By	4	Science is going on around me	*"…I think generally being on this campus. It's a very science oriented feel even if you're not studying science."*

Appendix I

Code structure and counts for Research Question 3: What are the salient forms of science identity among different gender and racial groups enrolled in a post-secondary STEM degree program?

Codes	Count	Code Description	Example
Recognition: Experience with STEM Gaps			
Gender	11	Shared personal experience related to gender that shaped science identity	*"I want to do well in it because I know that there's lots of opportunity for women in science and I know that it's something that is wanted and needed more … I think kind of that societal pressure to do well and understand."*
Minority	7	Shared personal experience related to race that shaped science identity	*"I'm usually the only person of color within my classrooms."*
Recognition: Scientist (+) "Yes, I see myself as a scientist"			
+ Science Practice	7	I am doing science (performance)	*"Oh, for sure. Um, yeah, I mean, like I'm working in a lab."*
+ Science Knowledge	3	Knowledge in science (competence)	*"…Yes … even if you're just taking science classes and, you know, like even if you're taking lab classes or just learning about more science."*
+ Scientist In-Training	3	Yes, but I am still learning	*"I'm studying towards becoming a scientist."*
Recognition: Scientist (-) "I do not see myself as a scientist… yet"			
- Science Practice	14	I am not doing science research, publishing, etc. (performance)	*"Probably not, because I wouldn't be working towards academic papers or I wouldn't be contributing much to society."*
- Science Knowledge	10	I am not knowledgeable enough yet (competence)	*"I consider myself becoming a scientist, not all the way up there. I still feel like there's a lot of things I need to learn."*
- It's Complicated	1	Not a scientist yet, but for reasons other than lack of knowledge or performance	*"And I want to be a scientist. But right now, I'm still like, 'do I want to be a scientist?' I don't know."*