FLORIDA STATE UNIVERSITY

COLLEGE OF EDUCATION

# EXCLUSIVITY THROUGH CHALLENGE:
# DIFFICULTY AND TALENT BELIEFS IN
# MATHEMATICS-INTENSIVE SCIENCE FIELDS

By

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A Dissertation submitted to the
Department of Educational Leadership & Policy Studies
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

2018

Samantha Nix defended this dissertation on March 21, 2018.

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*To Cassian*

## ACKNOWLEDGMENTS

My greatest thanks to those who helped me write this dissertation.

First, my appreciation to funders. To the National Academy of Education (NAEd)/Spencer Dissertation Fellowship for the generous award, connection to other fellows, opportunity to workshop ideas, and mentorship with NAEd members. To the P.E.O. Scholar Award for the financial assistance and for connecting me to P.E.O.—thank you Chapter FP for your sisterhood. To the W. Hugh Stickler Memorial Dissertation Award for the assistance in purchasing software. The Center for Higher Education Research, Teaching, and Innovation provided funds to purchase a new computer which allowed me to complete the multiple imputation model described in Chapter 3—thank you for this. Finally, to Dr. Shouping Hu and the Center for Postsecondary Success. You provided financial assistance, office space, and general support that was invaluable to the development this dissertation.

Next, my deepest thanks to the participants in the studies. The 24 interview participants not only gave me two or more hours of their time, but entrusted me with their stories. Thank you. My thanks also to the FSU Office of Institutional Research staff, especially Rashad Aziz for turning around my data request on such a short timeline and becoming true collaborators in the data collection process. Rashad also provided some feedback on my quantitative study that was meaningful. Also to the National Center for Education Statistics. Thank you for providing access to and assistance with the restricted-use Education Longitudinal Study dataset, which provided my first measurements of perceived difficulty.

There were two major inspirations for this dissertation. First, to Jessica Shackleford Flinn—thank you for arguing with me about who had a more difficult major when we were in college. We decided then—and it’s clear now—that the answer doesn’t matter as much as why we were asking the question. Thank you for being my best friend, an inspiration, and a huge source of support throughout this process. Next, to the 2009-2014 cohorts of the Women in Math, Science, and Engineering (WIMSE) living learning community. Thank you for sharing your experiences with me. Your stories propelled me to act through research. My greatest hope is that these findings will positively impact you and the women that follow.

I want to thank Madeline Ginn and Abigail Smith, Undergraduate Research Opportunities Program mentees. Abigail assisted with piloting the interview questionnaires and building some of the tables in the quantitative findings section. She provided momentum when I was just starting the dissertation process. Madeline has come in on the back end of this process, providing literature review assistance, editing, and table building. It was a pleasure to work with you both!

To my peers, fellow doctoral students that commiserated with me along the way and proved that misery really does love company. Fellow full-time doctoral students Vivechkanand Chunoo, Sally Watkins, and Shermin Murji: You pushed me to learn, stay honest, and work harder than I have ever done in my life, while still staying friends. Special thanks to Estee Hernandez who served as role model and who helped me think through gender expression in the dissertation. Also my thanks to Allison Peters for taking notes during my prospectus defense and for providing lots of feedback to me in the early proposal and qualitative data collection stages.

Thank you to Taylor Kelliher for copyediting this dissertation. You are probably the only person outside of the committee who will read it. I am grateful that I had an editor that I could truly trust.

To Rebecca Brower, for her role as peer reviewer of the qualitative study and as a friend and mentor. Rebecca—thank you for taking me under your wing for the past two years and for sharing your love of grounded theory. I have learned so much from you. Your advice and insights have been invaluable.

To Chenoa Woods, my thanks for our daily walking pact. You heard about this dissertation easily 2-3 times a day. Thank you for your insights as a mixed methodologist as well as your pragmatism about getting through this process. You kept me grounded and healthy.

To the committee members—Tamara Bertrand Jones, Brad Cox, and Susan Blessing. TBJ, you knew me when I was practically a different person. Thank you for investing in me, giving me space to grow, and for all of the random, "short" conversations. Brad, I fell in love with research under your guidance. You taught me to ask the hard questions, think big, and diagram everything. I work harder because of you. Susan, conversations with you are why this dissertation exists. I know this research will go somewhere because *you* care. Thank you for believing in me.

Thank you to my advisor, mentor, and friend, Lara Perez-Felkner. It's hard to imagine where I would be without your help, interest, and nudges. You saw the potential in a short course presentation and told me to run after it. You pushed me to lead a paper during my second year in the doc program. You told me to stand up taller, speak more slowly, and stop doubting myself. You encouraged me to apply for fellowships that I didn't think I'd be considered for. You encouraged me to work with others and expand my skillset. Thank you for giving more of yourself and your projects than was expected, than was even required. Your feedback and mentorship directly impacted my development as a scholar. Even more, thank you so much for allowing me to be human through this process. And thank you for doing this for the first time with me—your advisees are truly lucky to have you.

Finally, thank you to my family. Robert Schwartz once told me that a doctoral program will be the most selfish thing I'll ever do. It truly has been. Thank you to my parents, Jerry and Le Nix, for encouraging me to follow my dreams, and for providing me with the emotional resources to thrive. To my son, Cassian Mills. I'm sorry that you had to share so much time with a document that very few people will read. Thank you to my mother-in-law, Sheila Mills, for loving Cass during many writing sessions. And finally, thank you to my partner, Chris Mills. When we made our marriage commitment to one another, neither of us anticipated that we'd be doing two all-consuming things at the same time (graduate school and raising a child). We chose to do this because we believed in the strength of our relationship. I couldn't have made it through this beast of a project without your support, encouragement, and sense of humor. Thank you for being an amazing husband, man, and true partner.

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# ABSTRACT

This dissertation presents a framework for understanding how beliefs about difficulty and talent in science, technology, engineering, and mathematics (STEM) influence students' subsequent decisions to major and complete degrees in those domains. Recent evidence suggests that mathematics-intensive subjects like computer science, engineering, and physics (Nix, Perez-Felkner, & Thomas, 2015; Perez-Felkner, McDonald, Schneider, & Grogan, 2012) are perceived as difficult and are appropriate only for those possessing innate gifts (Dweck, 2008; Leslie, Cimpian, Meyer, & Freeland, 2015). Research additionally points to differences in ability beliefs by race/ethnicity and gender (Litzler, Samuelson, & Lorah, 2014; OECD, 2015). However, *how* these beliefs might create barriers to women's and racial/ethnic minorities' participation in STEM fields is not yet fully understood. Using nationally representative Education Longitudinal Study: 2002/12 data as well as original interview data drawn from a stratified, robust sample, this mixed methods dissertation (1) gauges the existence of specific ability beliefs about the role of difficulty and talent in STEM participation, (2) examines how these beliefs may be developed through the educational pipeline, (3) measures the association between perceived difficulty and mathematics-intensive science field major and degree, and (4) investigates how the postsecondary experience and identity shapes perceptions of difficulty and talent in STEM fields. Findings from the studies in this dissertation help inform researchers, practitioners, and policymakers of the existence, associations, and development of these ability beliefs.

# CHAPTER 1

# INTRODUCTION

Science, technology, engineering, and mathematics (STEM) participation and achievement has been historically associated with intellectual giftedness (Fleming, 1960; Jolly, 2009; Snow, 1961; Thelin, 2011; Thomas & Williams, 2009). Mathematics-intensive science fields, such as computer science, engineering, and physics (Perez-Felkner et al., 2012), are thought to require “brilliance” (Leslie et al., 2015; Meyer, Cimpian, & Leslie, 2015). Associations between these fields and talent may be rooted in individual beliefs about the role of innate ability in mathematics achievement. Encountering difficulty or challenge has been associated with both lowered ability beliefs (Dweck, 2000, 2006) and increased engagement (Csíkszentmihályi, 1990; Csíkszentmihályi & Csikszentmihályi, 1988) in a particular domain of study. Women and racial/ethnic minority students in particular may believe that mathematics is difficult for them due to lack of talent (Dweck, 2007, 2008). Decades of previous research also attributes attrition in STEM to discriminatory and chilly postsecondary climates and cultures (Cheryan, Master, & Meltzoff, 2015; Hall & Sandler, 1982, 1984; Margolis & Fisher, 2002). As women and minority populations are the least represented in these fields (Anderson & Kim, 2006; Corbett & Hill, 2015; NSF, 2015), it is important to understand how experiences in mathematics-intensive college majors have contributed to perceived ability and fit in STEM. This dissertation specifically examines how students’ perceptions of difficulty and talent are shaped by college experiences.

In this dissertation, I present a framework for understanding the evolution and outcomes of perceived difficulty and talent in mathematics-intensive science fields. Using an integrated quantitative and qualitative methodology, I first investigate differences in difficulty perceptions by gender and race/ethnicity, as well as its association with declared degree field. Quantitative secondary data analysis of a nationally-representative sample was used to conduct the first study. Then, original qualitative data collection and analysis was used to understand how students' educational experiences shaped their perceptions of difficulty and talent in STEM fields. For this second study, I interviewed 24 physics, engineering, and computer science leavers and stayers of diverse gender and racial/ethnic identities using a robust, two-stage sampling strategy.

## Problem Statement

Decades of research by scholars (Deboer, 1984; Eccles, 1987; Riegle-Crumb, King, Grodsky, & Muller, 2012), government agencies (NSF, 2011, 2013), and foundations (Berryman, 1983; Hill, Corbett, & St Rose, 2010) has considered the relatively homogenous composition of college students pursuing STEM bachelor's degrees. Two major mechanisms explaining lack of parity by women and minority students have been identified in the literature. First, a major driver of Black and Latino STEM attrition compared to White and Asian students appears to be the delayed academic progress (Anderson & Kim, 2006; Chen, 2009). Second, low parity for women is the result of fewer girls selecting these fields before entry to college (Corbett & Hill, 2015; Hill et al., 2010). A variety of explanations for why these mechanisms occur have been proposed, such as biological differences (Hedges & Nowell, 1995; Summers, 2005), pre-college academic preparation (Hanson, 2004; Riegle-Crumb, 2006), size and composition of universities (Griffith, 2010), faculty support (Cole & Espinoza, 2008; Hurtado et al., 2011), and institutional type (Leggon, 2006; Perna et al., 2009), to name a few.

STEM participation research may focus on students' subjective orientations toward mathematics (Perez-Felkner et al., 2012), or their interests in, valuation of, or ability beliefs in the mathematics and science domains. Gendered socialization can influence career interests

(Eccles, 1994, 2015) and the development of a scientific identity (Cribbs, Hazari, Sonnert, & Sadler, 2015). Many studies on the relationship between ability beliefs and STEM outcomes use theoretical frameworks such as self-concept (Guay, Marsh, & Boivin, 2003; Markus & Wurf, 1987; Marsh, 1986), self-efficacy (Bandura, 1977; Pajares, 1996; Rittmayer & Beier, 2009), and expectancy-value theory (Eccles, 1987, 1994; Wigfield & Eccles, 2000). Yet, these ability beliefs do not stay constant. Research shows that students can experience threat, causing mathematics anxiety (OECD, 2015) or stereotype threat (Spencer, Steele, & Quinn, 1999; Steele, 1997), often as a result of specific field cultures (Cheryan et al., 2015; Margolis & Fisher, 2002).

Cultures within mathematics-intensive science fields like computer science, engineering, and physics may be particularly exclusive. Attrition from these fields is high for all college students (Chen, 2009; NSF, 2013) and particularly for women (Corbett & Hill, 2015; Hill et al., 2010). Theories about ability beliefs, which encompass mindset theory (Dweck, 2000, 2006) and field-specific ability beliefs (Leslie et al., 2015; Meyer et al., 2015), may be unique for these fields. Studies of academics and lay people show a correlation between perceived need for brilliance in physics, engineering, and computer science fields and the percentage of female and African American Ph.D.-holders in those domains (Leslie et al., 2015; Meyer et al., 2015). Mindset theory links perceived mathematics ability and effort required to complete a task, suggesting that some students believe that the more work required to complete a task, the less talent they possess (Dweck, 2008; Rattan, Good, & Dweck, 2012).

Despite the depth of STEM participation and ability belief research, we have yet to understand how students—especially individuals of diverse gender and race/ethnicity identities— perceive difficulty and talent in mathematics-intensive fields. This dissertation seeks to address this gap in the literature. The proposed studies explore ability beliefs and assesses their relationships with both postsecondary outcomes and gender and race/ethnicity. In the first study, I examined the association between difficulty orientations and computer science, engineering, and physics major selection and degree completion for women and minorities. In the second study, I learned how and why educational experiences in mathematics-intensive science fields shape perceptions of difficulty and talent from a group of college seniors who spent at least two semesters as a computer science, engineering, or physics major.

## Purpose and Overarching Research Questions

This dissertation investigates ability beliefs and presents a framework of how they may influence students' decisions to major and complete degrees in mathematics-intensive science fields. Recent evidence suggests the existence of beliefs that STEM fields—especially mathematics-intensive subjects like physics, engineering and computer science (Nix et al., 2015; Perez-Felkner et al., 2012)—are extremely difficult and are appropriate only for those possessing innate gifts (Dweck, 2008; Meyer et al., 2015). Research additionally points to differences in ability beliefs by race/ethnicity and gender (Correll, 2001; OECD, 2015). However, *how* these identities and the educational experience affect perceptions of difficulty and talent in STEM are not yet fully understood.

My dissertation addresses this gap in knowledge using multiple forms of data. First, secondary analyses of nationally-representative Education Longitudinal Study (ELS) data measures relationships between difficulty orientations, race/ethnicity and gender intersections, and mathematics-intensive science major persistence and degree completion. Second, a qualitative analysis of original interview data illuminates how students' difficulty experiences and beliefs about talent in mathematics-intensive science fields as well as their identities inform their decisions to participate in these majors.

Five central research questions form the basis of the overall dissertation:

1. Do specific beliefs about difficulty and talent in STEM exist?
2. How are these beliefs developed through the educational experience?
3. What are the associations between perceived difficulty and postsecondary mathematics-intensive science outcomes?
4. How do postsecondary experiences shape perceptions of difficulty and talent in STEM fields?
5. How does gender and race/ethnicity relate to beliefs about difficulty and talent in mathematics-intensive science fields?

Research questions specific to the quantitative and qualitative studies are described in Chapter 3.

## Significance

Lack of gender and racial/ethnic parity in science and mathematics fields has been widely documented (Anderson & Kim, 2006; Hill et al., 2010; NSF, 2013). This research is often noted in relation to policy makers' assertions that strengthening the STEM pipeline is a public good (Augustine, 2005; Obama, 2013; PCAST, 2012). The lower rates of women and minority racial/ethnic populations in STEM postsecondary education is additionally significant given the potential private benefits earned through science and mathematics careers for these historically underserved populations. For instance, the unemployment rate for scientists and engineers was about half that of the national average in 2010 (Langdon, McKittrick, Beede, Khan, & Doms, 2011; NSB, 2014), and women with STEM bachelor's degrees stood to earn between 17% and 27% more than their non-STEM counterparts in their first jobs (Olitsky, 2014). Research by DeNavas-Walt and Proctor (2014) shows that women still earn less than their male counterparts overall. In addition, on average Black and Latino families earn less than the median household income, and about a quarter of people in these groups live below the poverty line (DeNavas-Walt & Proctor, 2014). Thus, it is important to investigate mechanisms of exclusion from the most stable and profitable fields of study, such as mathematics-intensive science fields.

Encountering difficult material or finding some work challenging is a necessary part of being a student. This dissertation is significant because it examines if perceiving some fields as more difficult than others acts as a barrier to women and minority groups' participation in mathematics-intensive science majors. The proposed studies each contribute to the literature in specific ways. First, nationally-representative samples have not yet been used to examine perceived difficulty by gender and race/ethnicity identity groups, and how those perceptions might relate to degree completion in specific STEM fields. Second, the qualitative study accounts for the role of both pre-college and college experiences in shaping these beliefs, leading to important implications for scholars, practitioners, and policy makers.

## Constructs and Operational Definitions

The following terms will be used throughout this dissertation: CEP or computer science, engineering, and physics, declared major, degree major, difficulty, difficulty orientations, educational experiences, gender, mathematics-intensive science or CEP fields, minority, race/ethnicity, STEM, and talent.

Declared Major: The process of committing to specific majors. For the quantitative study, this is defined as the major declared by two years after high school. The qualitative study included students who spent at least two semesters majoring in CEP, but some participants may have initially declared an undecided major before selecting a CEP field.

Degree Major: Primary field of study in which the student earned a degree. In the quantitative study, this is measured eight years after high school and focuses on CEP fields. In the qualitative study, participants referred to the major that they intended to earn a degree in, but no other effort to confirm degree completion was made. In both studies, participants may have graduated with a degree outside of the mathematics-intensive sciences. The quantiative sample only includes students who earned a bachelor's degree. In the qualitative study, students may not yet have completed or have plans to complete their degrees.

Difficulty: When students must work harder to learn or answer a question, they often refer to this as "difficult" or "challenging" material. "Challenge" has a positive connotation in educational literature, theorized to encourage engagement and positive outcomes (Csíkszentmihályi, 1990; Csíkszentmihályi & Csikszentmihályi, 1988). In contrast, "difficulty" is a more neutral term and was selected for this dissertation. In the quantitative study, perceived difficulty is measured via difficulty orientations (see definition below). In the qualitative study, "difficulty" is used to generally refer to students' "hard," "challenging," or "difficult" academic experiences.

Difficulty Orientations: I operationalize difficulty orientations in the quantitative study using survey items. These questions measured students' reported belief that they can understand the most "difficult" or "hard" material in a specific domain. "Orientations" was selected for this measure as it is part of a term developed by Perez-Felkner et al. (2012)'s study of mathematics subjective orientations, an inspiration of this study.

Educational Experiences: I refer to both structural (departmental structure, academic requirements, etc.) as well as social aspects (departmental student organizations, peer-to-peer discussion, faculty-student interaction, etc.) when using the term “educational experiences.” The quantiative study uses objective measures of educational experiences shown in the literature to relate to STEM participation. Specifically, high school educational experiences are measured through both school characteristics (percentage free and reduced lunch, region, and urbanicity) as well as student academics (standardized test scores, science course taking, GPA, value of mathematics, and mathematics growth mindset). College experiences in the quantiative study are measured using characteristics of the first postsecondary institution attended (control and selectivity) and the only measure of student engagement: student reports of participating in undergraduate research. In the qualitative study, participants described a number of educational experiences. These included attending specific types of schools (public, private, Montessori, charter, magnet, etc.), engagement in special school programs (gifted, honors, advanced placement, international baccalaureate, etc.), and the perceived demographic make-up of pre-college peers especially around race/ethnicity and socio-economic status. Qualitative participants also described a number of interactions with individuals or groups (teachers, faculty, staff, family, friends, or classmates/peers).

Gender: This dissertation primarily refers to gender in a binary manner: men and women. Although the quantitative study examines the consequences of a gendered experience, the variable used for gender actually refers to biological sex (male or female). All participants in the qualitative study save one referred to their gender or biological sex using binary terms. The participant who had a non-binary gender identity reported being agender. This dissertation is chiefly interested in students' percepetions of difficulty and talent in the postsecondary setting, rather than a deep examination of gender identity development. Thus, the binary, general terms for gender (he/him/his or she/her/hers) were selected for the dissertation, except in the case of the agender student, who is referred to as agender and using they/them/their pronouns.

Mathematics-Intensive Science or CEP Fields: When referring to mathematics-intensive science fields, I mean computer science, engineering, and physics (CEP). I often use the terms interchangeably. There has been an increasing interest in specific subject areas within the STEM umbrella given heterogenous patterns of participation across these fields (Ceci, Williams, & Barnett, 2009; Corbett & Hill, 2015; Schneider, Milesi, Perez-Felkner, Brown, & Gutin, 2015). This dissertation concentrates on mathematics-intensive science majors as a result of four recent studies. First, Perez-Felkner et al. (2012) and Schneider et al. (2015) compared pysical science, engineering, mathematics, and computer science college major choice to other fields of study using ELS. Second, Leslie et al. (2015) and Meyer et al. (2015) found that these same fields had the lowest participation of women and African Americans, but the highest peceived requirement of "brilliance." Therefore, mathematics-intensive science or CEP fields are an appropriate grouping of subject areas on which to focus.

Minority: In some places, I describe minority students. When I use the term "minority," I mean non-White students. This population include Asian, Black, Latino, Native American, or people with multiple racial/ethnic identities. Race/ethnicity itself is defined below.

Race/Ethnicity: When referring to race/ethnicity, I primarily mean the perceived race of students given their physical appearance, as well as the socio-cultural background of the student. Unless I am summarizing others' research, I use Asian, Black, Latino, Native American, White or some combination of these five race/ethnicity groups. As with gender, qualitative participants had an opportunity to describe their own race/ethnicity. In some cases, participants distinguished their racial identities from their ethnic identites.

STEM: In this dissertation, STEM is used to generally describe science and mathematics. My review of literature in Chapter 2 began with a broad investigation of STEM fields. The previous points about the specificity of mathematics-intensive sciences led to more focused research on those fields. In addition, qualitative participants sometimes referred to STEM broadly or as an umbrella term for all science and mathematics fields.

Talent: Refers to perceptions of innate ability, rather than objective measurses of academic achievement. Perceived innate ability has been shown to be important in students' persistence on difficult mathematics tasks (Dweck, 2000, 2006; Mangels, Good, Whiteman, Maniscalco, & Dweck, 2012; Rattan et al., 2012). There may also be an association between perceived need for "brilliance" and women's achievement in CEP fields (Leslie et al., 2015; Meyer et al., 2015). The survey used in the quantiative study does not have a direct measure of talent; instead, this study measures perceived difficulty. The qualitative study, however, includes rich data related to talent. Participants either used the term "talent" directly or a list of other terms to refer to the same concept: "natural ability," "being good at," "naturally good," "easy for me," etc.

## Research Design

My dissertation examines perceptions of difficulty and talent through two studies, one quantitative and the other qualitative. The first study is a secondary analysis of nationally representative ELS data. The purpose of this study is to measure the relationships between domain-general and domain-specific difficulty orientations, race/ethnicity and gender, and declared and degree major in mathematics-intensive science fields. A series of bivariate and multinomial logistic regression models are estimated to understand how difficulty orientations relate to mathematics-intensive science outcomes, and if gender and race/ethnicity act as moderating or mediating variables. Results are reported using predicted probabilities.

The second study is a qualitative analysis of original interview data with 24 college seniors at a very large southeastern public university. Participants were selected if they majored in a CEP field for at least two semesters during their time in college and based on their persistence and race/ethnicity and gender demographics. The two-stage sampling strategy used quota, maximum variation, and snowball sampling to expand the diversity of student voices in the study. Results of this study illuminate how students' understanding of difficulty and talent in mathematics-intensive fields developed and changed during their postsecondary experience.

At the conclusion of these studies, I discuss a hypothesized theoretical model that emerged from my synthesis of both the quantitative and qualitative studies. I describe each part of the model and put it in context of the data and/or current literature. Then, I provide implications for researchers, practitioners, and policy makers.

## Assumptions and Limitations of the Research

Key assumptions are made in this research. Related to the assertions above, I assume that people make college major decisions and complete their degrees partially as a result of their educational experiences. In addition, I assume that difficulty orientations are measureable aspects of this decision-making process. In the quantitative study, I assume that participants have answered the survey questionnaire truthfully and that their responses represent their difficulty orientations. In the qualitative research, I assume that participants will identify pivotal or key experiences and beliefs related to and talent in STEM. I further assume that they will be truthful and comprehensive in their descriptions of their experiences.

Research suggests that beliefs about and value of STEM career fields are solidified as early as primary school (Eccles, 2005, 2011). My proposed research investigates the experiences of adult students, including those who may have initially committed to a mathematics-intensive science field of study, but changed their trajectory at some point during postsecondary education. Therefore, the research is confined to describing the experiences of college students in my samples, rather than those who did not attend college. While the quantitative study's complex sample design is nationally representative and can be interpreted as such through weighting procedures, the sample is limited to describing $10^{th}$ graders in 2002 and, therefore, is not generalizable to future cohorts of students.  In addition, the qualitative study included only specific students at a single four-year institution in the southeast.

## Organization of the Dissertation

The dissertation is organized in the traditional manner. This first chapter is the introduction to the dissertation. Chapter 2 is a review of the relevant literature to provide context for each of the studies. The quantitative and qualitative study's methods are described in Chapter 3. Chapter 4 details findings from the quantitative study. Qualitative findings are split across Chapters 5 and 6. Chapter 5 discusses how perceptions of difficulty and talent in STEM or mathematics-intensive science fields are developed. Chapter 6 follows with qualitative findings about how those perceptions are shaped by the educational experience and identities, including and beyond race/ethnicity and gender. Chapter 6 also describes reported outcomes of these beliefs. Last, Chapter 7 synthesizes these findings through a description of the hypothesized theoretical framework, discussion in context of the literature, and implications for researchers, practitioners, and policy-makers.

## Summary

In this chapter, I defined the problem of lower participation of women and underrepresented racial/ethnic minorities in STEM fields. I also described how perceptions of talent could be the source of lower participation in mathematics-intensive science fields. Next, I outlined the purpose of this dissertation to examine women and minority students' perceptions of difficulty and talent. The research questions were also identified and defined. In the fourth section of this introduction, I described the significance of this research. Eleven constructs or terms were defined. Finally, I provided an overview of methods, limitations, and organization of the dissertation. In the following chapter, I situate the proposed studies within the current scholarship.

# CHAPTER 2

# LITERATURE REVIEW

The purpose of the following literature review is to situate the proposed studies within the current scholarship, as well as to provide deeper theoretical explanations for studying difficulty and talent perceptions. The review opens with a discussion of the gender and race/ethnicity variation in mathematics-intensive science fields, to frame the overarching problem of lack of diversity in these subject areas. Next, I describe four prominent explanations for the variation: biological sources, academic preparation, postsecondary experiences, and social psychological processes. Then, I discuss two theoretical perspectives related to the overall research objectives: ability belief theories and intersectionality theory.

## Participation in Computer Science, Engineering, and Physics

Mathematics-intensive science fields—computer science, engineering, and physics (CEP)—are the focus of this dissertation for four reasons. First, inequities in STEM fields in particular have been a focus of research literature and policy over several decades (Augustine, 2005; Obama, 2013; PCAST, 2012). Second, careers in CEP fields specifically may help close gaps in economic inequities for women and underrepresented racial/ethnic minorities (Langdon et al., 2011; NSB, 2014; Olitsky, 2014). Third, due to reported perceptions that these fields require extraordinary talent, which I will describe later in this literature review (Leslie et al., 2015; Meyer et al., 2015). Finally, smaller participation rates in these fields by women and underrepresented groups compared to White and Asian men (Corbett & Hill, 2015; NSF, 2015). Although mathematics-intensive fields may include majors such as accounting, economics, and finance, for the reasons listed above I focus on mathematics-intensive *science* fields of study: the computer sciences, engineering, and physics.

Figure 1 shows the proportions of degrees earned in mathematics-intensive science fields compared to all other STEM fields[1] and non-STEM fields. About 34% of all bachelor's degrees in the U.S. are earned in STEM fields, with less than 10% of all degrees from CEP fields. Population statistics funded by the National Science Foundation (NSF) [2] provide further details on degree attainment by field of study, gender, race/ethnicity, disability, and citizenship status. I report these statistics and others gathered from nationally representative surveys to provide baseline information on diversity in mathematics-intensive science fields.

**Women**

This dissertation is primarily concerned with the participation of men and women across racial/ethnic identities[3] in computer science, engineering, and physics. The most recent statistics show that if examining STEM fields in the aggregate, women have gained parity (NSF, 2015). Women earn about 57% of all bachelor's degrees in the U.S., and about half of degrees in all STEM fields (NSF, 2015). Figure 2 illustrates the participation of women and men in CEP fields, all other STEM fields, and non-STEM fields. Women dominate in non-STEM and all other STEM fields, earning over 60% of the degrees in those categories. In the physical sciences, almost 40% of all degree earners are women. However, less than 20% of all degree earners in the computer sciences and engineering are women.

[1] The National Science Foundation includes the following categories as science and engineering (or STEM) fields: agricultural sciences, biological sciences, computer sciences, earth, atmospheric, and ocean sciences, engineering, mathematics and statistics, physical sciences, psychology, and social sciences.
[2] These datasets that make up this data include the Survey of Earned Doctorates, Survey of Graduate Students and Postdoctorates in Science and Engineering, the Scientists and Engineers Statistical Data System, the Integrated Postsecondary Education Data System Survey, the National Postsecondary Student Aid Study, the Current Population Survey, and the Survey of Engineering and Technology Enrollments and Survey of Engineering and Technology Degrees.
[3] I use "race/ethnicity" throughout the dissertation as is the convention in social sciences. Race is usually a measurement of perceived physical features, whereas ethnicities are groupings based on culture that include people of multiple races and/or nationalities (Hirschman, 2004). These terms are often conflated in the literature, and ethnic groups can become racialized (Hirschman, 2004; Smith, 2009). The race/ethnicity groups in this dissertation are, unless otherwise specified, Asian, Black, Latino, Native American, White or some combination of these five groups.

Within the fields of engineering and computer science, Corbett and Hill (2015) reported further disaggregations, showing wide variation in women's degree attainment. For instance, women most highly participated in environmental, biomedical, chemical, and agricultural engineering, where they represented between 31% and 45% of the degree holders in 2013. Women earned the fewest degrees in computer software, mechanical, electrical, and nuclear engineering fields, where they only represented between 8% and 15% of the 2013 graduating class. Notably, computer software, mechanical, electrical, and nuclear engineering fields are more mathematically-intensive than environmental, biomedical, chemical, and agricultural engineering.

Within computer science, the most popular fields were software media applications (34%), information science studies (22%), and systems analysis (21%); and the least popular fields were systems networking and telecommunications (10%), programming (13%), and computer science (13%). Here, too, it appears that women are least attracted to subjects within fields of study that may require more mathematics. Together, these reports emphasize that women's participation is nuanced and variable, both when disaggregating the term "STEM" and when looking within specific fields (Corbett & Hill, 2015; NSF, 2015).

**Racial/Ethnic Groups**

There is also wide variation in STEM degree attainment within race/ethnicity categories.[4] About 41% of all STEM degrees were earned by non-White students (not shown, calculated from NSF, 2015 statistics), versus about 38% of non-STEM degrees. Excluding Asian students

[4] Throughout the literature review, I use the language of cited authors. Therefore, Black/African American and Hispanic/Latino may be used interchangeably.

from the calculation, however, about 32% of all STEM degrees were earned by underrepresented racial/ethnic minority students.[5]

Turning to CEP fields versus all other STEM fields of study, White students earned over half of the degrees each in the computer sciences, engineering, and physical sciences (Figure 3). Hispanic or Latino students earned 8% of all physical science degrees and 10% each of computer science and engineering degrees. This group appeared more successful in other STEM fields, where they earned about 12% of the degrees. Black or African American students earned 4% and 6% of engineering and physical sciences degrees, but 10% of computer science degrees and 9% of all other STEM degrees. Multi-racial/ethnic students represented 2-3% of all STEM fields, with similar rates of earning degrees in both CEP and all other STEM fields. Similarly, indigenous peoples[6] earned less than 1% of degrees in each of the STEM categories, with equitable rates in both CEP and all other STEM fields. Asian students were more highly represented in CEP science fields where they earned 10-12% of degrees in each, compared to 9% in all other STEM fields and 5% of non-STEM fields. While examining participation within each CEP field of study illustrated biases against women, there is more nuanced participation by race/ethnicity.

**Gender and Race/Ethnicity Together**

The studies in this dissertation use an intersectional framework. Figure 4 shows degree attainment rates by gender and race/ethnicity within and beyond mathematics-intensive science fields. The figure most immediately illustrates the relative success of men in computer science

[5] For this calculation, I included the following NSF categories as underrepresented racial/ethnic minorities: American Indian or Alaska Native, Asian, Black or African American, Hispanic or Latino, Native Hawaiian or Other Pacific Islander, Two or more races, and other or unknown race or ethnicity.
[6] Due to small numbers, I aggregated NSF categories American Indian or Alaska Native and Native Hawaiian or Other Pacific Islander into the indigenous peoples category.

and engineering compared to women. The largest participation gaps occur between White men and women in the computer sciences and engineering. Similarly, within each non-White group, men earn higher proportions of computer science and engineering degrees compared to their female counterparts. Differences between non-White men and women's degree attainment is smaller in the physical sciences. Notably, Black or African American women earn a higher proportion of physical science degrees than Black or African American men.

The statistics shared in these sections illustrate a key purpose of this dissertation; namely, to understand why degree attainments by identity groups are particularly dissimilar in CEP fields. There is more similar participation in other STEM and non-STEM fields compared to mathematics-intensive science fields. This dissertation specifically examines participation in CEP fields to better understand their unique variation. The lack of participation by women and variable participation by race/ethnicity group, the unique ability beliefs that they may hold, and the economic benefits they stand to gain through careers in these fields makes this research imperative.

**Other Areas of Diversity**

Gender and race/ethnicity are not the only identity categories of interest by scholars, practitioners, and policy makers. Figures 2-4 display national figures on the participation of domestic versus temporary residents, or international students. International students seem particularly attracted to mathematics-intensive science fields, especially engineering. These students earn about 5% of all degrees in the computer sciences and physical sciences, and 8% of degrees in engineering. In contrast, international students earn only 4% of degrees in all other STEM fields and 3% of degrees in non-STEM fields. Disability status is also a category studied in the literature. Unfortunately, there is only data available for doctorate recipients. Figure 5 shows that the rate of doctoral recipients with a disability hovers around 6% across both STEM and non-STEM fields.

Although there is no national data on it, socio-economic status (SES) as an aspect of diversity in STEM fields has recently come of interest. SES encompasses multiple demographic dimensions such as parental education, parental employment status, family income, and school and neighborhood resources to represent general access to an array of resources, both physical and informational (Cowan et al., 2012). While there are currently no large-scale statistics showing participation by SES in mathematics-intensive postsecondary majors, there is information on high school science course-taking. Three nationally-representative cohorts across a 20 year period were analyzed to understand the longitudinal participation of high schoolers in science courses (Dalton, Ingels, Downing, & Bozick, 2007). As of 2004, just over half of high schoolers in the highest SES quartile (53%) took at least two science courses beyond chemistry I or physics I. In contrast, only 21% of students in the lowest SES quartile took advanced science coursework that could support students' entry and persistence in college mathematics-intensive science majors (Dalton et al., 2007). While gender and race/ethnicity are the two major aspects of diversity studied in the literature, other demographic factors such as residence status, disability, and SES may also be important areas of research.

## Central Explanations for Variable Participation in STEM

### Entry vs. Persistence

Previous scholars have noted the contrasting pathways to STEM degrees for women and minority students. It has been suggested that women's lower participation in some STEM fields is the result of lower interest in these majors at the beginning of the college experience. Multiple studies on nationally-representative datasets show that men declare STEM majors at about double the rate of women (Chen, 2009; Hill et al., 2010). When disaggregating the fields of study, gendered patterns of interest arise. Only 10% of women versus 30% of men intended to major in CEP and mathematics/statistics majors before college[7] (NSF, 2015). Despite their lower interest at matriculation, women appear to have less attrition in STEM once they enter these bachelor's degree fields (Ma, 2011b). Therefore, the gender gap in STEM may be largely driven by pre-college decision-making.

Non-White students appear to be more interested in pursuing STEM degrees than White students. However, minority groups do not persist in college STEM fields at the same rates as White students. Nationally-representative data shows African Americans, Hispanics, and Asian Americans had enrollment rates between 0.6% and 8.4% higher than Whites in STEM fields (Anderson & Kim, 2006). Yet, they also found that around half of Hispanics and African Americans who initially declared majors in STEM fields earned a degree in those fields within six years (Anderson & Kim, 2006; Chen, 2009). Therefore, examining college experiences for minority groups, especially Black and Latino students, is of particular importance and one focus of this proposed dissertation.

**Biological Sources**

There is wide discussion on biological differences between men's and women's achievement in STEM. Summers (2005) most recently suggested that there are higher rates of men in STEM fields because of biological variations, concentrating more males at either of the highest or lowest achieving tails. Meta-analyses of over 100 studies repute this theory, showing that the variance in boys' and girls' mathematics achievement is not meaningful—their scores were more alike than different (Hyde, 2005; Hyde, Lindberg, Linn, Ellis, & Williams, 2008).

[7] This data did not allow me to disaggregate mathematics and statistics from the other mathematics-intensive science fields.

Additionally, the gender gap in mathematics achievement and STEM participation is not stable across all countries, suggesting a cultural effect (Ceci et al., 2009; Charles, 2011; Charles & Bradley, 2009). Last, top mathematics performers in middle school include more males than females, but these women tend to outperform men in high school mathematics courses and earn nearly equitable amounts of mathematics bachelor's, master's, and doctoral degrees, suggesting that biology alone cannot predict performance (Spelke, 2005).

Compared to gender, it is far less common to see arguments that differences in achievement by race is the result of biology. Yet its occurrence has resulted in a statement published by the American Association of Physical Anthropologists (1996) that intellectual differences are wider across individuals rather than groups. Smedley and Smedley (2005) also countered the suggestion that standardized test achievement by race/ethnicity group was biologically based. They pointed out the many historical and social inequalities as better explanations for the racial/ethnic variation in achievement. It appears that there is little evidence to support the claim that there are biological sources for the gap in achievement between men and women and racial/ethnic groups.

This dissertation focuses on factors that are more malleable within individuals' lives than their biology, such as educational experiences and the development of perceptions. One way biological explanations are uniquely informative for this dissertation is that broader academic discussions of these matters could have contributed to perceptions of talent as necessary for participation in specific fields. After all, the suggestion that biological differences in ability level is a causal factor for gender and race/ethnicity variation in STEM participation automatically elevates the status of those fields into the most desireable for people with some form of natural talent. As will be fully discussed in the theoretical frameworks section, perceptions of innate ability are meaningful factors in students' persistence on difficult tasks.

**Academic Preparation and Contexts**

Although students should arrive to universities similarly prepared for college-level coursework, research shows that differences exist in academic preparation. These differences may influence later decisions to enroll in or leave STEM fields. As of the mid-1990s, high school girls have selected and earned a comparable number of credits in mathematics compared to boys (Hill et al., 2010; Hyde et al., 2008). Girls' participation in the highest level of mathematics—calculus—is approaching (Riegle-Crumb et al., 2012) or is on-par with boys' (Cunningham, Hoyer, & Sparks, 2015). Scores on mathematics assessments are similar between the genders until $12^{th}$ grade, when boys outscored girls (Cunningham et al., 2015; Reilly, Neumann, & Andrews, 2015). Girls' participation and performance in the highest level of secondary mathematics courses could have a bearing on their selection of and success in CEP majors.

Science course-taking was also variable for high school girls and boys, and may be one source of disparity in postsecondary major selection. High school girls were more likely than boys to take biology, chemistry, and health, but less likely than boys to take computer/information science, engineering and engineering/science technologies, and physics (Cunningham et al., 2015; Riegle-Crumb et al., 2012). Although small, Reilly et al. (2015) found significant differences between girls' and boys' scores on these subjects, favoring boys in $4^{th}$, $8^{th}$, and $12^{th}$ grade earth science, and $8^{th}$ and $12^{th}$ grade physical science. Such participation and achievement statistics mirror the selection and persistence patterns shown at the postsecondary level (Corbett & Hill, 2015; Hill et al., 2010; NSF, 2015).

High school academic achievement is a commonly investigated factor in overall postsecondary access and success for minority groups (e.g., Adelman, 2006) and is also relevant to participation in STEM. Advanced high school mathematics course-taking was more common among White students than their counterparts of color (including Asians) (Riegle-Crumb, 2006). Further, Black girls were more successful in middle school mathematics courses and were no more likely to take high school science coursework in general than White girls (Hanson, 2004). However, White girls earned higher science GPAs and standardized test scores than their Black and Latina counterparts (Hanson, 2004). In addition, Black and Latino boys' participation in Algebra I in 9th grade had a significant and negative impact on their progress to higher mathematics classes later in high school, even when controlling for grades (Riegle-Crumb, 2006). School quality has been shown to be a significant factor in Black and Hispanic participation in advanced coursework (Fletcher & Tienda, 2010).

Some studies suggest that minority students do well in science and mathematics before high school and aspire to careers in STEM fields. Black girls and Latina's interest and feelings toward mathematics was similar to both their male racial/ethnic counterparts and White males (Riegle-Crumb & King, 2010). Black females' aspirations for science careers are controlled by their science test scores, while science enjoyment is the most significant controlling factor for Latina students' science career aspirations (Riegle-Crumb, Moore, & Ramos-Wada, 2011). Women and minority students' interest, high school course-taking, and academic success differ from their respective comparison groups and may be related to their selection and completion of CEP majors.

**Postsecondary Experiences**

The overarching purpose of this dissertation is to understand how perceptions of difficulty and talent might be altered through the postsecondary experience. The research summarized above illustrates that women overall may be making gains in high school science and mathematics course selection and achievement (Cunningham et al., 2015; Hill et al., 2010; Reilly et al., 2015; Riegle-Crumb et al., 2012). Black and Latina women are especially resilient when facing challenge in pre-college mathematics, and have high aspirations and interests in mathematics (Riegle-Crumb & King, 2010; Riegle-Crumb et al., 2011). Furthermore, minority groups as a whole appear to select STEM fields at a higher rate than their White or Asian counterparts (Anderson & Kim, 2006). Yet, there are fewer than expected women and racial/ethnic minority people earning degrees in mathematics-intensive fields, suggesting that the postsecondary experience may act as a mediating factor in these groups' pursuit of science or mathematics careers. This section first describes important structural characteristics of postsecondary institutions (selectivity and mission) and then college experiential factors (peer-to-peer and faculty-student interaction) that are related to STEM persistence and degree completion.

**Structural Characteristics of Postsecondary Institutions.** Research shows that college structural characteristics are related to persistence in STEM fields. Through a cross-institutional, longitudinal study, Chang, Sharkness, Hurtado, and Newman (2014) found that the more selective an institution's admissions policies, the less likely that Black and Latino students were to persist in STEM fields. Similarly, large institutional size and research expenditures were negatively related to women and minority students' persistence in STEM fields (Griffith, 2010). Something about large, selective, research-focused univerisites may negatively impact diversity in STEM based on gender and race/ethnicity.

Institutional mission may also affect women and minority students' persistence. Historically Black colleges and universities (HBCUs) may be particularly positive spaces for Black women (Leggon, 2006; Lundy-Wagner, Vultaggio, & Gasman, 2013; Perna et al., 2009), and potentially less helpful for Black men (Lundy-Wagner & Gasman, 2011). Students' local academic contexts might also support STEM persistence. Hierarchical linear modelling of over 9,000 academic departments in a 15-year period reveals more meaningful variation in women's STEM persistence at the departmental, rather than institutional, level (Sonnert, Fox, & Adkins, 2007). Thus, via changing majors students may be making choices to change their local academic contexts, which could impact their persistence and degree attainment outcomes.

**Engagement and Interactions.** Beyond structural characteristics, aspects of the college environment which impact students' individual experiences has been studied in the literature. In general, student engagement on campus may differ based on field of study (Brint, Cantwell, & Hanneman, 2008). The role of faculty-student interaction in students' STEM success has been the focus of some research. Faculty support and encouragement led to GPA increases for Latino/a students in one study (Cole & Espinoza, 2008); and in another, large HBCUs were specifically sources of increased faculty-student interaction for Black students (Hurtado et al., 2011; Perna, Gasman, Gary, Lundy-Wagner, & Drezner, 2010). Interaction with faculty are meaningful to minority students.

Interactions with people other than faculty is also meaningful. Increasing female or minority graduate student rates by 10% is related to a 5% increase in minority persistence in STEM, perhaps because graduate students in these fields have high interaction with undergraduates through teaching and research assistantships (Griffith, 2010). Other student experiences beyond faculty-student interaction have been noted as related to women and minority students' participation in STEM. Undergraduate research, group studying, and supportive student organizations have been cited as important to minority students' STEM achievement (Chang et al., 2014; Perna et al., 2009; Thiry, Laursen, & Hunter, 2011).

**Social Psychological Processes**

Due to the limitations of biological, academic preparation, and postsecondary environment explanations for the variation in higher education STEM outcomes, researchers have increasingly turned to the role of social psychological factors in influencing women's and minority students' decisions to select, persist, and graduate in STEM fields. In the next sections, I describe the social psychological processes that are related to participation in STEM: socialization and science identity, self-concept and self-efficacy, field culture, mathematics anxiety and stereotype threat, and expectancy-value and mathematics subjective orientation.

**Socialization and Scientist Identity.** Throughout their life course, people are socialized, meaning they are acclimated to the social norms, values, and beliefs of cultures and identity groups (Lutfey & Mortimer, 2006; Parsons, 1951; Perez-Felkner, 2013). Direct and indirect communication, experiences, observations, and even play are sources of socialization for children and adolescents (Perez-Felkner, 2013). Socialization has been suggested as an important process in students' decisions to select majors and careers in STEM. Before children even enter the classroom, they are influenced by their family's perceptions of appropriate careers in or out of scientific fields based on gender (Eccles, 2015; Eccles Parsons, Adler, & Kaczala, 1982). What scientists, in addition to parents, say to women, minority, and low-SES students about STEM careers is especially important to their socialization towards these fields of study (Jahn & Myers, 2014; Myers, Jahn, Gailliard, & Stoltzfus, 2010).

Upon entering postsecondary education and careers, people experience professional socialization, contributing to the development of a science identity. Carlone and Johnson (2007) operationalized science identity through a qualitative study of 15 minority women participating in science careers or graduate programs. They theorized that science identity was an overlap of competence, performance, and recognition, such that someone has the ability to be, performs as, and is understood to be a scientific person. They additionally developed three sub-identities: research scientists, altruistic scientists, and disrupted scientists (students with a science identity that is not acknowledged by others), and included more aspects of recognition in their final grounded model. Stets et al.'s (2017) research shows that science identity predicts participation in STEM careers after college and can be a mediating factor in minority racial/ethnic students' persistence in these fields.

Science identity development has been associated with multiple characteristics and experiences. Undergraduate research participation has been identified as a particularly meaningful experience for socialization and science identity development (Chang, Eagan, Lin, & Hurtado, 2011; Hurtado, Newman, Tran, & Chang, 2010; Lane, 2016; Stets et al., 2017). Racial stigmas and negative racial experiences can threaten the development of a science identity (Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2009), and ultimately persistence in the major (Chang et al., 2011). In addition, minority students who have negative group work experiences (such as being left out of decisions or having their ideas disregarded) felt that the recognition of their science identities was limited. Others in students' academic and personal lives can influence their decisions to persist in STEM fields.

**Field Culture.** Science fields may have specific cultures that inhibit the participation of women and minority students. Studies on computer science field culture are notable. People who study and work in computer science are stereotyped as "geeks" (Cheryan, Plaut, Davies, & Steele, 2009; Margolis & Fisher, 2002). Cultural cues can be transmitted through factors as simple as how spaces are decorated (Cheryan et al., 2009). Early pre-occupation with computers through gaming or high school coursework more frequently taken by boys leads to a higher concentration of men boasting about their abilities in the college classroom (Eisenhart & Finkel, 1998; Margolis & Fisher, 2002). Together, these aspects of culture can negatively influence women's confidence and persistence.

Underrepresented racial/ethnic minority students might experience more explicitly racist field cultures. The Black women in Charleston et al.'s (2014) study reported discriminatory practices on the part of their faculty members and peers. Minority women may also feel particularly isolated in predominantly masculine and White cultures (Charleston, George, et al., 2014). Field cultures are more malleable than socialization; stakeholders have better access to changing aspects of a field's culture than most of a student's prior socialization (Cheryan et al., 2015).

**Mathematics Anxiety and Stereotype Threat.** In the previous sections, I discussed the ways socialization and field culture can impact confidence and science identity. Research also shows that people with stereotyped demographic identities (such as women or minority racial/ethnic groups) tend to feel anxiety or threat. Despite having comparable mathematics test scores, 5% to 15% more girls than boys reported worrying about encountering difficulty in mathematics, feeling tense or nervous while completing mathematics homework or assignments, helplessness during a mathematics task, or having concerns about low grades in mathematics (OECD, 2015).

Stereotype threat may be one process impacting students. Through their studies, Steele and his colleagues argued that African Americans and women were aware of negative stereotypes about their academic abilities, and experienced fear or anxiety that they would confirm these stereotypes through failure. (Spencer et al., 1999; Steele, 1997; Steele & Aronson, 1995). The anxiety felt through stereotype threat has been shown to inhibit working memory, negatively impacting performance (Beilock, 2008; DeCaro, Rotar, Kendra, & Beilock, 2010; Good, Aronson, & Harder, 2008).

**Self-Concept and Self-Efficacy.** Within threat or anxiety responses, students' self-concept and self-efficacy are at risk. Literature reviews of self-concept describe it as how people understand or perceive themselves through an evaluation of feedback from others or messages in the environment (Markus & Wurf, 1987; Marsh, 1990). The connection between self-concept and academic achievement was sharpened about 25 years ago, when Marsh developed the Self-Description Questionnaire and started to describe *academic* self-concept (Marsh, 1986, 1990; Shavelson, Hubner, & Stanton, 1976). Academic self-concept is domain-specific and describes one's perceived ability within a field of study.

Scholars often use synonyms such as "confidence" or "self-perceptions" when discussing self-concept. Compared to White men and controlling for all other factors—minority men were moderately more confident in STEM, and White females were slightly less confident (Litzler et al., 2014). Students' educational contexts can be a factor in developing self-concept. Peer tutoring has a positive relationship with self-concept, while institutional selectivity and faculty/student interaction is negatively related (Sax, 1994). A cross-national study additionally shows that in countries or schools with higher average science achievement and standards, students have lower science self-concepts (Van de Gaer, Grisay, Schulz, & Gebhardt, 2012). In addition, research evidence shows that women's mathematics self-concept varies based on college major (Sax, Kanny, Riggers-Piehl, Whang, & Paulson, 2015). These findings indicate that individuals compare their abilities to others in their local and national environments.

Unlike self-concept, which describes domain-level confidence, self-efficacy describes perceived ability to do a specific task or fulfill a specific goal. Self-efficacy was described by Bandura (1977) and has been extensively used to frame research on academic achievement and participation in STEM (Pajares, 1996; Rittmayer & Beier, 2009). Although most research links mathematics self-efficacy to positive STEM outcomes, the relationships are not always conclusive. Research using the National Educational Longitudinal Study shows a positive and significant effect for mathematics self-efficacy separate from self-concept in predicting long-term intent to participate in a science career (Wie-Cheng, 2003), but no significant effect for STEM degree attainment (Maltese & Tai, 2011).

Notably, eighth grade girls generally scored lower than boys in both mathematics and science self-efficacy measures, with mathematics having a particularly wide gap between boys and girls (OECD, 2015). Researchers additionally propose that increased self-efficacy, especially during college years, can improve the academic success of minority students (Bonous-Hammarth, 2000; Chang et al., 2014; Charleston, Adserias, Lang, & Jackson, 2014), though none of this research specifically identifies if and to what extent men and women of different race/ethnicities may have variable levels of self-efficacy by domain. The lack of empirical research on the racial/ethnic differences in self-efficacy could be the result of limitations of the theory pointed out by previous scholars, such as the relative difficulty in measuring the concept as a whole and the existence of too many similar constructs (Pajares, 1996; Zimmerman, 2000).

**Valuing Science: Expectancy-Value and Subjective Orientations.** Beyond the concepts already described, people's general value toward science careers matters to their decision to earn degrees in those fields. Expectancy-value theory combines constructs like self-concept and self-efficacy (expectancies) with perceptions that a task is important for people to do (subjective values) to describe why there is unequal gender variation in STEM participation (Eccles, 1987, 1994; Wigfield & Eccles, 2000). Eccles and her colleagues have made the point that with similar levels of achievement and expectancies, subjective task value rises in importance to women's and men's choice-making process (Eccles, 1987, 1994). Thus, an investigation of gendered values for mathematics-intensive fields is particularly important.

Recent research suggests that the greater number of young women with both high-mathematics and high-verbal ability, but low interest in STEM careers compared to young men, is the result of gendered socialization which leads to lower value for those occupations (Wang, Eccles, & Kenny, 2013). High school girls with higher beliefs of mathematics usefulness over generally liking the field were more likely to be interested in mathematics-intensive career fields (Watt, 2006). Compared to girls, twelfth grade boys across all race/ethnicity groups, but especially in Black and Hispanic groups, were significantly more interested in math and science and considered those courses amongst their favorites (Cunningham et al., 2015). Studies have also shown that interest or value in a field or set of occupations is tightly entwined with perceived competence (Denissen, Zarrett, & Eccles, 2007; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002). Therefore, while value for a career is a meaningful predictor of major choice, it is impossible to separate the development of interest from domain achievement.

Similar to the way expectancy-value compounded multiple concepts, Perez-Felkner et al. (2012) operationalized mathematics subjective orientation to include mathematics engagement, value, confidence or self-concept, mindset, and participation. The focus of their study was the relationship between subjective orientation and gender in declaring mathematics-intensive science majors. Their results showed mathematics subjective orientations were positively associated with majoring in physics, engineering, mathematics, and computer science fields, and that gender was a significant moderating factor in this relationship. The authors also found strong evidence that the most mathematically prepared women were entering biological or health science fields, and that there were meaningful participation patterns when considering gender and race/ethnicity together. Investigated together or separately, social psychological processes are an important piece of the puzzle in understanding lower participation of women and lower degree attainments for minorities in mathematics-intensive science fields.

## Theoretical Perspectives

This dissertation emerges from two primary theoretical perspectives. The first set of theories deal with ability beliefs. Resilience, grit, and flow, mindset theory, and field-specific ability beliefs each address perceptions or respones to difficulty or talent. Next, intersectionality theory provides a basis for the studies' focus on gender and race/ethnicity seperately and together.

### Ability Belief Theories

Ability beliefs have been theorized throughout the literaure, most recently in a particular field of study named positive psychology. The rise of positive psychology marked a shift in cultural awareness, from addressing deficts and illness to emphasizing strengths and optimism to help people live happier, more optimal lives (Gable & Haidt, 2005; Linley, Joseph, Harrington, & Wood, 2006; Seligman & Csikszentmihalyi, 2000). The earliest positive psychology studies or articles focused on items such as self-determination, optimsim, and happiness (Seligman &

Csikszentmihalyi, 2000). Notably, Linley et al. (2006) described positive psychology as an effort to fill two voids neglected by psychology at the time: assisting with the development of fulfilling lives and "nurturing high talent" (p. 1). Accoridngly, theories that fall under positive psychology are often concerned with overcoming difficulty and cultivating talent. In this dissertation, I discuss resilience, grit, and flow, mindset theory, and field-specific ability beliefs.

**Resilience, Grit, and Flow.** Resilience, grit, and flow are terms often present in discussions of difficulty and talent. Psychological resilience has many definitions, all related to overcoming adversity or difficulty to result in a positive outcome (Fletcher & Sarkar, 2013; Pangallo, Zibarras, Lewis, & Flaxman, 2015). Resilience's many definitions are the result of the concept being applied in several domains and to several different populations (Fletcher & Sarkar, 2013). Across these diverse definitions and applications is the belief that resilience can be developed in people or that people can be taught a resilience process (Fletcher & Sarkar, 2013; Hu, Zhang, & Wang, 2015). Resilience has been correlated with positive mental health outcomes, and seems particularly strong for people who experience adversity (Hu et al., 2015). This finding indicates that exposure to difficulty is necessary for the development of this trait or ability. Resilience may also depend on people's appraisal of difficulty as anxiety-inducing or excitement-inducing (Lazarus, 1991). Lastly, one criticism of resilience measures was that they often did not account for interactions between individuals and their environment (Pangallo et al., 2015).

Similar to resilience, grit is a quality developed by overcoming challenges. However, grit is more specifically defined as "perseverance and passion for long-term goals," (Duckworth & Gross, 2014; Duckworth, Peterson, Matthews, & Kelly, 2007, p. 1). Grit research shows that those who have a specific, grand goal in mind and who pursue it tirelessly are more successful than those who do not, regardless of objective measures of intelligence (Duckworth, 2016; Duckworth et al., 2007). Notably, grit has been validated across samples of children and adults in pursuit of some educational or career goal (Duckworth et al., 2007; Duckworth & Quinn, 2009).

There are positive relationships between grit and college outcomes. For instance, Strayhorn (2013) utilized the Grit-S questionnaire in a study of Black college men at primarily White institutions. The resarchers found that grit was positively related to students' high school and college GPAs, controlling for all other variables. However, grit was not related to college physics students' academic succcess (Bazelais, Lemay, & Doleck, 2016). Instead, previous academic achievement was more predictive of physics grades.

Recently, grit has been criticized (Strauss, 2016; Tampio, 2016; Yeh, 2017). At the heart of these criticisms is the point made by scholars that concepts like grit ignore structural inequalities: some people cannot simply passion themselves into success. Despite these criticisms, grit and resilience are helpful frameworks for understanding this dissertation's interest in difficulty and talent.

Resilience and grit describe successful or talented people as those who must overcome difficulty. Within Csikszentmihalyi's flow theory challenge is a positive tool. Challenge motivates engagement and discourages boredom if a person's skill meets or is slightly below what is required by the difficult material (Csíkszentmihályi, 1990; Csíkszentmihályi & Csikszentmihályi, 1988; Csíkszentmihályi & Schneider, 2000). Flow theory was developed through the study of creative people, such as artists (Nakamura & Csikszentmihalyi, 2002). As such, flow theory has been applied to research on integrating the arts or innovation into STEM education, to help increase interest and improve learning experiences (e.g., Ferguson, Cawthorne

Jr, Ahn, & Ohland, 2013; Kerr & McKay, 2013). Thus, difficulty or challenge does not automatically have to be a negative experience for students studying advanced scientific fields.

**Mindset Theory.** Mindset theory proposes that people have two potential frameworks for understanding characteristics of the self. The first is that the characteristics of the self are primarily static and perhaps pre-ordained at birth, a "fixed" mindset. The second framework is that characteristics of the self are malleable and developed over time, a "growth" mindset (Dweck, 2000, 2006). A large body of research using mindset theory is focused on pre-college populations. A review of mindset theory research in the context of mathematics showed that girls were more likely than boys to hold a fixed mindset (Dweck, 2007). In addition, the highest achieving girls in elementary school were the most likely to hold a fixed mindset and had the largest drop off in mathematics achievement scores when reaching the more difficult level of work expected in middle school (Dweck, 2007). Middle school interventions where children are taught about the malleability of the brain and intelligence have been associated with increases in girls' performance on standardized mathematics tests and minority and low-income students' performance on standardized reading tests (Good, Aronson, & Inzlicht, 2003).

College interventions have also been shown to improve performance, as was the case in Mangels et al. (2012) where stereotype threat was specifically countered through messaging about the usefulness of problem solving. Such findings have opened a line of research on the role of mindset in variation of STEM participation (Dweck, 2008), leading prominent foundations to suggest changes in mindset to encourage improvement in the STEM gender gap (Corbett & Hill, 2015; Hill et al., 2010). Recent studies of nationally representative datasets have shown that agreement with items related to growth mindset in mathematics is positively related to majoring in mathematics-intensive fields (Nix et al., 2015; Perez-Felkner et al., 2012).

Mindset theory contributes to the dissertation's theoretical framework by providing a perspective on how individuals perceive their ability and their encounters with difficulty. Implicit in fixed mindsets is the idea that talent is both innate and quantifiable. This dissertation builds from the previous research by focusing on college students' shift in mindsets during the postsecondary experience, where they may encounter more challenge than ever before and begin to question their ability levels. Mindset theory suggests that students who encounter difficult work with a strong growth mindset would use mastery-oriented behavior and experience less doubt about their ability to complete a bachelor's degree in their chosen field compared to students with a fixed mindset. Previous research has shown that individuals with fixed mindsets might have high achievement levels, and not suffer the feelings of helplessness associated with the mindset until an educational transition or a jump in academic challenge occurs (Dweck, 2007; Good et al., 2003). This dissertation aims to extend this research by examining the academic transitions that occur within the postsecondary educational experience. In addition, this dissertation explores not only college women's mindsets, but also students of color, who seem less represented in the mindset theory research. Finally, this dissertation will more explicitly link stereotypes and messages conveyed in the college experience that might impact mindset.

**Field-Specific Ability Beliefs.** New in the literature is the concept of field-specific ability beliefs, proposed by Leslie et al. (2015). Field-specific ability beliefs describe the manner in which some fields of study are assumed to require innate ability or "brilliance" for success at the highest levels. In establishing this theory, the authors surveyed over 28,000 academics from over 30 diverse disciplines (STEM and non-STEM). In the survey, they asked participants about their agreement with a statement that raw talent means more than hard work in their field, or "field-specific ability beliefs." STEM fields were on average more likely to have high scores on the question. Their findings also showed that field-specific ability beliefs accounted for about a third of the variance in female representation at the Ph.D. level, and that field-specific ability beliefs were a better predictor than the "STEM" categorization. Finally, about 70% of the relationship between field-specific ability beliefs and women's participation was mediated by average beliefs that they are able to function at a high scholarly level and that the field is welcoming to women. Therefore, field culture as well as beliefs about raw talent might be related to women's persistence in STEM.

In a follow-up to the first article, Meyer et al. (2015) surveyed 609 adult, Amazon Turk users through two studies to understand the field-specific ability beliefs of non-experts. The authors set out to understand how college exposure, perceptions of these fields requiring mathematical or verbal ability, and belief that these fields include solitary or competitive work interact with beliefs that certain fields required brilliance. Using correlations and regressions, the authors found that participants with college-level exposure to one of the 30 fields in the study were better able to predict the gap between men and women in randomly selected fields than non-college goers. This finding suggests that the college experience contributes to people's beliefs about certain fields. In addition, the authors found that perceptions of fields as competitive and solitary mediated the relationship between beliefs that some fields require brilliance and smaller proportions of women in certain fields. Similar to the first study on field-specific beliefs, this finding suggests that stereotypes of field culture and beliefs about innate ability are related to participation of women and underrepresented groups.

This emerging research is highly aligned with the dissertation because it describes the relationship between broad perceptions of raw talent as necessary for success in specific fields and the ratio of women and African Americans in the field. However, it still falls short of explaining how and why these perceptions arise throughout individuals' lifetimes and how, if at all, gender and race/ethnicity together might relate. Mindset theory may provide some insight on how perceptions of difficulty and talent evolves through the postsecondary experience. However, field-specific ability belief and mindset theory has not yet been considered in tandem, and both have gaps in the literature. The proposed studies seek to occupy the space between these two theories, exploring the existence of these ability beliefs, and how they are shaped by the college experience and race/ethnicity and gender identities.

**Intersectionality Theory**

Intersectionality theory further informs the studies in this dissertation. Generally, scholars cite intersectionality as emerging out of legal literature (Crenshaw, 1989, 1991); though, some place the roots of intersectionality theory as far back as the 1800s related to the struggle for equality by African Americans (Cole, 2009). Intersectionality theory proposes that an examination of identity on a single axis is not sufficient for understanding or advocating for groups marginalized in multiple ways (Cho, Crenshaw, & McCall, 2013; Crenshaw, 1989, 1991).

Cho et al. (2013) differentiate studies that use intersectionality as a methodological tool to address social inequalities, and those that engage the theory in an effort to evaluate and improve it. They feel that both methods have a place in the area of intersectionality studies. Cole (2009) criticized the field of psychology for its relative dearth of research using intersectionality frameworks. She was additionally critical of research examining both gender and race/ethnicity without adequately using an intersectionality framework to address inequalities and similarities between groups.

Museus and Griffin (2011) had similar criticisms for the field of higher education. While they acknowledge that higher education scholars have occasionally used intersectionality, they advocate for more widespread use. They argue that more frequent adoption of intersectionality frameworks would more accurately represent diverse college student identities, give voice to students "at the margins" (p. 9), and enhance our understanding of educational inequalities as a result of intersectional identities. Within one of the fields of interest—engineering—researchers conducted a literature search for intersectional research (Beddos & Borrego, 2011). Even using a liberal definition of intersectionality (studies that include statistics on multiple identities), Beddos and Borrego (2011) found that few studies published between 1995 and 2008 took an intersectionality approach.

Regarding STEM participation, intersectional research is most often accomplished by looking at the dimensions of gender and race/ethnicity. Reviewing the previously shared statistics from a gender and race/ethnicity intersectionality perspective, 18% and 54 % of non-White and non-Asian women and men, respectively, graduated with engineering, computer science, or physical sciences degrees. Data by group is shared in Figure 4. Some scholars have chosen to look at intersectional identities with gender (Charleston, Adserias, et al., 2014; Harper, Wardell, & McGuire, 2011; Johnson, 2011; Strayhorn, 2015). Others have examined both gender and race/ethnicity at the intersection of some other construct, such as STEM attitudes (Else-Quest, Mineo, & Higgins, 2013), engineering confidence (Litzler et al., 2014), STEM stereotypes (O'Brien, Blodorn, Adams, Garcia, & Hammer, 2015), and engineering learning outcomes (Ro & Loya, 2015). While much STEM research looks at the intersections of gender and race/ethnicity, nativity and social class are also relevant categories to explore (Ma, 2011a; Rubin et al., 2014).

## Summary

In this chapter, I have presented an overview of the existing literature related to participation rates in mathematics-intensive science fields, explanations for the lower participation of women and minorities, and theories which make up the foundation of the studies in this dissertation. Specifically, I have used national statistics to describe degree outcomes by gender, race/ethnicity, gender and race/ethnicity together, citizenship status, and disability. I then described various explanations for the gap between minority men and women and White students' participation in STEM. These explanations included entry vs. persistence, biological sources of intelligence, academic preparation and contexts, postsecondary experiences, and social psychological processes. Within the category of social psychological processes, I described many key theories such as socialization and scientist identity, field culture, mathematics anxiety and stereotype threat, and expectancy-value theory and subjective orientations towards mathematics. Last, I described the two foundational perspectives on which these dissertation studies are based: ability belief theories and intersectionality. The ability belief theories that inform the studies include resilience, grit, and flow, mindset theory, and field-specific ability beliefs. Intersectionality theory provides a framework for understanding the studies' focus on gender and race/ethnicity separately and together. In the next chapter, I discuss the methods for the two studies in greater detail.

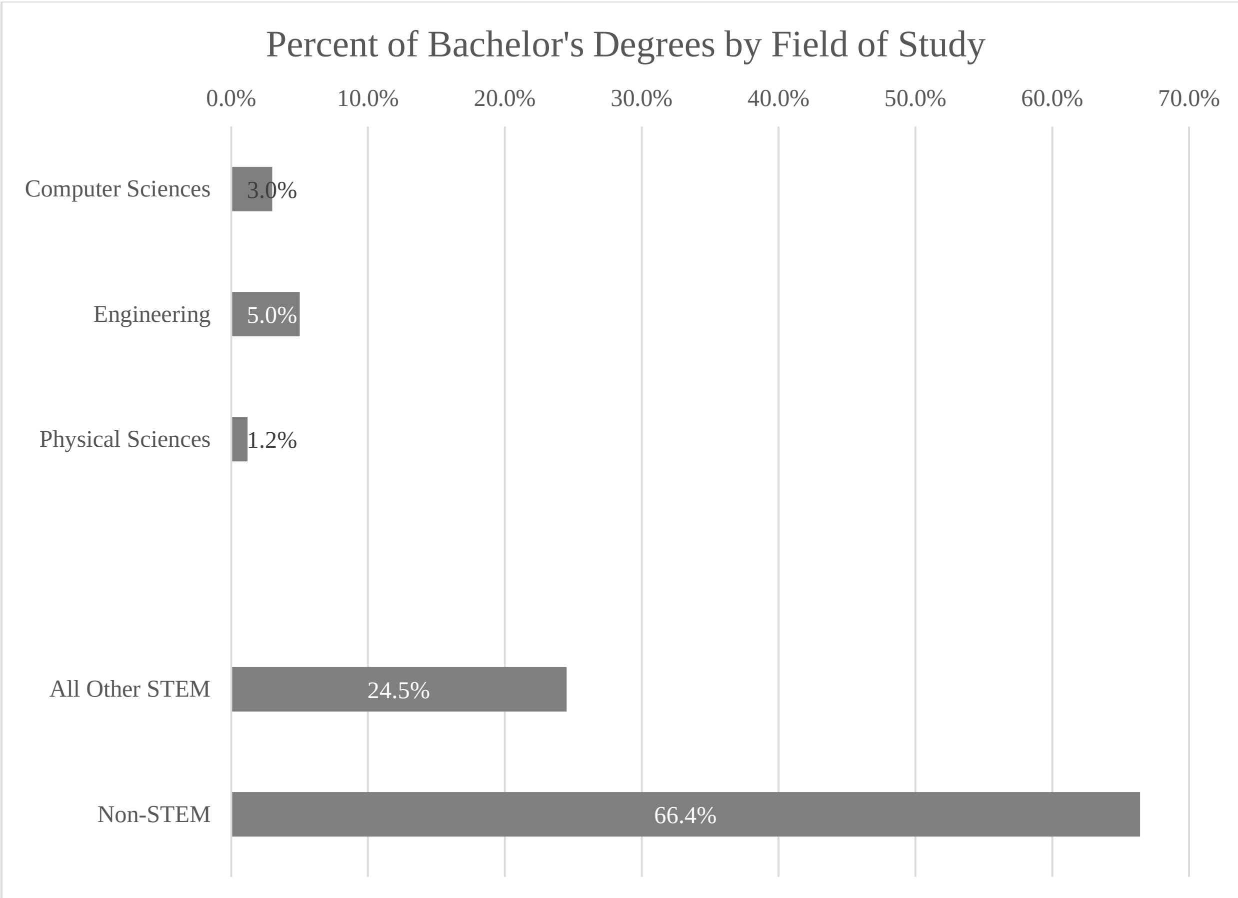


Figure 1. Percent of Bachelor’s Degrees by Field of Study

*Source:* Figures developed by the author using National Science Foundation National Center for Science and Engineering Statistics’ Women, Minorities, and Persons with Disabilities in Science and Engineering report retrieved from https://www.nsf.gov/statistics/2017/nsf17310/

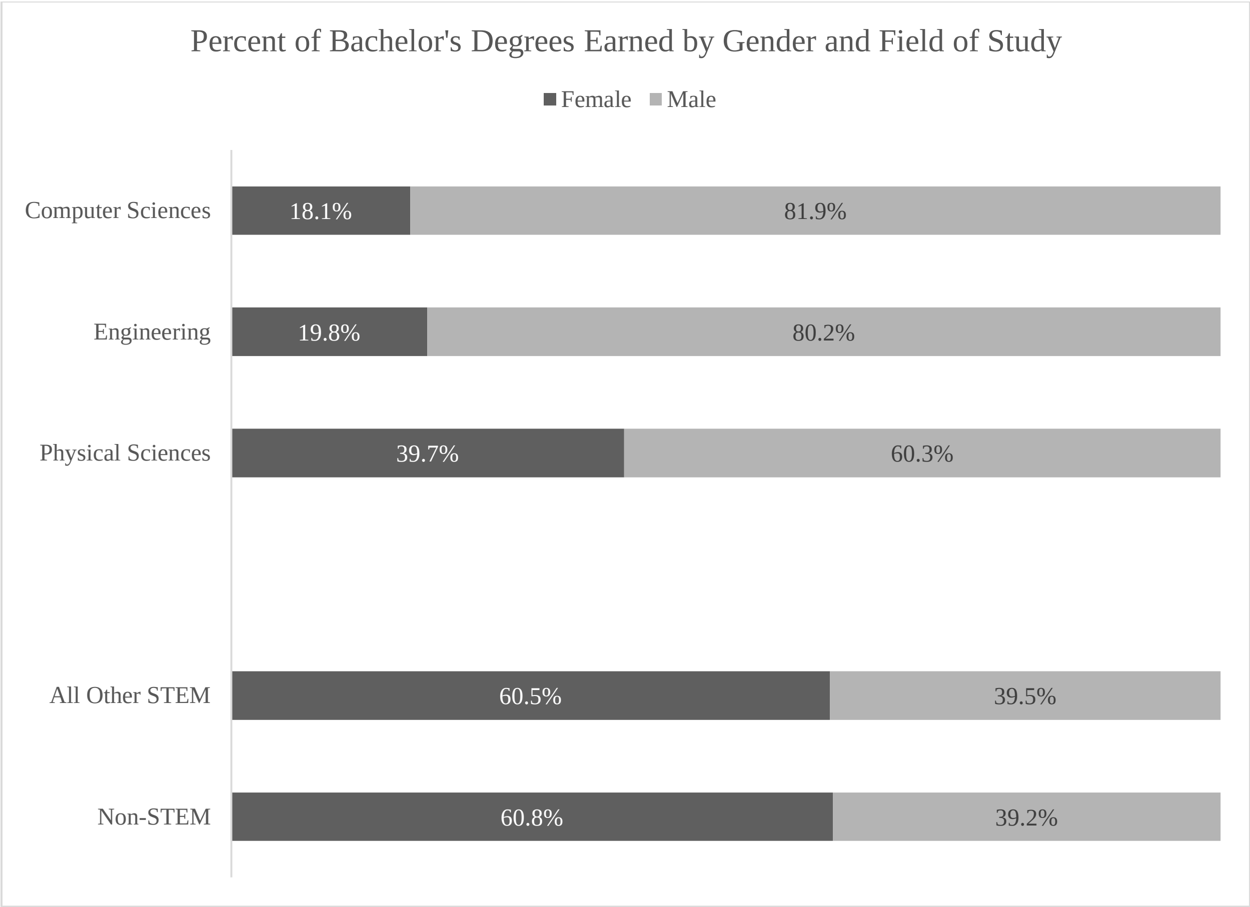


Figure 2. Percent of Bachelor's Degrees Earned by Gender and Field of Study

*Source:* Figures developed by the author using National Science Foundation National Center for Science and Engineering Statistics' Women, Minorities, and Persons with Disabilities in Science and Engineering report retrieved from https://www.nsf.gov/statistics/2017/nsf17310/

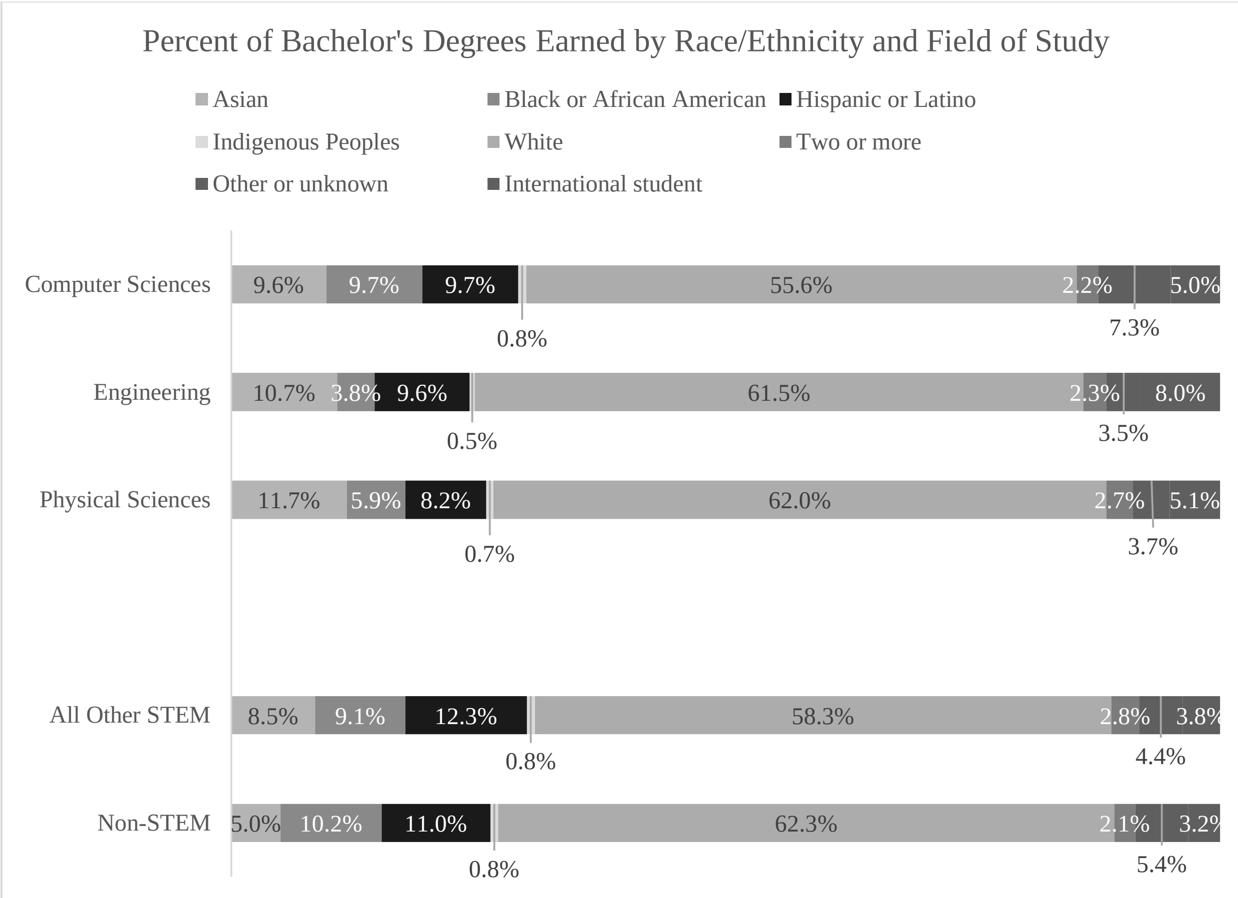


Figure 3. Percent of Bachelor's Degrees Earned by Race/Ethnicity and Field of Study

*Source:* Figures developed by the author using National Science Foundation National Center for Science and Engineering Statistics' Women, Minorities, and Persons with Disabilities in Science and Engineering report retrieved from https://www.nsf.gov/statistics/2017/nsf17310/

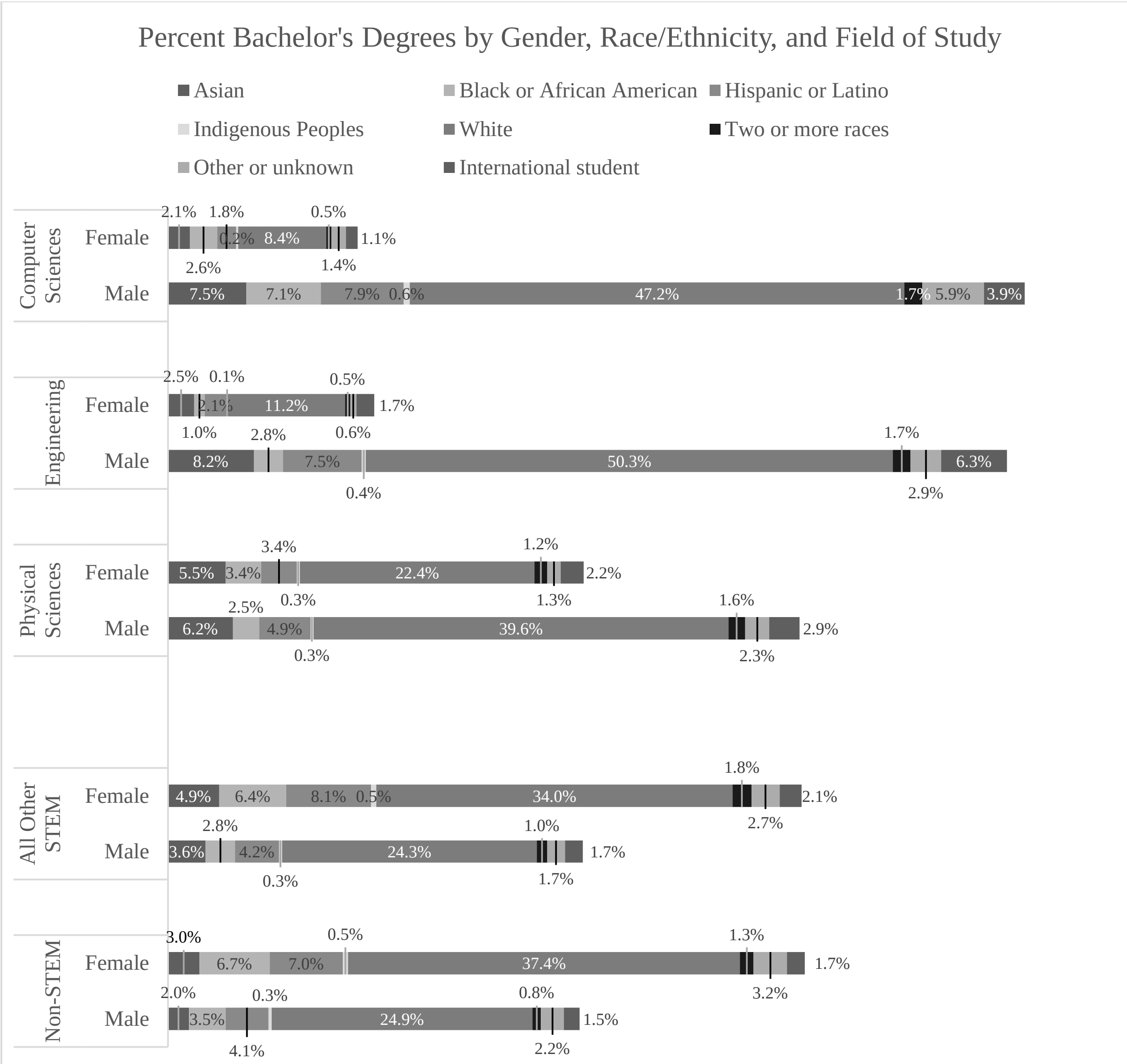


Figure 4. Percent of Bachelor's Degrees by Gender, Race/Ethnicity, and Field of Degree

*Source:* Figures developed by the author using National Science Foundation National Center for Science and Engineering Statistics' Women, Minorities, and Persons with Disabilities in Science and Engineering report retrieved from https://www.nsf.gov/statistics/2017/nsf17310/

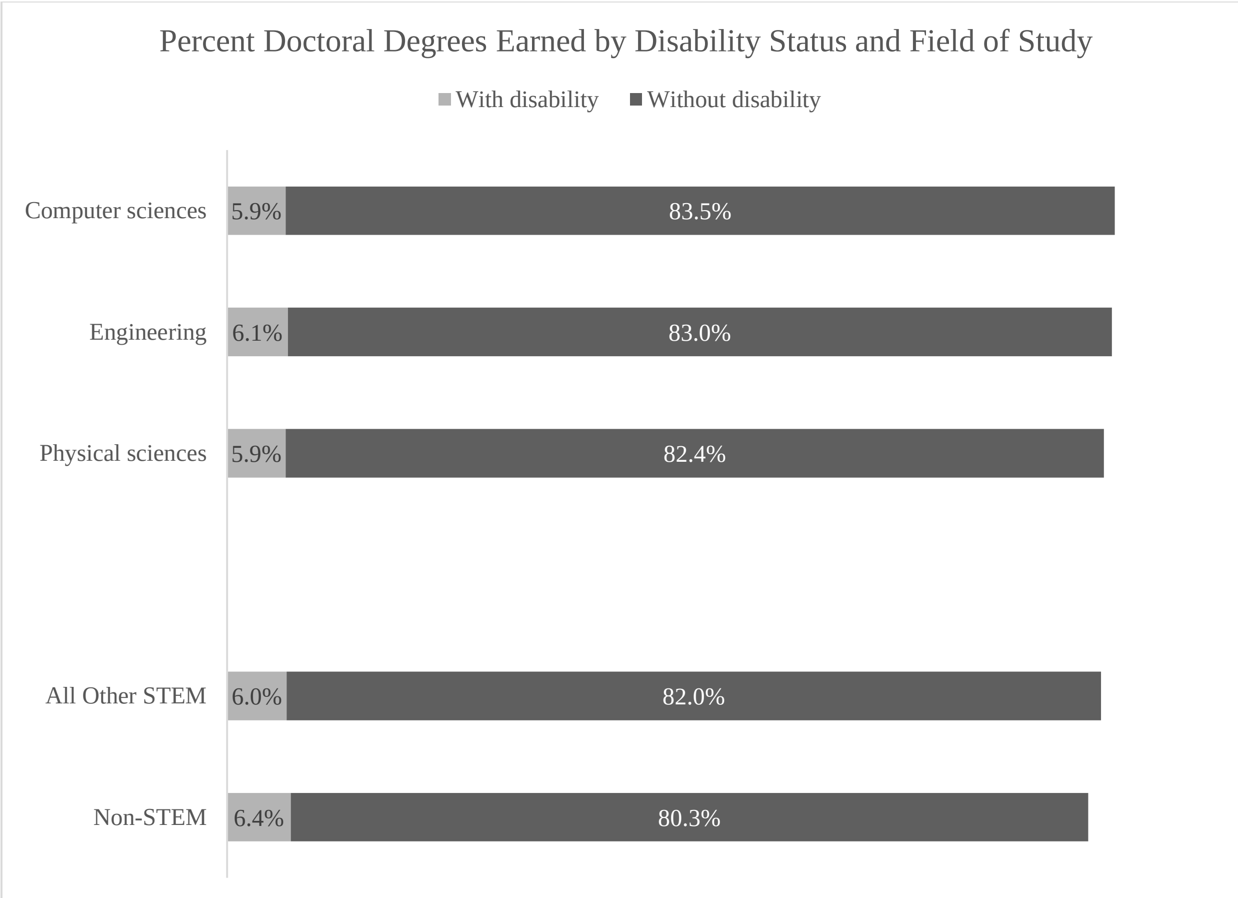


Figure 5. Percent of Doctoral Degrees Earned by Disability Status and Field of Study

*Source:* Figures developed by the author using National Science Foundation National Center for Science and Engineering Statistics' Women, Minorities, and Persons with Disabilities in Science and Engineering report retrieved from https://www.nsf.gov/statistics/2017/nsf17310/

# CHAPTER 3

# METHODOLOGIES

This dissertation examines 1) perceptions of difficulty and talent in STEM, 2) how those perceptions are shaped by identity and educational experiences, and 3) the relationship between those perceptions and persistence in mathematics-intensive fields. To accomplish these research goals, I engaged in both quantitative and qualitative inquiry. The methodologies for each of the studies are described in the following sections, preceded by an explanation of mixed methods research design.

## Mixed Methods Research

The final product of this dissertation is a framework synthesized from quantitative and qualitative findings. I therefore engaged in mixed methods research to draw inferences and answer the overarching research questions in Chapter 1. There are varying definitions of mixed methods research (Creswell & Clark, 2007; Johnson, Onwuegbuzie, & Turner, 2007), but they all include the use of more than one method either within a single study or multiple studies in a larger research project (Johnson & Onwuegbuzie, 2004; Johnson et al., 2007; Teddlie & Tashakkori, 2010). Mixed methods has multiple purposes, including managing weaknesses in research design (Johnson & Onwuegbuzie, 2004) and accurately representing the complexity of human experience and behavior (Liber & Weisner, 2010). Mixed methods typologies are concerned with the order of quantitative and qualitative methodologies as well as the dominance of one methodology over another (Creswell & Clark, 2007; Johnson et al., 2007).

I define this dissertation as a multi-sample (Teddlie & Tashakkori, 2010), qualitative dominant (Johnson & Onwuegbuzie, 2004; Johnson et al., 2007), convergent parallel (Creswell, 2013) mixed methods study (Johnson et al., 2007). Described in the following sections, the quantitative study used a national dataset collected by other researchers in 2002-2012. In contrast, the qualitative study's data was collected by me and included 24 college seniors at a single institution in 2016. Therefore, conclusions are drawn from two different samples, providing two perspectives on the overarching research questions (Teddlie & Tashakkori, 2010). The framework that is presented in Chapter 7 emerged primarily from the qualitative findings, making the framework qualitative dominant (Johnson & Onwuegbuzie, 2004; Johnson et al., 2007). While the quantitative study commenced first, analysis for both studies co-occurred and concluded at around the same time. The results are described separately in Chapters 4-6, but are interpreted and synthesized into a unified framework, qualifying this research as convergent parallel (Creswell, 2013). Finally, because this dissertation incorporates two distinct studies rather than qualitative and quantitative methods within one study, it is best described as a mixed methods design (rather than mixed model) (Johnson & Onwuegbuzie, 2004).

Mixed methodologists largely support mixing quantitative and qualitative approaches in a way that will best answer the overarching research question (Creswell & Clark, 2007; Johnson & Onwuegbuzie, 2004; Johnson et al., 2007). In this dissertation study, the overarching research questions are concerned with measuring and understanding the development, dimensions, and outcomes of ability beliefs. The quantitative study provided evidence of measureable beliefs about difficulty and how they differed in nuanced ways by gender and race/ethnicity. From that evidence, I initiated the qualitative study. This study initially focused on how difficulty and talent beliefs developed, and the role of gender and race/ethnicity identity in that process. The postsecondary experience became a larger focus of the qualitative study when the quantitative findings were consistently stronger for earlier outcomes and as my frustration with the limitations of that data built. Therefore, while method integration (Johnson & Onwuegbuzie,

2004) formally occurred through the development of the framework and the discussion in Chapter 7, the research was conducted iteratively, moving between qualitative and quantitative methodologies (Teddlie & Tashakkori, 2010).

## Study One: Quantitative Study

In the previous chapters, I discussed this dissertation's purpose to investigate ability beliefs in mathematics-intensive sciences by gender and race/ethnicity. The quantitative study fulfills that purpose by focusing specifically on perceptions of difficulty. Using a gender and race/ethnicity intersectionality approach, I seek to establish whether difficulty orientations in general, verbal, and mathematics domains significantly differ by race/ethnicity and gender categories. This study additionally includes analyses to explore the extent to which these race/ethnicity, gender, and difficulty orientation variables separately and together relate to major selection and degree completion in mathematics-intensive fields. The following questions guide the research:

1. Do domain-specific and domain-general difficulty orientation measures differ by race/ethnicity and gender identity categories?
2. To what extent do difficulty orientation measures predict selection and degree attainment of mathematics-intensive majors?
3. Do the relationships between difficulty orientation measures and PEMC outcomes differ by race/ethnicity and gender categories?

### Data Source and Participants

This study uses the most recent release of nationally-representative, restricted-use Education Longitudinal Study 2002/2012 (ELS) data including Postsecondary Education Transcript Study data from the National Center for Education Statistics. In 2002, approximately

16,200 10th graders from about 750 high schools responded to the first ELS survey. Follow-up surveys were distributed in 2004 (students' 12th grade year), 2006 (two years after high school), and 2012 (eight years after high school) (Ingels et al., 2007). I defined the population of interest as 10th graders in 2002 who earned at least a bachelor's degree by 2012, eight years after completing high school ($n$ = 11,540).

The ELS dataset was constructed over a ten year timespan, following participants through multiple educational and career transitions. Therefore, it is not surprising that there was a large amount of missing data across all independent or dependent variables for the sample (Table 7, Appendix B). Through an exploration of the missing data structure, I determined that the data were missing at random. I chose to address this missing data problem using multiple imputation. I determined that multiple imputation was preferable to other missing data methods, because it more accurately reflects the potential range of responses for missing data, including randomness, than other potential missing data methods (Cox, McIntosh, Reason, & Terenzini, 2014; Rubin, 2004). I used the Monte Carlo chained equation method built into Stata 14 to develop 10 datasets after running 100 imputations for each dataset. I plotted the means and standard deviations of the variables across the datasets and determined that it was sufficiently random. I also used NCES-provided panel weight *f3bypnlpswt* during both the multiple imputation and analyses to more accurately reflect the national population. For all of our analyses and descriptive statistics, I produced the correct pooled estimates through Stata 14's *mi estimate* commands.

**Measures**

**Dependent Variables.** Dependent variables include participants' declared major in 2006, two years after high school (declared major) and first degree field as of 2012 or eight years after high school (degree major). Majors are coded to compare mathematics-intensive science fields (computer sciences, engineering, and physical sciences, or CEP) with other STEM fields (biological sciences, health sciences, and social/behavioral and other sciences including mathematics and statistics) and non-STEM fields. Declared major includes an undeclared/undecided category to capture students who had not yet selected a field of study or who had delayed entry into postsecondary education.

**Independent Variables: Difficulty Orientations.** Questionnaires in students' 10th grade year included items regarding perceived ability to learn the most "difficult," "hard," or "complex" material in general and English or mathematics classes. Each of these variables measure students' perception of their individual abilities related to difficult or challenging material (Table 8, Appendix B). After developing our 10 datasets using multiple imputation, I used factor analysis to develop three scales that reflect students' difficulty orientation by domain: the General Scale, Verbal Scale, and Mathematics Scale.

**Covariates.** Given the prominence of background factors in the literature and our interest in learning how the postsecondary experience impacts difficulty orientations, the analysis additionally included demographic factors (gender, race/ethnicity, family income and parent education), high school experiences (standardized test scores, science course-taking, GPA, value of mathematics, and mathematics growth mindset[8]), high school characteristics (percentage free and reduced lunch, region, and urbanicity), participation in undergraduate research with a faculty member, and postsecondary institutional characteristics (control and selectivity of the first attended institution). Table 9 in Appendix B shows pooled sample descriptive statistics for each of the covariates listed.

[8] The 10th grade ELS survey included an item asking participants about their agreement with the statement, "Most people can learn to be good at math," (Ingels et al., 2007). We have labeled "growth mindset" given its relationship with Dweck's (2000, 2006) construct.

**Analysis**

To respond to each of the research questions, I estimated a series of regression models. To answer the first research question I estimated bivariate linear regression models to determine how domain-specific and domain-general difficulty orientation measures differ by race/ethnicity and gender identity categories.[9] To address the second research question I estimated multiple multinomial logistic regression models, progressively introducing difficulty orientation measures to explore the relationships between them and declared/degree major while controlling for the covariates listed in the previous section. For instance, I started with a base model (eq. 1), which included the outcome variable of interest, gender, race/ethnicity, and control variables.

$$mlogit(major) = \beta_0 + \beta_1 gender + \beta_2 race + \beta_3 S + \beta_4 HS + \beta_4 research + \beta_5 PSI + u$$

Where

$major =$ declared or degree major (see "Dependent Variables" section),
$S =$ student-level controls (family income, parent education standardized test scores, science course taking, GPA, value of mathematics, and growth mindset),
$HS =$ high school characteristics (percentage free and reduced lunch, region, and urbanicity), and
$research =$ participation in undergraduate research as a college student
$PSI =$ postsecondary institutional characteristics (control and selectivity of the first attended institution)

(eq. 1)

To understand the potential change in the relationship between the outcomes given difficulty orientations, I estimated four additional models. The first three replicated the base model, but separately included the General Scale, Verbal Scale, and Mathematics Scale (eq. 2-4). The last model in this sequence included all three of the difficulty orientation scales (eq. 6).

$$mlogit(major) = \beta_0 + \beta_1 gender + \beta_2 race + \boldsymbol{\beta_3 general} + \beta_4 S + \beta_5 HS + \beta_6 research + \beta_7 PSI + u$$

(eq. 2)

[9] Traditionally, I would use mean-item *t*-tests and one-way analysis of variance tests to address this question. However, Stata 14 does not allow the estimation of these statistics using multiply-imputed data.

$$mlogit(major) = \beta_0 + \beta_1 gender + \beta_2 race + \boldsymbol{\beta_3 verbal} + \beta_4 S + \beta_5 HS + \beta_6 research + \beta_7 PSI + u$$

(eq. 3)

$$mlogit(major) = \beta_0 + \beta_1 gender + \beta_2 race + \boldsymbol{\beta_3 math} + \beta_4 S + \beta_5 HS + \beta_6 research + \beta_7 PSI + u$$

(eq. 4)

$$mlogit(major) = \beta_0 + \beta_1 gender + \beta_2 race + \boldsymbol{\beta_3 general} + \boldsymbol{\beta_4 verbal} + + \boldsymbol{\beta_5 math} + \beta_6 S + \beta_7 HS + \beta_8 research + \beta_9 PSI + u$$

(eq. 5)

Where

*general* = non-domain specific difficulty orientation scale,
*verbal* = verbal difficulty orientation scale, and
*math* = mathematics difficulty orientation scale

The final research question addresses differences in the relationship between difficulty orientation and PEMC declared or degree major by gender and race/ethnicity. To respond to this question, I first refer to the results for gender and race/ethnicity on eq. 1-5 above. Next, I tested for significant differences in gender and race/ethnicity slopes by including three groups of two-way and one group of three-way interactions in separate models with all of the difficulty orientation and covariate measures. Mathematical expressions of these models are not shown because the results of the interaction terms were not significant. However, to provide clarity about what interaction effects were tested, I included the following two-way cross-product terms separately in the model shown on eq. 5:

a) gender*race/ethnicity,
b) gender*math, and
c) race*math.

I also tested a three-way interaction model by including gender*race*math with its corresponding two-way conditional effects (the same equations show above, 5a, 5b, and 5c).

Although there are no slope differences in gender and race/ethnicity before and after accounting for the scales, there could still be meaningful differences in PEMC declared and degree major given difficulty orientations by identity group. Multinomial logistic regression results are also difficult to interpret because of multiple comparison groups. To further explore Research Question 3, better understand potential differences by race/ethnicity and gender categories, and to simplify interpretation of our results, I report predicted probabilities. I estimated predicted probabilities using *mimrgns*, a user-written Stata command that correctly produces pooled estimates of multiply-imputed data using Stata's built-in margins command (Klein, 2016). Post-estimation significance tests using the *pwcompare* option allowed us to examine significant differences in predicted probabilities by different levels of difficulty orientations and across race/ethnicity and gender identities.

Specifically, I first generated predicted probabilities to declare a major or earn a degree in PEMC by both gender and race/ethnicity for the $10^{th}$, $25^{th}$, $50^{th}$, $75^{th}$, and $90^{th}$ percentiles of the mathematics difficulty orientation scale. These predicted probabilities were generated holding all other variables in eq. 5 constant. I compared significant differences between men and women within race/ethnicity group (e.g. Latinos vs. Latinas) and race/ethnicity groups within gender categories (e.g. Latinos vs. White men). I also examined significant differences in the probabilities as each identity group increased in percentile difficulty orientation. For instance, I tested if the probability for Latinas at the $25^{th}$ percentile differed from the probability for Latinas at the $10^{th}$ percentile. Together, these results provide insights on the manner that PEMC outcomes are related to intersections between gender, race/ethnicity and difficulty orientation.

## Study Two: Qualitative Study

Although the quantitative study confirms the existence and significance (both statistically and practically) of perceived difficulty, my understanding of how and why these perceptions develop and relate to race/ethnicity and gender was limited. In addition, I suspected from my review of the literature and previous professional experiences that perceived difficulty was not the only consequential ability belief. I also hoped to learn about perceived difficulty and talent. Therefore, I conducted qualitative interviews with 24 mathematics-intensive science major leavers and stayers during their last year at a research-intensive institution. The main purpose of the qualitative inquiry is to discover how these students perceived difficulty and talent in STEM before college; how and why those perceptions may have changed during their postsecondary experience; the way that students' identities informed those perceptions; and, the reported influence that those perceptions had on students' decisions to persist in the major.

**Grounded Theory Method**

Because I aimed to develop a framework for understanding perceptions of difficulty and talent, I focused my methodological reading on grounded theory method. The methodology is most often recognized for its ability to help researchers develop frameworks. Grounded theory method stipulates that the theory emerges from the data, and that the researcher does not approach the project with pre-conceived ideas about the constructs or processes being studied (Corbin & Strauss, 2015; Urquhart, 2013). This dissertation does not neatly fit these requirements. I ground the qualitative findings and synthesized model in the interview data, but I conducted the first rounds of quantitative analysis before the qualitative analysis. In addition, the dissertation writing process required my reading about and development of hypothesized conceptual frameworks. However, my hope was that grounded theory methodology would give me the tools to learn even more about the potential developmental processes for students' beliefs about difficulty and talent in STEM and mathematics-intensive science fields.

There are two major arms of grounded theory method. This research makes use of Corbin and Strauss (2015)'s perspectives on the method. The Corbin and Strauss (2015) version of grounded theory method provides structure and tools for both data collection and analysis. I used theoretical sampling, process, and theoretical coding to conduct this study. These strategies are discussed in detail in the following sections.

**Sampling Design and Participants**

The study was conducted using a sample of 24 college seniors at a large, public, southeastern research institution. Quota and maximum variation sampling—selecting a set number of participants by category and selecting participants based on being particularly unique, respectively—were used. This initial stage of sampling resulted in a list of 800 participants from the initial population of about 1,400 seniors who majored in CEP fields for at least two semesters. An email invitation was sent to the sample of 800 students. A larger number of White male students and those with experiences in engineering responded. Initial data analysis also showed that two groups had unique experiences that merited further investigation 1) women and minority students and 2) students who majored physics or computer science. Therefore, about halfway through the data collection period I engaged in theoretical sampling via snowball sampling. Theoretical sampling is a grounded theory method effort to follow up leads in the data by engaging participants that can provide information on the topic (Corbin & Strauss, 2015; Patton, 2002). I invited interviewed participants to inform eligible classmates about the research opportunity. This effort at theoretical sampling ultimately yielded higher participation by minority students and computer science students, who were lacking in the study. A physics faculty member also sent an email invitation to students in that department, yielding an increase of participants with experiences in that field.

Participants' demographic and academic characteristics are shown in Table 5. Forty-two percent of the participants I interviewed were women, 21% women of color. Twenty-five percent of the participants were men who identified as Asian, Black, Latino, or of multi-racial/ethnic descent. Half of the participants had their primary mathematics-intensive science experiences in engineering. Twenty-nine percent had their primary experiences in physics and 21% in computer science. Compared to the institutional population, the participants in this study are disproportionately women, people of color, and STEM majors.

**Research Setting**

I recruited participants from a single, public, four-year institution located in the southeastern region of the United States of America. The institution is classified as a research institution with very high research activity by the Carnegie Classification system and has a high undergraduate enrollment. The institution's Office of Institutional Resarch reported a total undergraduate enrollment of 32,621 in 2014, with an average undergraduate age of 21. Women made up about 55% of the total student body. The institution reports that 63.7% of its students are White, 16.0% Hispanic, 8.1% Black, 2.5% Asian, 2.6% multi-racial/ethnic, and 7.1% some other race/ethnicity classification. Given the high percentage of White students, this is a primiarily White institution where students of color may experience marginalization. The college with the highest number of graduates in the 2013-2014 school year includes the major fields of interest, the College of Arts & Sciences. The College of Engineering at this institution is unique in that it is shared with a historically Black university, potentially exposing students in engineering to a wider racial/ethnic diversity of peers and faculty.

**Data Collection and Analysis**

I met with participants individually for a two-hour interview in summer and fall 2016 semesters. Through the semi-structured interviews, the participants discussed their retrospective perceptions of STEM and mathematics-intensive science fields as well as difficulty and talent in mathematics and science domains throughout their lifetime. The interview protocol is shared in

Appendix C. The data were transcribed by a transcription company and checked by me. Pseudonyms were chosen to protect participants' privacy. I used a random name generator for options, but was intentional in selecting pseudonyms that reflected participants' actual names and backgrounds.

I conducted two rounds of coding: open/axial coding and theoretical coding. Open and axial coding occurs when a researcher approaches qualitative data with no coding structure in hand and engages in coding maintenance (Patton, 2002; Saldana, 2009). I developed three types of products through the open/axial round of coding. First, I used pattern coding—finding similar passages that express a similar idea—to develop nodes in Nvivo 11 (Saldana, 2009). These nodes were evaluated for their uniqueness and the node structure was pruned throughout the first round of coding. I also wrote concept memos during the coding process to discuss meaningful themes, or collections of codes that represent a larger construct (Corbin & Strauss, 2015; Patton, 2002). Last, I created participant profiles.

Participant profiles included a) an overview of each participant's interview, b) significant themes that emerged from that participant's interview, c) themes unique to the participant's interview, and d) themes that the participant's interview had in common with others. Participant memos provided structure in the constant comparative analysis method, a process of evaluating each participant's account against another's (Corbin & Strauss, 2015; Urquhart, 2013). In the second round of coding, I looked across memos, codes, transcripts, participant profiles, and member checking responses to engage in theoretical coding (Corbin & Strauss, 2015; Saldana, 2009; Silverman, 2011). The purpose of theoretical coding is to unveil processes. Therefore, I paid particular attention to statements from participants regarding cause/effect relationships, conditions, actions and inactions, and outcomes (Corbin & Strauss, 2015). Focusing on perceptions of difficulty and talent in STEM, I identified an overarching process and its components. I checked the existence of processes within the narratives of each participant, and identified counter examples. Aspects of the processes will be discussed in Chapters 5 and 6. The theory will be described in Chapter 7.

**Trustworthiness Efforts**

I engaged in three primary methods to ensure trustworthiness of my analysis. First, I communicated with participants via member checking. Participants were provided with their interview transcripts and their participant profile. In the message that contained the documents, I asked for feedback on the conclusions that I drew. Three participants responded, providing general notes. Their comments did not change the analysis. In addition to member checking, I also engaged in the peer debriefing process. My peer, Dr. Rebecca Brower, is a more experienced and senior researcher with specific training and experience in grounded theory methodology. She met with me before the data collection process, twice during data collection and early analysis, and once early in the theory building process. The peer debriefer provided grounded theory resources, suggestions, and asked critical questions. Lastly, I evaluated the theory against all of the participants' interview data and identified confounding cases. These cases were few in number and there are aspects to the participants' stories that support the theory.

**Limitations and Assumptions**

Like all qualitative research, the findings in this study are contextual. The theory shared here is built around the experiences of 24 college seniors with at least two semesters of experience in computer science, engineering, and physics. Thus, their experiences may be unique to the institution, these fields of study, their gender experience, or their cultural experiences. In addition, participants knew through informed consent forms that the research was focused on social perceptions of difficulty and innate ability in STEM fields.

Most participants did not acknowledge this aspect of the research directly. Rather, the topic naturally emerged from the conversation. Two participants, however, directly acknowledged this line in the informed consent form, and one of those participants discussed researching the researcher on the internet. While this could be considered priming, all participants discussed meaningful aspects of their experiences that were not the focus of this study, but are found in related literature. In addition, all participants were given an opportunity to refocus the interpretation of the interview through member checking, and none did. Finally, one potential assumption of the study is that the participants accurately remember occurrences that they retrospectively reported. However, because this study is primarily concerned with how participants' believed their experiences with talent and difficulty in STEM related to their major decision-making processes, truth or reality is not the focus. If the participant saw value in the memory, it is considered valuable to the study (Brown, Stevens, Troiano, & Schneider, 2002; Corbin & Strauss, 2015; Urquhart, 2013).

**Reseacher Reflexivity**

My own professional and educational experiences, gender, and race/ethnicity idenities influence my perspecitve as a researcher and the data collection process. As a multi-racial/ethnic woman, the manner in which I related to each participant varied based on participants' identity salience and my assumptions of how they perceived me. Cisgender (gender-conforming) women participants might have related to me intially due to shared gender identity, while cisgender men may have held back in describing experiences related to their masculine identities. Multiple men spoke about their perceptions of the gender gap in STEM and/or concerns they had about women counterparts fulfilling their potential in their science majors. The men who talked about this always discussed the issues in a sympatheic manner. I cannot know if these men related these experiences because I am a cisgender woman, a researher of these issues, or due to my professinal experiences with women in STEM. In addition, women openly discussed their experiences with gender socialization or gender microagressions. The participant who identified as agender seemed to comfortably discuss their identity with me. They opened up even more when I asked about the correct gender pronouns, perhaps indicating to them my acceptance and understanding of their gender identity.

My racial/ethnic appearance is ambiguous. I may pass as White for many, while others may identify me as a racial/ethnic minority. In an effort to connect with particiapnts about racial or ethnic experiences, I often framed questions about that topic with some disclosure of my own race and ethnicity. Because of my Vietnamese ethnic background, Asian and immigrant participants in particular used phrases like “You know how it is,” when discussing issues around their race, ethnicity, or family. Black and Latino participants seemed to take note of my racial/ethnic disclosure, but they did not connect to it in the same way. Still, most Black and Latino participants spoke at length about their racial experiences at this predominantly White institution, and a couple of those participants said that they appreciated the opportunity to talk openly about it. Finally, White students ranged from expressing threat to dismissal of my questions about race and ethnicity in STEM fields. A few participants discussed their racial identity from the perspective of recognizing priviledge. I had hoped that being able to pass as White may have allowed me to have deep conversations about the topic with these participants. However, it’s possible that for White participants in my study, race was not salient enough to merit discussion (Evans, Forney, Guido, Patton, & Renn, 2010).

I approached this project with professional experience mentoring students in STEM. Working with students who felt discouraged as a direct result of their experiences with difficulty or challenge or their perceptions of talent in STEM directly inspired this research. In addition, growing up I was refused entry into honors and AP mathematics and science courses due to my grades. I developed a belief that I was not meant to participate in STEM. This belief was challenged in graduate school, when I committed to learning advanced statistical techniques to conduct my research. Therefore, I identified with some of the experiences of the participants in this study.

My own college experiences were sometimes a topic of discussion during interviews. Many participants asked me about my undergraduate major and how I came to this research. As I never majored in the fields of study that I am sampling from, nor did I attend the chosen institution as an undergraduate, I may have be seen as an outsider by participants. I often described this lack of personal experience in conjunction with my professional experiences with students in STEM, which I believe increased my trustworthiness for these participants. My professional experiences also meant that I have familiarity with jargon, academic programs, and faculty/staff. Once I promised confidentiality within the extent of the law, participants seemed at ease to refer directly to programs and people that they knew I would be familiar with. Overall, I approached my role as a researcher to bring to light these students' perceptions and accurately reflect their experiences.

# CHAPTER 4

# FINDINGS FROM THE QUANTITATIVE STUDY

## Introduction

This dissertation investigates perceptions of difficulty and talent in mathematics-intensive science fields with a particular focus on gender and race/ethnicity. The first study in this dissertation—a quantitative analysis—examines these perceptions using ELS data.[10] This sample provides the opportunity to understand relationships between postsecondary educational outcomes and high school difficulty perceptions using a nationally-representative sample. Specifically, this study examines the relationships between *difficulty orientations* and mathematics-intensive science major outcomes: declared and degree major. Analyses were conducted to understand variation in the magnitude of outcomes given gender and race/ethnicity, both separately and together. The research questions for this study are:

1. Do domain-specific and domain-general difficulty orientation measures differ by race/ethnicity and gender identity categories?
2. To what extent do difficulty orientation measures predict selection and degree attainment of mathematics-intensive majors?
3. Do the relationships between difficulty orientation measures and mathematics-intensive science major outcomes differ by race/ethnicity and gender categories?

More details about the methods for this study are provided in Chapter 3.

[10] The study presented here is similar, though distinct in its sample and findings, to a study co-authored by Dr. Lara Perez-Felkner and currently under review. For both this chapter and the submitted manuscript, I produced the multiple imputation design, created the tables and figures, and wrote the first drafts of conference papers that—with feedback from both Dr. Perez-Felkner and discussants—form the basis of this narrative. Dr. Perez-Felkner provided even more substantive edits and contributed to the literature review on the submitted manuscript as co-author.

## Descriptive Statistics

Descriptive statistics for the sample are shown in Appendix B, Table 8 (difficulty orientation scale descriptions), Table 9 (covariate descriptive statistics), Table 10 (declared and degree major by sex) and Table 11 (declared and degree major by race/ethnicity). In brief, these statistics show that the sample is gender balanced (48.4% women and 51.6% men), majority White (63.8%), and majority middle income (52.6% from families earning $25,001-$75,000 per year). Fewer participants in the sample were advanced science course completers (20.6% finished two years of chemistry and physics courses in high school), and majority were public college attendees (76.6%) (Table 9, Appendix B).

Other important demographics are of note. Mathematics-intensive science majors rank third for men's declared and degree major (13.4% and 12.4%, respectively), but last for women's declared and degree major (3.2% and 2.9%, respectively) (Table 10, Appendix B). Asian/Pacific Islander, Black, and other race/ethnicity students are more likely than White students to declare mathematics-intensive science majors (12.0%, 10.7%, and 8.1%, respectively, vs. 7.8%), but Asian/Pacific Islanders are the only group more likely to earn degrees in these fields than White students (11.4% vs. 8.0%) (Table 11, Appendix B). Black students' rate of participation in mathematics-intensive science fields drops from 10.7% two years after high school to 6.7% eight years after high school. These statistics help frame the study and show meaningful variation, particularly between gender and racial/ethnic groups in pursuit of mathematics-intensive science majors and degrees.

## Difficulty Orientations by Gender and Race/Ethnicity Identity

This study is chiefly interested in how difficulty orientations and gender and race/ethnicity identities relate to mathematics-intensive science major outcomes. Clear differences in mean difficulty orientations were found between men and women, but differences between White and non-White students were less clear. High school boys and girls vary the most in their mathematics difficulty orientation: their scores differ by almost three standard deviations (Table 1; $p < 0.001$). While boys on average scored 0.2 standard deviations above the mean in their orientation towards difficulty in mathematics, girls scored on average 0.1 standard deviation below the mean. This finding suggests boys are more open to and more confident in their ability to learn the most difficult mathematics concepts than girls. In contrast, there are no significant differences between girls' and boys' general or verbal difficulty orientations.

Turning to differences by race/ethnicity, Table 2 shows that the only group disadvantaged in difficulty orientation compared to White students were Latino students. Their general and mathematics difficulty orientations were each 1 standard deviation below White students (both $p < 0.01$). Latinos were even more disadvantaged in their verbal difficulty orientations compared to White students, falling 2 standard deviations below ($p < 0.01$). In contrast, Asian students were more likely to have higher difficulty orientations, but only in the mathematics domain. On that scale, Asian students scored 2 standard deviations above White students ($p < 0.01$). Notably, Black and other race/ethnicity students' difficulty orientation scores were not significantly different from White students' scores. Thus, it appears that the only group disadvantaged in difficulty orientation compared to White students were Latino students, while Asian students were more likely to have higher difficulty orientations only in the mathematics domain.

**Difficulty Orientations and Mathematics-Intensive Science Outcomes**

Next, estimated multinomial logistic regression models progressively introduced difficulty orientation measures to understand their relative impacts (Tables 3 and 4)[11]. Mathematics difficulty orientation was the only belief scale which positively predicted declaring a mathematics-intensive science major. One standard deviation increase in the mathematics difficulty orientation score predicted 30.4% increase in the risk of choosing a CEP major versus a non-STEM major (RRR = 1.30; $p < 0.01$) (Table 3). Mathematics difficulty orientation measured in isolation of other difficulty orientations was not related to CEP degree field (Table 4). In contrast, verbal difficulty orientation is negatively related to mathematics-intensive science outcomes. When measured with only covariates (student-level controls, high school characteristics, participation in undergraduate research, and characteristics of the first postsecondary institution), the verbal difficulty orientation scale is associated with a 15.7% (RRR = 0.84; $p < 0.05$) and a 23.9% (RRR = 0.76; $p < 0.01$) lower risk of declaring and earning a degree in a mathematics-intensive science field, respectively, net of all previously mentioned variables (Tables 3 and 4).

After controlling for all difficulty orientations, both the verbal and mathematics difficulty orientations are significantly associated with both CEP major outcomes, in opposite directions. Specifically, the verbal scale is associated with 24.1% (RRR = 0.76; $p < 0.01$) and 28.3% (RRR = 0.72; $p < 0.01$) decreased risk of declaring and earning a degree in mathematics-intensive science fields, respectively. Mathematics difficulty orientation predicts a 44.8% (RRR

[11] Due to space, findings for only one category of the outcome variables is reported: CEP declared and degree major. Tables displaying results for undeclared/undecided, biological sciences, health sciences, and social/behavioral and other sciences declared and degree majors are available by request.

= 1.45; $p < 0.001$) and 31.8% (RRR = 1.32; $p < 0.05$) increased risk of declared and degree CEP major, respectively.

**Participation in Mathematics-Intensive Science Fields by Gender and Race/Ethnicity**

The relationship between difficulty orientations and mathematics-intensive science outcomes differ by gender and race/ethnicity groups. Findings for gender and race/ethnicity are first described separately. Then, an intersectionality approach is used to discuss results for specific gender and racial/ethnic groups in the next section. For clarity, predicted probabilities are reported.

Before controlling for any difficulty orientations, women have a 3.3% predicted probability of declaring a CEP major (RRR = 0.21; $p < 0.001$) and a 3.1% probability of earning a CEP degree (RRR = 0.24; $p < 0.001$) (Tables 3 and 4). In the next models, single difficulty orientations were consecutively controlled. In the last model, all difficulty orientations were included. Across all of these models, the negative relationship between female gender and mathematics-intensive science outcomes persists. The probability continues to hover around 3.3% and 3.1% when controlling singularly for general and verbal difficulty orientations. However, Table 1 showed that girls' mathematics difficulty orientation falls three standard deviations below boys', on average, indicating the importance of that scale. Compared to the general and verbal scales, the mathematics difficulty orientation scale increases the probability of women declaring a CEP major, but only slightly. When accounting for mathematics difficulty orientation, women see a 0.1 percentage point gain in their probability to declare a mathematics-intensive science major, but no gain in their probability to earn a CEP degree.

Multinomial regression analysis yielded significant findings for only one race/ethnicity group: Black students. Furthermore, there were no significant findings for Black students or any other race/ethnicity group when modeling degree completion. When modeling declared major, Black students have a 12.3% predicted probability (RRR = 2.06; $p < 0.001$) to major in mathematics-intensive science fields before including any difficulty orientations in the model, which equates to a 4.9 percentage point higher predicted probability than White students. Controlling for verbal difficulty orientations increases Black students' probability of declaring mathematics-intensive science majors by 0.3 percentage points. Mathematics difficulty orientations, however, decreases probability of declaring a CEP major from the base model by 0.2 percentage points. This finding suggests that Black students are more likely to declare mathematics-intensive science majors as a result of their confidence in their ability to learn advanced verbal—not mathematics—material. Further, increased mathematics difficulty orientation may actually be related to pursuing other careers for Black students. Turning to the degree completion models, there are no relationships between race/ethnicity and degree field when controlling for difficulty orientations singularly or all together.[12]

**Gender and Race/Ethnicity Intersectionality**

Multinomial logistic regression models show that gender and race/ethnicity function differently when examined separately. The results are now examined from an intersectional perspective. First, I estimated multinomial logistic regression models with two-way and three-way interaction terms. There were no significant findings on the interaction terms, indicating that

[12] Notably, these findings differ from those in the previously described related article submitted to a journal. One difference between the submitted article and this study is this study excluded mathematics and statistics majors from the mathematics-intensive science field category. In the submitted article, the focus was physics, engineering, mathematics, and computer science (PEMC). Compared to this study's findings, Black race/ethnicity is associated with over 1 percentage point higher predicted probability to declare a mathematics-intensive science major in the submitted article. Further, the degree major model that includes verbal difficulty orientations singularly and the full model with all difficulty orientations has a significant predicted probability for Black students. This analysis shows no significant results on race/ethnicity for the degree major models. This difference indicates that there may be specific experiences for Black students in mathematics and statistics majors. However, as it is not the focus of this dissertation, I will not discuss the finding further in this chapter or the concluding chapter.

there is no evidence of slope differences between gender, race/ethnicity, and gender and race/ethnicity categories in CEP outcomes given mathematics difficulty orientations.

While there were no significant slope differences, predicted probabilities provide an additional opportunity to examine nuanced differences by race/ethnicity and gender. Three notable overarching results emerged from analyzing these probabilities. First, women of every race/ethnicity had a lower probability than men of every race/ethnicity (even within race/ethnicity group) to select a CEP major or earn a CEP degree. Second, for all identity groups each percentile increase in mathematics difficulty orientation score is more associated with a significant increase in probability to declare a CEP major than to earn a CEP degree. Last, Black men and women had more positive mathematics-intensive science fields outcomes compared to their White counterparts.

Figures 6 and 7 most immediately illustrate the differences between men and women's probability to declare or earn a degree in mathematics-intensive science fields, respectively. Compared to men regardless of race/ethnicity, women were less likely to declare or earn degrees in mathematics-intensive science fields. In both figures, women's predicted probabilities fall well below men's, regardless of race/ethnicity. In general, men's predicted probabilities to declare a CEP major range from 7.1% to 26.6% between the $10^{th}$ and $90^{th}$ percentiles. Women's predicted probabilities for the same outcome range between 1.8% and 8.4%.

In one case, a group of women are more likely to major in a mathematics-intensive science field than some men. Black women at the highest mathematics difficulty orientation scores have between a 0.7 and 1.3 percentage point higher predicted probability of declaring a CEP major than all men except Black men. This finding is helpful for understanding Black women's rates of participation compared to multiple groups including their within-race counterparts.

For degree major, men's predicted probabilities range from 6.0% to 17.1%, whereas women's range from 1.5% to 4.8% from the lowest to the highest percentiles. Of the two dependent variables (declared major and degree major), mathematics-intensive science degree major has the widest sex differences between men's and women's predicted probabilities.

The second overarching finding that is not as clear from Figures 6 and 7 are significant gains in CEP outcomes given increases in mathematics difficulty orientations. Predicted probability results help us understand how gender intersects race/ethnicity in the relationship between difficulty orientations and major choice. Figures 8-11 show that for all gender and race/ethnicity groups, there are significant gains in probability to declare a mathematics-intensive science major when moving from the 10th to the 25th percentile (0.6%-3.3%), the 25th to the 50th percentile (0.4%-2.3%), the 50th to the 75th percentile (0.4%-2.3%), and the 75th to the 90th percentile (1.3%-5.9%) mathematics difficulty orientation. However, looking across the figures, there is a stronger association between mathematics difficulty orientation and CEP declared major than degree field. The gains in probability to earn a mathematics-intensive science degree are roughly half those for declaring a CEP major (1.5%-5.9% vs. 0.7%-2.7% for men and 0.4%-2.3% vs. 0.2%-0.9% for women).

In addition, there is significance across all percentile increases on Figures 8-9, but not on Figures 10-11. On those figures, Asian and Latina women as well as other race/ethnicity men's gains are no longer significant after the 50th percentile of mathematics difficulty orientation. White and Black women as well as Asian and Latino men's gains lose significance after the 75th percentile of mathematics difficulty orientation. Other race/ethnicity women never see significant gains in their probability to earn CEP degrees given increases in their mathematics difficulty orientation. Therefore, while increasing mathematics difficulty orientation was positively associated with majoring in CEP fields, it is not necessarily associated with earning degrees in these fields for all gender and race/ethnicity groups.

Moreover, the largest gains in mathematics-intensive science outcomes were for Black men and women. As reported in Figure 6, Black men and Black women were more likely than their White counterparts to major in mathematics-intensive science fields. Compared to White men, Black men are between 5.3 and 9.8 percentage points more likely to major in CEP fields (all $p < 0.01$) across increasing levels of mathematics difficulty orientation. Black women are 1.5 and 3.6 percentage points more likely to major in CEP fields compared to White women (all $p < 0.01$) as mathematics difficulty orientation increases.

Reflective of the multinomial regression models, Black men and women are more likely than White students to enter CEP fields irrespective of mathematics difficulty orientation, as shown by the 5.3 and 1.5 percentage point difference in the groups at the lowest measured percentile score. As difficulty orientation increases, so too does the gender gap among Black and White students. Black men and women's probability to select CEP majors benefits more from their confidence in ability to learn the most difficult material in mathematics than for White men and women. These same relationships do not exist for mathematics-intensive science degree completion, where Black students do not significantly differ from White students in their predicted probabilities.

Black women and men also benefit more from mathematics difficulty orientation than all other race/ethnicity and gender groups (Figures 8-11). Increases in predicted probabilities for White, Asian, Latino, and other race/ethnicity men fall between 0.8 and 1.7 percentage points below Black men's in probability to declare a CEP major and between 0.1 and 0.3 percentage points to earn a CEP degree. Similarly, White, Asian, Latino, and other race/ethnicity women fall 0.4-1.0 and 0.1-0.4 percentage points below Black women in their predicted probability increases to declare and earn degrees, respectively, in a CEP field given shifts in mathematics difficulty orientation. Therefore, Black men and women have a higher likelihood of declaring a mathematics-intensive science field major than their counterparts as their mathematics difficulty orientation increases.

## Conclusion

The findings illustrate the nuanced relationships between mathematics difficulty orientation and mathematics-intensive science field outcomes for men and women across race/ethnicity groups. Men and women differ in their difficulty orientations in mathematics domains, favoring men, as has been observed in other studies (Nix, Perez-Felkner, & Thomas, 2015; Perez-Felkner, Nix, & Thomas, 2017). In addition, Black and other race/ethnicity students had similar mathematics difficulty orientations as White students, while Latino students had lower mathematics difficulty orientations. Asian students had higher mathematics difficulty orientations compared to White students. These difficulty orientations positively predict mathematics-intensive science outcomes, holding all other factors constant. Also, net of all other variables, women are less likely than men to declare a mathematics-intensive science major or earn a degree in these fields. Black students are more likely to declare a CEP major and more likely to earn a CEP degree compared to White students, holding all else constant.

I opened this study by discussing the importance of examining gender and race/ethnicity intersections in STEM participation research. There was no change in directionality given race/ethnicity and gender intersections in the predicted probabilities of declaring or earning a degree in CEP fields given difficulty orientations. However, the magnitude of the relationships between mathematics difficulty orientations and CEP outcomes shifted given gender and race/ethnicity identity categories individually. Differences were the most consistent and largest between men and women: women's mathematics difficulty orientations were 3 standard deviations below men's and they were 10 and 8 percentage points, respectively, less likely than men to declare or earn degrees in mathematics-intensive science fields.

In contrast, there were only significant findings for one race/ethnicity group. Black students were about 6 percentage points less likely than White students to declare a mathematics-intensive science major; they were no more or less likely to earn degrees in these fields. These findings suggest that gender is a stronger predictor of mathematics-intensive science postsecondary outcomes than race/ethnicity. Notwithstanding, Black men and women show higher than expected gains in probability to declare a mathematics-intensive science major compared to their White, Latino, Asian, and other race/ethnicity counterparts, 0.8-1.7 and 0.4-1.0 respectively. In addition, Black women at the highest percentiles of mathematics difficulty orientations were about 1 percentage point more likely than all men but Black men to declare a CEP major. Therefore, race/ethnicity may moderate the relationship between mathematics-intensive science outcomes and difficulty orientations.

While this study provides some insight on the potential relationships between ability beliefs and postsecondary outcomes for mathematics-intensive science fields, it is limited. We cannot know using this quantitative data how and why students' beliefs about difficulty and talent in mathematics-intensive sciences formed in such a way to indicate the relationships shown in this study. Furthermore, gender and race/ethnicity intersectional relationships were nuanced, but this could be the result of statistical power rather than actual absence of an association. The qualitative study, which I turn to in the next two chapters, was designed to address some of these limitations. It provides further insight into the development and outcomes of perceived difficulty and talent in mathematics-intensive science fields.

Table 1. Difficulty Orientations by Gender

| | Men | | Women | | | | |
|---|---|---|---|---|---|---|---|
| | Mean | SE | Mean | SE | Sig. | Min | Max |
| General Academic Scale | 0.0 | 0.0 | 0.0 | 0.0 | NS | -1.7 | 1.1 |
| Verbal Scale | 0.0 | 0.0 | 0.0 | 0.0 | NS | -1.7 | 1.4 |
| Mathematics Scale | 0.2 | 0.0 | -0.1 | 0.0 | *** | -1.4 | 1.5 |

*Note.* $n$ = 11,540 respondents from the National Center for Education Statistics' Education Longitudinal Study 2002/2012 restricted data. Restricted-use NCES data requires rounding these descriptive results to the nearest tenth. Scales were developed using factor analysis, which automatically standardizes them so that the mean = 0 and SD = 1. * p <.05, ** p <.01, *** p<.001.

Table 2. Difficulty Orientations by Race/Ethnicity

| | White | | Asian/ Pacific Islander | | | Black | | | Latino | | | Other Groups | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SE | Mean | SE | Sig. | Mean | SE | Sig. | Mean | SE | Sig. | Mean | SE | Sig. | Min | Max |
| General Academic Scale | 0.0 | 0.0 | 0.1 | 0.0 | NS | 0.0 | 0.0 | NS | -0.1 | 0.0 | ** | 0.0 | 0.1 | NS | -1.7 | 1.1 |
| Verbal Scale | 0.1 | 0.0 | 0.0 | 0.0 | NS | 0.0 | 0.0 | NS | -0.1 | 0.0 | ** | 0.0 | 0.1 | NS | -1.7 | 1.4 |
| Mathematics Scale | 0.0 | 0.0 | 0.2 | 0.0 | ** | 0.0 | 0.0 | NS | -0.1 | 0.0 | ** | 0.0 | 0.1 | NS | -1.4 | 1.5 |

*Note.* $n$ = 11,540 respondents from the National Center for Education Statistics' Education Longitudinal Study 2002/2012 restricted data. Restricted-use NCES data requires rounding these descriptive results to the nearest tenth. Scales were developed using factor analysis, which automatically standardizes them so that the mean = 0 and SD = 1. Significance levels are produced comparing against means on White. * p <.05, ** p <.01, *** p<.001.

Table 3. Mathematics-Intensive Science Major Declared Two Years after High School, by Sex, Race/Ethnicity, and Difficulty Orientations

| | Base Model | | | Base + General | | | Base + Verbal | | | Base + Math | | | Base + All D.O. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PP | RRR | SE | PP | RRR | SE | PP | RRR | SE | PP | RRR | SE | PP | RRR | SE |
| *Demographic Characteristics* | | | | | | | | | | | | | | | |
| Sex | | | | | | | | | | | | | | | |
| Male (Reference) | 12.99% | - | - | 13.01% | - | - | 13.05% | - | - | 12.67% | - | - | 12.61% | - | - |
| Female | 3.34% | 0.21*** | 0.03 | 3.33% | 0.21*** | 0.03 | 3.32% | 0.21*** | 0.03 | 3.44% | 0.22*** | 0.04 | 3.45% | 0.23*** | 0.04 |
| Race/Ethnicity | | | | | | | | | | | | | | | |
| White (Reference) | 7.46% | - | - | 7.46% | - | - | 7.45% | - | - | 7.49% | - | - | 7.48% | - | - |
| Asian/Pacific Islander | 8.07% | 1.27 | 0.26 | 8.03% | 1.27 | 0.26 | 7.92% | 1.25 | 0.26 | 8.22% | 1.30 | 0.27 | 8.09% | 1.26 | 0.26 |
| Black | 12.34% | 2.06*** | 0.43 | 12.39% | 2.06*** | 0.43 | 12.56% | 2.11*** | 0.45 | 12.12% | 2.00** | 0.43 | 12.39% | 2.06*** | 0.44 |
| Latino | 7.50% | 1.12 | 0.29 | 7.51% | 1.12 | 0.29 | 7.53% | 1.12 | 0.30 | 7.40% | 1.09 | 0.29 | 7.39% | 1.08 | 0.29 |
| Other | 8.05% | 1.16 | 0.51 | 8.05% | 1.15 | 0.51 | 8.09% | 1.16 | 0.52 | 7.98% | 1.14 | 0.50 | 7.97% | 1.12 | 0.51 |
| *Difficulty Orientations* | | | | | | | | | | | | | | | |
| General Academic Scale | | | | | 0.979 | 0.106 | | | | | | | | 0.951 | 0.137 |
| Verbal Scale | | | | | | | | 0.84* | 0.07 | | | | | 0.76** | 0.074 |
| Mathematics Scale | | | | | | | | | | | 1.30** | 0.109 | | 1.45*** | 0.148 |
| Constant | | 0.01*** | 0.01 | | 0.01*** | 0.01 | | 0.01*** | 0.01 | | 0.01*** | 0.01 | | 0.01*** | 0.01 |
| *f*-statistic | 6.90*** | | | 6.75*** | | | 6.77*** | | | 6.71*** | | | 6.51*** | | |
| Observations | 11,540 | | | 11,540 | | | 11,540 | | | 11,540 | | | 11,540 | | |

*Note.* *n* = 11,540 respondents from the National Center for Education Statistics' Education Longitudinal Study 2002/2012 restricted data. Parent education, family income, 10th grade standardized test scores, science course taking, high school GPA, mathematics value, mathematics growth mindset, percentage free and reduced price lunch, high school region, high school urbanicity, participation in undergraduate research, institutional control, and college selectivity was included in the model, but not shown for space. Full table is available upon request. * p <.05, ** p <.01, *** p<.001.

Table 4. Mathematics-Intensive Science Degree Major Eight Years after High School, by Sex, Race/Ethnicity, and Difficulty Orientations

| | Base Model | | | Base + General | | | Base + Verbal | | | Base + Math | | | Base + All D.O. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PP | RRR | SE | PP | RRR | SE | PP | RRR | SE | PP | RRR | SE | PP | RRR | SE |
| *Demographic Characteristics* | | | | | | | | | | | | | | | |
| Sex | | | | | | | | | | | | | | | |
| Male (Reference) | 11.78% | - | - | 11.81% | - | - | 11.86% | - | - | 11.67% | - | - | 11.62% | - | - |
| Female | 3.09% | 0.24*** | 0.04 | 3.08% | 0.23*** | 0.04 | 3.07% | 0.23*** | 0.04 | 3.12% | 0.24*** | 0.04 | 3.14% | 0.24*** | 0.04 |
| Race/Ethnicity | | | | | | | | | | | | | | | |
| White (Reference) | 7.60% | - | - | 7.59% | - | - | 7.57% | - | - | 7.61% | - | - | 7.59% | - | - |
| Asian/Pacific Islander | 7.41% | 1.15 | 0.25 | 7.34% | 1.14 | 0.25 | 7.22% | 1.12 | 0.24 | 7.47% | 1.16 | 0.25 | 7.35% | 1.14 | 0.25 |
| Black | 8.60% | 1.31 | 0.38 | 8.71% | 1.33 | 0.39 | 8.88% | 1.37 | 0.40 | 8.54% | 1.29 | 0.38 | 8.83% | 1.35 | 0.40 |
| Latino | 6.78% | 0.98 | 0.23 | 6.78% | 0.98 | 0.23 | 6.83% | 0.99 | 0.24 | 6.75% | 0.97 | 0.23 | 6.73% | 0.97 | 0.24 |
| Other | 5.32% | 0.73 | 0.28 | 5.29% | 0.72 | 0.29 | 5.34% | 0.73 | 0.29 | 5.30% | 0.72 | 0.28 | 5.25% | 0.71 | 0.29 |
| *Difficulty Orientations* | | | | | | | | | | | | | | | |
| General Academic Scale | | | | | 0.88 | 0.13 | | | | | | | | 0.94 | 0.16 |
| Verbal Scale | | | | | | | | 0.76** | 0.07 | | | | | 0.72** | 0.07 |
| Mathematics Scale | | | | | | | | | | | 1.14 | 0.12 | | 1.32* | 0.15 |
| Constant | | 0.00*** | 0.00 | | 0.00*** | 0.00 | | 0.00*** | 0.00 | | 0.00*** | 0.00 | | 0.00*** | 0.00 |
| *f*-statistic | 5.53*** | | | 5.38*** | | | 5.27*** | | | 5.44*** | | | 4.88*** | | |
| Observations | 11,540 | | | 11,540 | | | 11,540 | | | 11,540 | | | 11,540 | | |

*Note.* n = 11,540 respondents from the National Center for Education Statistics' Education Longitudinal Study 2002/2012 restricted data. Parent education, family income, 10th grade standardized test scores, science course taking, high school GPA, mathematics value, mathematics growth mindset, percentage free and reduced price lunch, high school region, high school urbanicity, participation in undergraduate research, institutional control, and college selectivity was included in the model, but not shown for space. Full table is available upon request. * p <.05, ** p <.01, *** p<.001.

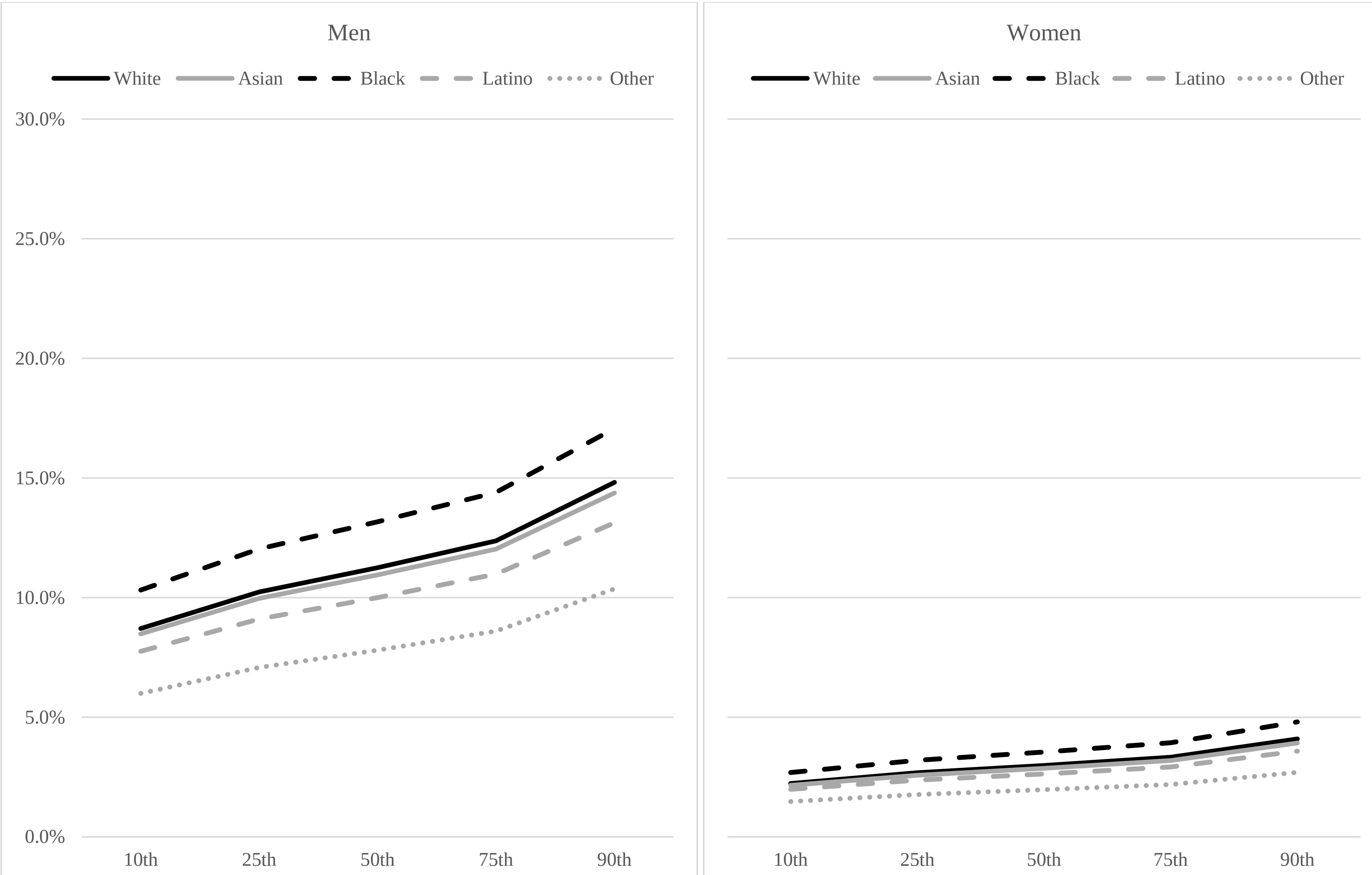

Figure 6. Mathematics-Intensive Science Declared Major Given Mathematics Difficulty Orientation Percentiles, Gender, and Race/Ethnicity

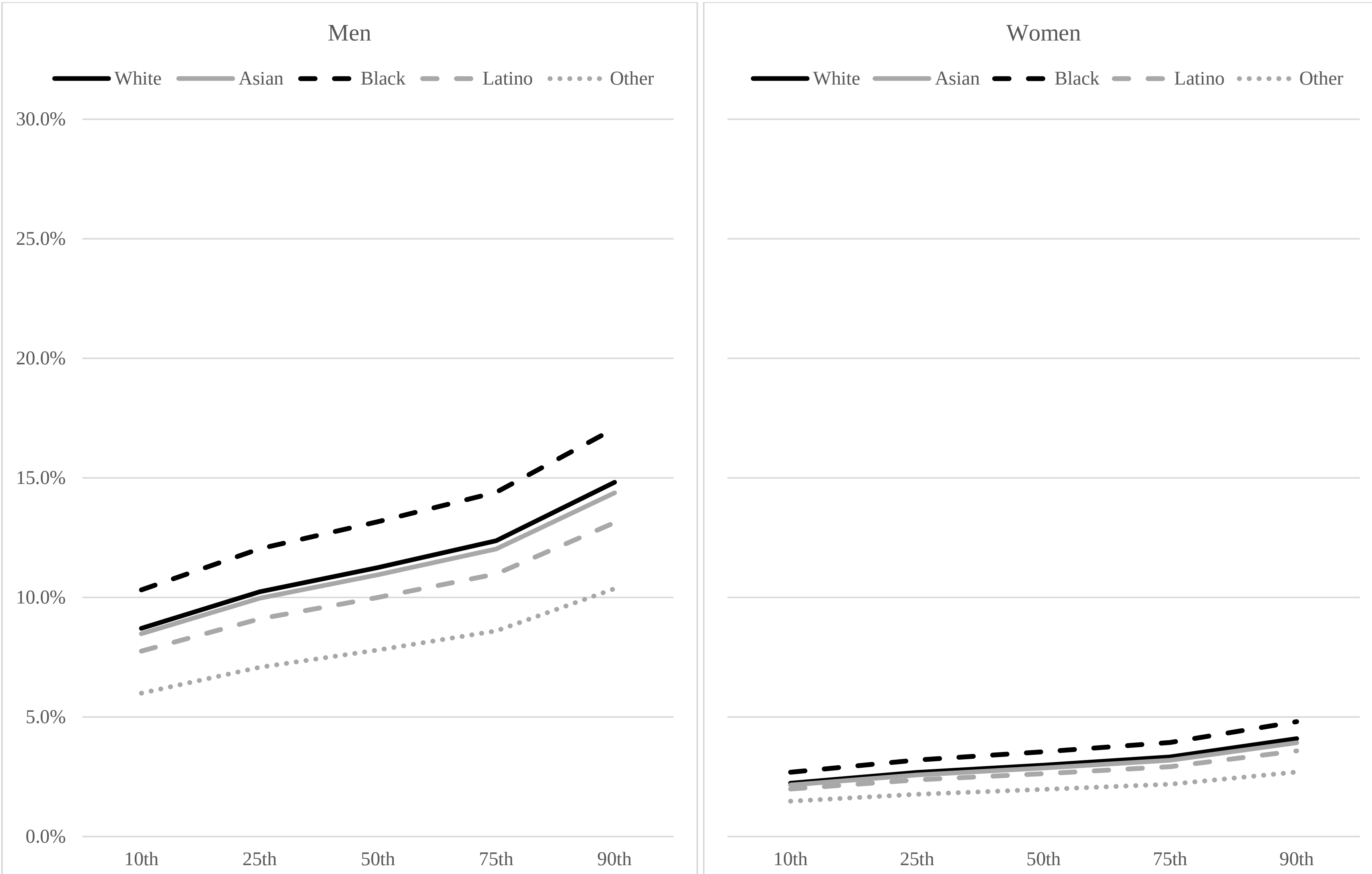

Figure 7. Mathematics-Intensive Science Degree Major Given Mathematics Difficulty Orientation Percentiles, Gender, and Race/Ethnicity

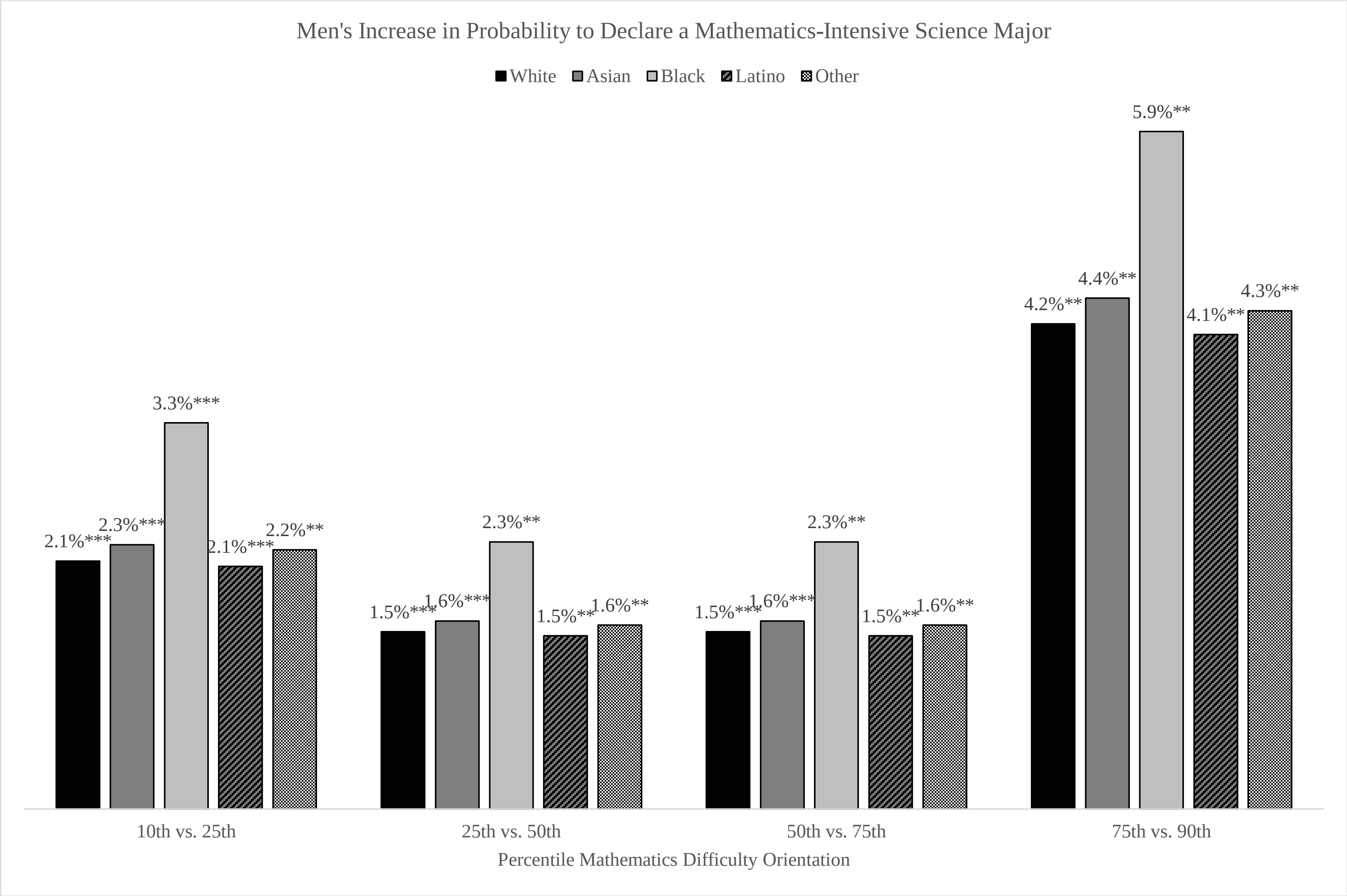


Figure 8. Men’s Increase in Probability to Declare a Mathematics-Intensive Science Major Given Percentile Increases in Mathematics Difficulty Orientations

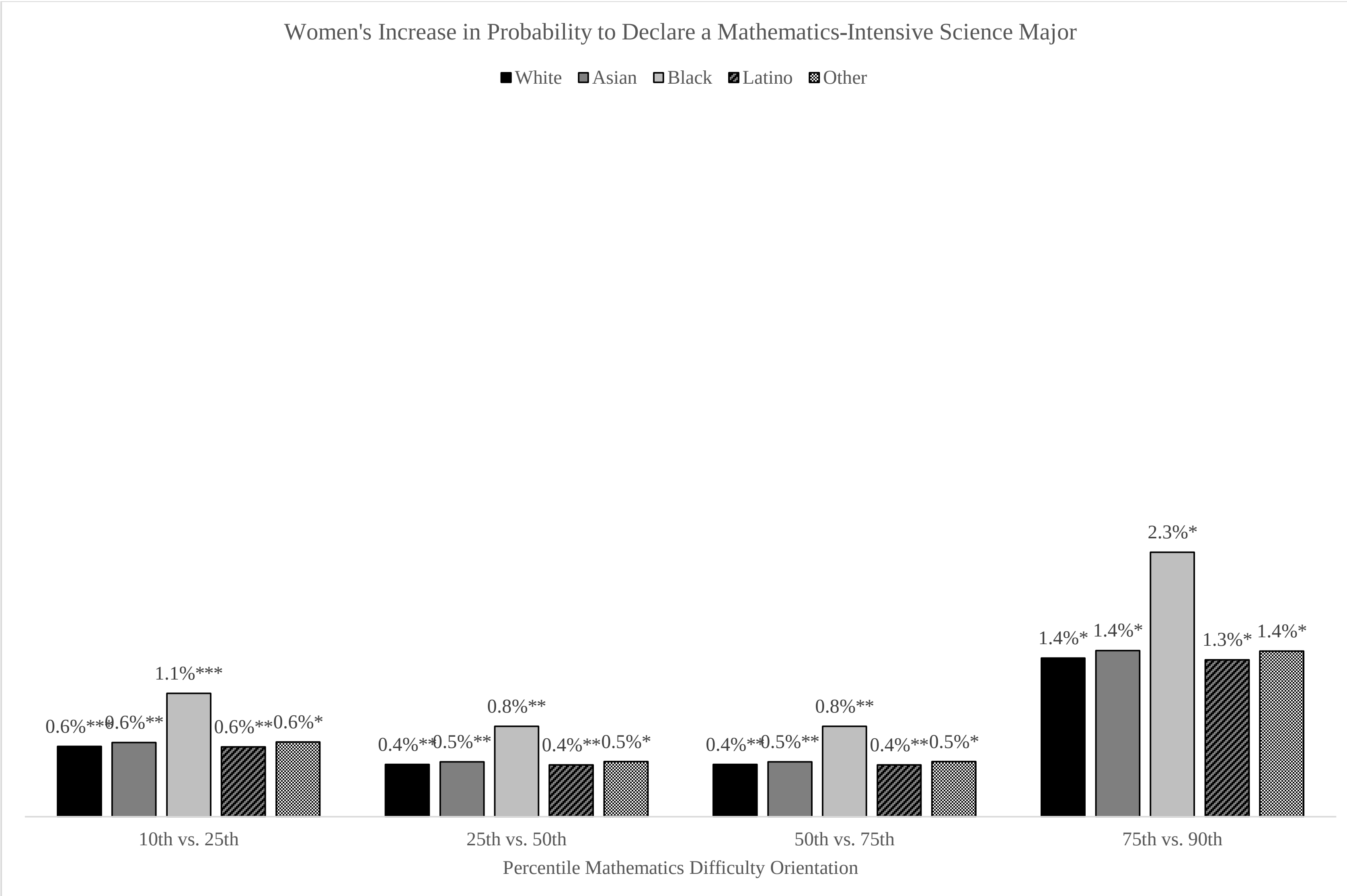


Figure 9. Women's Increase in Probability to Declare a Mathematics-Intensive Science Major Given Percentile Increases in Mathematics Difficulty Orientations

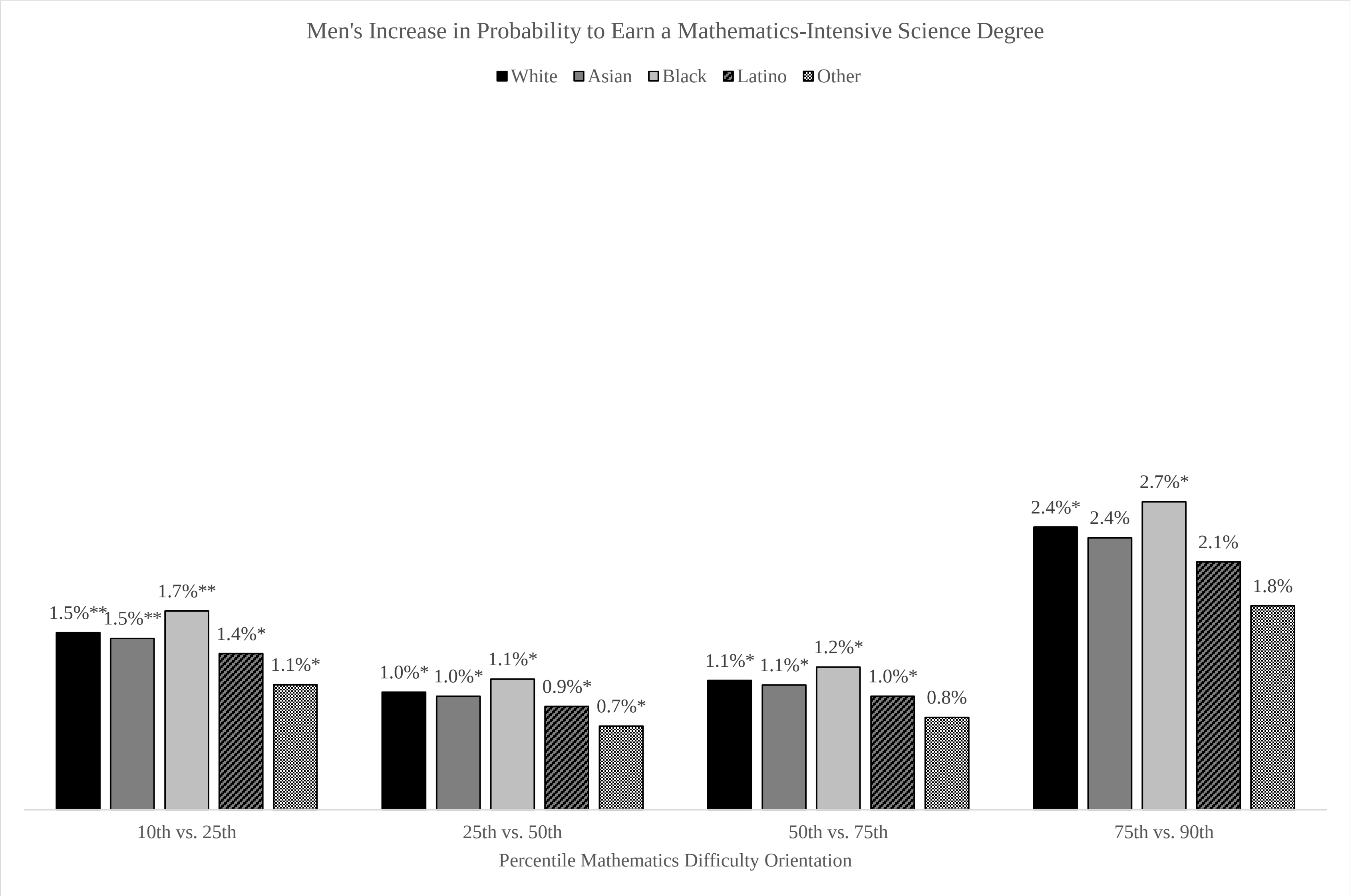


Figure 10. Men's Increase in Probability to Earn a Mathematics-Intensive Science Degree Given Percentile Increases in Mathematics Difficulty Orientations

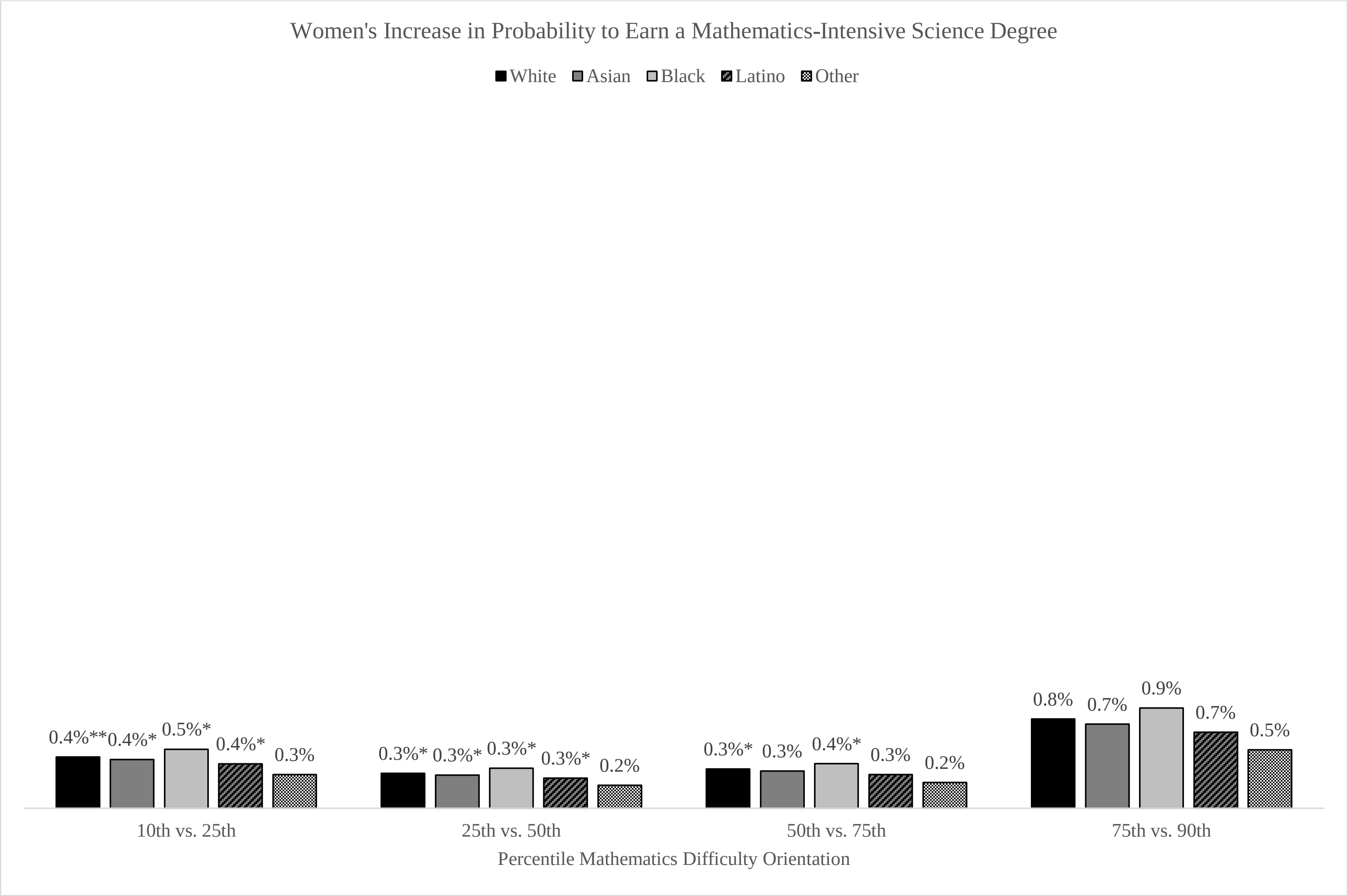


Figure 11. Women’s Increase in Probability to Earn a Mathematics-Intensive Science Degree Given Percentile Increases in Mathematics Difficulty Orientations

# CHAPTER 5

# DEVELOPMENT OF DIFFICULTY AND TALENT BELIEFS

## Introduction

The previous chapter reported findings related to mathematics difficulty orientations: students' level of agreement that they can understand the most difficult or complex material in mathematics. The results indicated that men are more confident in their ability to learn difficult math than women, even after controlling for background factors. Further, with each subsequent increase in mathematics difficulty orientation, Black students saw a greater return on probability to declare a mathematics-intensive science major than students of all other race/ethnicity groups. Black women with the highest mathematics difficulty orientations were particularly advantaged compared to all men but Black men. This study was useful in explaining the potential relationships between difficulty orientations, gender, race/ethnicity, and CEP outcomes. However, the study did not address how and why these perceptions developed.

The qualitative study addresses this limitation using interview data from 24 senior CEP leavers and stayers (Table 5). The study aims to understand ability belief development in STEM, or more specifically, mathematics-intensive science fields. This study also explores how participants' identities informed their perceptions. Methodology for this study was outlined in Chapter 3.

This chapter describes how perceptions of difficulty and talent were formed. Specifically, I discuss how students developed the dual belief that one must be talented to participate in STEM and that they possessed this talent. These perceptions were established through implied "ranking" of mathematics-intensive science or STEM fields above others, encouragement from family, teachers, and peers, and K-12 tracking. Furthermore, the college weed-out culture perpetuated these beliefs once students entered postsecondary education. After illustrating the development of these beliefs, I then report how they are shaped by the educational experience and identity in Chapter 6.

**"The Best Among Us Are Scientists": Ranking Mathematics-Intensive Science Fields**

Participants described believing that STEM or mathematics-intensive science fields were challenging because talent was necessary to participate in those fields. One way that this belief was created was through an informal ranking of majors. Within the first three interviews, a strong theme related to a hierarchical ranking of majors emerged. For instance, Morrison (a White man engineering leaver) told me that he felt engineering had a competitive culture. When I asked him to explain where he thought that culture came from, he said, "I would say it's because of the social stigma. Whereas, you're an engineer, therefore you're the smartest, like, one of the smartest people in society." Similarly, Alan (another White man engineering leaver) told me that he did not even consider careers outside of STEM because his "dad especially is a hyper-elitist, so and I got the same sort of reinforcement once I got into the sciences: everybody in the sciences looks down on all other fields." I began to get the sense that this comparison of majors against one another was potentially universal among CEP students when I asked Nessa (a Black woman Engineering stayer) to describe qualities of engineering students:

> *[T]hey believe that they're better than students in other departments, but I'm sure other students in other departments believe the same way about others. […] honestly I would say the engineering students work harder, I guess, because the course work is much more rigorous.*

From this point (about 12.5%) further in the data collection and analysis process, I began to note when participants indicated some *ranking* or *hierarchy* of majors. If this topic did not naturally arise in the conversation, I asked participants about it more directly near the end of the interview (see interview protocol in Appendix C). Participants described four primary methods of ranking majors against one another: (1) social value, (2) economic opportunity, (3) perceived difficulty of the fields, and (4) overall intelligence of the people in those fields.

**"Changing the World": Ranking by Social Value**

Growing up in a post-Cold War society and current or former majors of mathematics-intensive sciences, the students I spoke with were able to articulate a perceived high social investment in or value toward these fields. Following up on my previous quote from Alan, he told me "when you're an engineer, engineering is the greatest gift to mankind and everything else is a lesser study and should be looked down upon." This feeling that scientists were a "gift to mankind" was common across participants. For instance, Zachary (a White man Physics leaver) told me that his family felt "that because we were so smart, we had a responsibility almost, to go into STEM fields. Because STEM is where you would embetter society. You accomplish something when you're in STEM. You're not just working to work."

Similarly, Maya (a Black woman computer science major) told me that in professions like psychology or education (referring to my field of study):

> *all you're doing is just talking to people, but we're [computer scientists or engineers] actually doing things that's going to change the world or we're doing things that's going to have an effect on the rest of the world or the rest of the country. I'm building things or I'm creating things, and all you're doing is just talking-- I think people, anything that has to do with social interactions, aren't seen as valued as often as creating things.*

Gage (a Black man engineering leaver) told me that these distinctions can also occur within mathematics-intensive science fields:

> *I've heard people in engineering talk bad about physics majors […].The engineers would say the physics people were all theoretical, and they don't actually do things. The engineers would say they're the doers. People in physics just think about things; they don't actually do anything. People in physics would be like "the engineers only care about what; they don't about the why." So they don't really understand what they're doing.*

For these participants and others who made similar comments, mathematics-intensive sciences were spaces to help advance society through physical, rather than theoretical or social, change. This quality, according to the participants, made these fields of study more valuable than others, and therefore required "smart" people.

**"The Big Majors": Ranking by Economic Opportunities**

Related to feeling that mathematics-intensive science fields are more socially relevant than others, participants also believed that these majors were more important because of the economic benefits attached. As a prime example, Gage told me:

> *I always thought there was-- the STEM majors were kind of put on a pedestal because people always talked about STEM. STEM, they make a lot of money. You know, science, technology, engineering, and math. I always thought that was the big thing. Okay, if you want to make money, you need to be in STEM. Those are the big majors.*

This belief was reinforced by media for most participants. For instance, Luis (a Latino man Physics stayer) said that he understood mathematics-intensive science fields were more important than others "Because if you look at the top 20 majors, 19 of them are engineering." Similarly, Alisha (a Black woman engineering stayer) described, "you know those little Yahoo stories [about] which majors make the most money […] five different types of engineering are at the top and chemical engineering is usually at the top."

Income alone was not the only economic opportunity that participants referred to when they ranked majors in this way. Perceived job availability and stability were also factors. For example, Casey (a White woman engineering stayer) told me:

> *I think a lot of people will also choose the sciences because they want to get a job out of college. Whereas you look at some of the liberal field of studies like liberal arts or English majors. A lot of the jobs they get out of school are teaching, or I forget what-- I have a friend who is majoring in literature and she was telling me about the job predictions of fields and how hers is so much less than engineering is, and how much less it is in comparison with computer science or nursing or things like that, things that are always growing with the population.*

Related, Alan believed that more people pursue these fields because "during the whole housing collapse, the only people who were getting jobs for a while were STEM majors." Therefore, perceived high income, job growth, and stability were aspects of mathematics-intensive science careers that participants mentally referred to when placing value on these fields above others.

**"If It Were Easy, A Lot More People Would Do It": Ranking by Difficulty**

Intertwined with perceptions of social value and economic opportunity, participants also felt that fields of study could be ranked based on difficulty. For instance, Antonio (a White Latino man computer science stayer) told me that he perceived major ranking as "based off of a mixture of the difficulty of the field, as well as how much money you can make, as well as what you can actually do in the betterment of humanity." Gage phrased it a different way "It seems to be that the more money that you can make in a major, the more difficult that major will be." He explained:

> *For instance, I had never heard of actuarial science I think it is, and I looked into it when I was thinking about switching majors. When I saw the requirements, it's like you can never get below a C in any math course ever. I looked at how much they made and I was like, "They're in the top."*

For Josiah (a White man computer science stayer) lack of participation in STEM fields was indicted by both higher income and difficulty:

> *I think if it's easy, a lot more people would get into it. If it was not challenging a lot more people would do it. If it was really easy to become a doctor and really well paying, why wouldn't everybody want to be a doctor? There's a reason why they get paid so much, because you have to have a really specific and really intense knowledgeable skill set.*

While Josiah seemed to view this neutrally, ranking majors by ease was used in a negative way in Eva's (a White woman physics to engineering swapper) experience.

> *I: So you were intentionally being told to drop a major. Who told you that?*
>
> *R: Well, just a few people. It wasn't an everyday thing or anything like that. It was straight up bullying I would say, but it was on the side. It was another thing on top of*

*everything. Like, "Man, I'm failing this class. This sucks." And somebody's like, "Oh, well. There's always civil engineering," or something like that. I'm just like, "Okay."*

*I: Why civil engineering?*

*R: Oh, there's an ongoing joke that I guess mechanical is the highest. Or I mean, I personally think computer is the highest. Computer engineering, then chemical, then biochemical, and then mechanical. But I guess civil is just easier. A lot of girls, I mean people, but mostly girls transfer to civil after the weed-out courses and they just found them much easier.*

Both of these examples highlight the potential influence that difficulty has on participation, but Eva's experience shows that ranking fields based on ease can have particular impacts on women.

Notably, two women in the sample perceived deeper intentions in ranking majors based on difficulty. Brooke (a White woman physics stayer) told me, "probably most people think that their own major is the hardest. […] I guess you see what you're doing as challenging." Casey had similar thoughts:

*A lot of the people I actually talk to they think that whatever major they have, whatever they're doing, they think it's the best thing that there is. […] I know when they're talking about it, they're making an attempt to justify their own choices and say, "Oh yeah, choosing biomedical engineering is so much harder than anything else." […] Some people just really like to justify their choices by belittling other people.*

Ranking majors by difficulty seemed to have two faces. On one hand, participants theorized that perceived difficulty could be what discourages participation. On the other, participants believed that difficulty was the source of higher income and increased pride or sense of importance. What's common across these examples is that participants articulated a belief that mathematics-intensive science fields were more difficult than other fields.

**"If You're Interested in Math and Science, You Must be Smart": Ranking by Intelligence**

Perceived intelligence was another dimension that participants reported as a ranking mechanism. For some participants, believing that there are more smart people in mathematics-intensive science fields was a generally accepted idea. For instance, Alisha told me:

*If you're interested in math and science, you must be smart. I feel like that's the general idea. […] I feel like it takes a smart person to be interested in numbers and elements and chemicals. If you can-- that stuff is really boring. So if you can be interested in that and want to make a career out of it for a long time, you must be someone that has a lot of talent or something.*

For other participants, ranking by intelligence was the result of other previously discussed dimensions. Nessa explained:

*[E]ngineers, they think that they have the hardest major and they're better than-- I wouldn't say better in terms of like, personality-wise or anything of that nature, but more so better in terms of, "My major's harder than yours, so I have to do more than you. So, I'm smarter than you." That's how I would rank it.*

In this quote, we see that Nessa connects ranking majors by difficulty with ranking majors by intelligence. She tells us that some students believe that majoring in a "harder" major means that they are "smarter."

Related to social investments, Erick (an Asian man engineering to computer science swapper) believed that there is a practical need for highly intelligent people in mathematics-intensive science fields:

*It's good that you have only smart people doing these things like engineering. A lot of lives will be in their hands in engineering. Let's say they're designing anything from an airplane to a car tire, or anything. So it's good to have smart people in that field.*

Despite this noble connection between high social value and intelligence, there seemed to be a dark side to ranking mathematics-intensive majors above others based on intelligence. Alan discussed what he called "the engineering club." He defined the engineering club as an exclusive group of people inducted as a result of their major in engineering and general philosophical orientation to beliefs like the following:

*Engineering club is when you're an engineer, engineering is the greatest gift to mankind and everything else is a lesser study and should be looked down upon. And everybody, the professors, the professors literally make fun of main campus, at the engineering college. Like literally, it's like, they're like, "Oh, so you have three other courses, and two of them are main campus courses. Ok, you don't need to worry about those." Like* *literally, it’s everything but engineering if you’re in engineering club is a joke. And for stupid people.*

These examples show that ranking majors by intelligence could be perceived in both positive and negative lights by the participants. Furthermore, this dimension of ranking seemed to greatly disconnect students majoring in mathematics-intensive fields from other fields, in a more judgement-laden way.

References to each type of ranking mechanism—social value, income, difficulty, and intelligence—seem to suggest an interrelated logic on the part of participants. Namely, participants perceive a high social value for mathematics-intensive fields rewarded by higher incomes and/or more stable careers. From their perspective, the importance of these majors to society make them more difficult and requiring higher intelligence. Zachary provided a poignant historical reference that illustrates this point:

> *We've always taken pride in our scientists. You look in history textbooks and it talks about America during World War II, I think. And it talks about how America won because we had the better scientists. We were on the forefront of cutting technologies. We were working harder. We were smarter. And so there's always just this constant idea that the best among us are the scientists.*

Whether they perceived the idea from historical references, general conversation, direct communication, or their own logic, participants broadly believed that mathematics-intensive science or STEM fields were separate and special compared to other fields. This belief supported the perception that to participate in these fields, one must be talented and able to manage difficult or challenging work for the greater good of mankind or for the personal economic rewards.

### Perpetuating “The Cult of STEM”: The Role of Family, Teachers, and Peers

Family, teachers, and peers supported the perception that talent was required to participate in mathematics-intensive science fields. These significant others further communicated to participants that they possessed this special talent.

**Pre-College Messages about Talent from Authority Figures**

Participants grew up generally believing that they had special innate ability. This belief was developed through both family and teachers. “[F]or years,” Stuart (a White man physics to engineering swapper) told me, “I'd already been told by my family that I was pretty smart.” Similarly, Katerina (a White woman physics stayer) said, “I'd always been really, really good at academics, in the sense that I got good grades, and the teachers would compliment me, and so on and so forth.” Alisha explained that she had been told throughout her childhood about her giftedness:

> *My mom and my parents made it seem like I was this way from birth, “Oh you could walk really early. You could talk really early. You could read at three.” This was something that other people couldn't just acquire. You had to be born with it or something.*

Therefore, participants took their cues from authority figures about their perceived talent.

Beyond generally believing that they were smart, participants also built a belief that they were talented in math and science from family and teachers. Brooke, who was homeschooled for part of elementary school felt insecure about her math ability until she entered middle school:

> *[I]n seventh grade, the [algebra] teacher specifically called me out and was like, “You're really good at this stuff.” […] [T]hat kind of changed my perspective and made me a lot more confident in math. […] I realized I was good at math. It helped my confidence a lot and I wanted to keep that because it was something I could always fall back on, “Well, at least I'm good in algebra.” It sounds silly, but it was kind of important to have that in the back of your mind when you're struggling with other things.*

Although Brooke was initially interested in a music career, she decided to “fall back” on a career in physics after learning about the physics of sound in high school. Ian (a White man physics leaver) told me relatives noted his abilities when he was trying to select a college major: “when I was actually talking about what I would major in towards the end of high school, my parents said, ‘Oh, well, you're good at math. Why don't you do engineering?’”

Tien (an Asian woman engineering stayer) recognized the influence that authority figures had on students' math ability She told me:

> *Most teachers I think are in the business to help people, but then you get the bad ones who kind of like tell people they're just not good enough, or telling them like, "Oh, because your math is really weak or something." And people get really scared of math. Out of every topic I've talked about, people are very scared of math for some reason. And I think they shy away from practicing it, and so therefore they assume that with engineering it involves a lot of math, which it does. They shy away from it because their entire high school career they're being told how bad they are at math.*

It was clear from her account that she had heard or seen examples of peers feeling discouraged by their teachers. Zachary had a unique perspective on talent and STEM participation built by his family. He told me:

> *I always resisted math but I was always very good at it. It came naturally to me and my mother took a lot of pride in that. So she encouraged me to pursue math. […] I say I was raised within the cult of STEM. It's that my mother and my grandfather, everyone in my family has this belief that only STEM is what intelligent people do, and it's where you get jobs. They're the only people who get jobs after college, those people that went into STEM fields. […] So the cult of STEM I guess is really the phrasing of, I think, my family's mentality rather than society's mentality though it could be applied to society. And so part of that vanity is specifically my family's vanity towards our intelligence. We are a rather smart family and we take a lot of pride in that.*

Before college, authority figures in the form of family and teachers influenced participants' perceptions of the need for talent and their innate ability in STEM or mathematics-intensive science fields.

**Responses to Major Choice**

Another key moment in the development of perceived difficulty and talent in mathematics-intensive science fields was when participants declared their chosen major to others, especially peers. There was a near-universal report that others would comment on the difficulty of participants' majors and the perception that the major indicated that the participant was particularly intelligent. The exact phrasing of the responses were highly similar:

*[W]henever I tell people I'm a computer science major, they're like, "Wow dude you must be smart. This is really hard. I couldn't do that."* (Josiah)

*For the most part, if somebody would ask, I would tell them, and I'd usually get a response something along the lines of, "Oh, wow. That sounds so hard. You must be so smart."* (Katerina)

*They're always like, "Oh wow, you're really smart or something." Kind of like, "Oh, damn, that's too hard for me." That's their reaction.* (Miguel, a Latino man engineering stayer)

*They would say, "Wow, that's so cool. Wow, you're so smart," which I liked. I'm not going to lie.* (Meredith, a White woman physics leaver)

*A lot of the responses were just like, "Wow, that sounds so hard" or "How can you do that?" Like, "How can you be an engineering double-major, that doesn't make any sense." Like, "You must have no free time."* (Morrison)

More examples of responses to students' majors is shared in Table 6. Almost all of the responses reported by participants included some reference to a) the perceived difficulty of the field of study, and b) the perception that the participant was intelligent. The implication of these responses is that participants' major choice makes it seem as if the participant has innate ability.

The experience of being told that their intelligence made them well-suited for a specific major initially pleased participants (as Meredith alluded to above); however, upon further reflection it made many of them uncomfortable. For instance, I asked Brooke how it felt to be labelled smart as a result of her major:

*I: Yeah, how did that make you feel?*

*R: Just weird. I guess it's a compliment, but at the same time it's like-- you have no idea. You just met me, and your assumption is that I'm studying physics, therefore I am smart, like someone who is not? Whatever smart means? Someone who is not smart can't do it because it's physics? And it's like most people have this really wrong perception of what physics is, just because of the way the media portrays it. But it was just bizarre-- I don't know.*

Brooke's sentiment was common. Most participants heard these types of responses at the beginning of their college experience, when introducing themselves at programs such as orientation or during core curriculum courses. What may have initially been an internal, subconscious association between their field interest and ability levels in high school suddenly became a topic of explicit conversation when entering college.

This added an element of stress for participants who changed majors during college, further emphasizing the perceived relationship between innate ability and major choice. Alan initially majored in engineering, but decided to change his major to statistics partway through college. I asked what the responses to his major in engineering were compared to his major in statistics:

> *[T]he second you tell someone that you're in engineering, they automatically look at you differently, they think, you know [whispers] "Oh man, this kid's smart!" All that sort of stuff. And the fact that… The fact that I was going to be losing that kinda hurt. Cause now it's like, "Oh, statistics…"*

Similarly, Meredith started college as a physics major but eventually swapped to a physical sciences major:

> *R: I didn't tell people, at first, when I switched to physical science. I was a little bit embarrassed about it […].*
>
> *I: Yeah. Why were you embarrassed by it?*
>
> *R: Because I think I was so proud, and I told you I would get so happy when people were like, "You're so smart. You're doing astrophysics." And then I was switched to physical science, and I was like, "Gee, everyone was so happy for me, and I was so cool and smart. And now I'm just regular."*

Both Meredith's and Alan's quotes illustrate that they felt they were losing the label of smartness with their choice to leave majors like engineering and physics. Notably, both participants left these majors for other STEM fields (statistics and physical sciences), suggesting that engineering and physics may have specific associations with intelligence.

Participants also pointed out differences in responses to their major based on who was speaking. Some participants told me that the typical responses they received listed above ("Wow, you must be so smart!" "That major is so hard!") were generally from non-STEM majors. Participants would receive more nuanced responses from STEM majors. Take, for example, Tien's description of this experience when I asked her about responses to her major in industrial engineering:

> *It just depends on who you talk to. If you talk to the non-STEM majors, or even in some science, but not the crazy neuroscience or things like that, they would be like, "Oh, my God, that's awesome. You're an engineer," and all they hear is engineer. They don't necessary hear I'm a certain type of engineer, and that's most of the feedback I get from non-science, non-huge STEM majors. But when you tell other engineers, they're almost shocked, because as industrial engineers, a lot of people call us imagineers […]. The imagineers-- how they're just calling us that is because they're saying that we think that we're engineers but we're actually more business major and I know there's a connotation with that but-- and it makes some other people mad but to me, I don't care what they think.*

In Tien's case, the type of engineering that she studied mattered to perceptions of her ability by other engineering majors, but not to non-engineering majors. Notably, Meredith and Alan in the examples above changed their majors from physics and engineering, respectively, to technical fields, yet they still worried about the perception of their ability being diminished by the exact major that they selected.

From this data and others like it, I conclude that before college participants did not distinguish between fields in science and mathematics—they simply thought of them as requiring innate ability that the participant possessed. Upon entry to college, responses to their major choice generally reinforced this belief: that participants had selected a major that was difficult and indicated their innate ability. However, as participants interacted with others in their major, they began to see slight differences in how fields of study are regarded as more or less intelligent, some concluding that selecting a field outside of physics, engineering, or computer science was considered less valuable despite still being under the general umbrella of "STEM."

## "The Cream of the Crop": K-12 Tracking Practices

More than being told by others, participants believed that they had a special talent in STEM through being selected for advanced academic coursework, grades, and lack of need to study in high school.

### Separate and Unequal: Gifted/Honors/AP/IB Participation

Participants described being selected for gifted or honors programs as early as elementary school. This early recognition of intellectual ability was the first step in the track to AP/IB participation. Almost all of the participants described their experience in these types of courses as separating them from other students. For instance, Miguel told me:

> *When I came from Peru I had to take these tests to pretty much figure out where they're going to place me […]. I qualified for Gifted in third grade. So, I did third, fourth, and fifth Gifted classes, and that's where I met most of my friends. Then we all went to another middle school, and then we all just immediately qualified for the Honors Classes. That made a pretty big divide between us and the rest of the school. We were known as that group that's just always together, taking those classes. We would have - not to alienate but the group would be outside enjoying our classes. But it was mainly us that was in those classes.*

Brooke concurred with this experience, saying, "[C]lasses like science and reading those were entirely our class of gifted students so I was always with the same students growing up. For most of my education." Miguel's and Brooke's experience highlights separation that occurs via tracking as early as elementary school.

The students who were part of the gifted or honors programs in elementary and middle school became a part of AP or IB courses in high school. These programs only served to further separate students, and in these cases, participants described separation with racial and social class implications. For example, Katerina described her experience:

> *So they brought in the IB program so that the average grade of the school would be bumped up so they'd get better funding. At least that's what everyone always told me, is how that happened. So the rest of the school, the* traditionals *- we even called them* trads, *it sounds like a slur - they were predominantly Black, and then there were us, the nerdy*

*white and Asian kids. We were separate, we didn't even share the same lunch period or the same hall time, like between classes periods because our classes were different times. I'm sure there is some nasty race stuff tangled in up in there, but I really was socially oblivious as I had mentioned.*

As Katerina described, the separation between advance tracked and non-advance tracked students was so deep, a slur was developed. This slur identified not only the mainstream students, but primarily students of color.

Notably, students of color with the exception of Alisha did not speak with as much clarity about the racial divide in advanced track programs. Some participants attributed their lack of racial salience to attending diverse or minority-majority schools. For instance, Miguel grew up in a predominately Latino area, where "the people talk to you in Spanish [at school]. The professors were Hispanic mainly. My physics professor was straight-up White American so that was interesting." Similarly, Luis noted "Half the population of my school was Hispanic." Race did not become salient to Luis until college: "I think I realize now how little Hispanic people are in science, but that's not something I noticed when I was growing up, ever." Even when racial differences were pointed out to Gage before college, he did not feel it was important. He told me:

*My parents were way bigger into it than I was. I became a safety patrol […] so my mom and my nanna would always be like "Oh, he's the only Black safety patrol" or whatever and I just never thought it was a big deal. […] In college I would say, yes, it became a lot more relevant to me just because of the social climate in America right now. I never really cared about the race stuff, but then the whole Trayvon Martin thing happened.*

The exception to these examples was Alisha's account of race in advanced programs, although she similarly felt that she attended diverse schools:

*[E]veryone was minority [in high school]. I was taking physics class with a Middle Eastern girl, my best friend was a gay kid, and the other people in the class were a Hispanic boy and then a White girl, so that's, I think all of [them] are defined as minorities. I was the only Black girl in there and for one of my AP classes, it started out as four Black girls and I was the only Black girl left. At times like that, that's when it became aware to me, but I was always friends with everyone in the classes, so I didn't really feel left out or the outlier or anything like that.*

The difference in White and non-White accounts of high school diversity and advanced programs is puzzling. It's possible, as Gage pointed out, that recent mainstream discussions of race framed the responses. Potentially, when I asked them to remember high school in terms of their identity, White students became aware of and had to grapple with their privilege. In contrast, minority students described becoming more aware of racial differences in college, before I asked them questions about it. Therefore, perhaps they were more focused on providing personal accounts rather than an analysis of the overall situation.

For some participants, the divide between advanced track and mainstream students was physical. Morrison explained that his advanced track classes were on the same floor, whereas other courses were spread throughout the building. Students who had full schedules of advanced courses could conceivably completely miss other students in the high school. Stuart similarly told me that his high school was separated by floors: IB students on the top floor, mainstream students on the bottom floor. Notably, as Ian pointed out, not only does advanced track coursework separate people physically or socially, but their very existence implies some sort of value judgment. He called the gifted program a "so-called gifted program."

*I: Okay. Why do you call it the so-called gifted program?*

*R: It's just a silly name.*

*I: Okay. Why is it silly to you?*

*R: It just implies superiority or something like that, like you have a gift. It's silly.*

Although Ian mocked advanced track classes, for some participants this gift was precious. Maya described her excitement at being selected for the honors program in middle school, and then her disappointment with being moved back out of the program:

> *My grades were declining and they had to call my mom and when they told me, they were like, "We have to take you out of the honors science and honors—" I was crying. I was like, "Please don't do this to me." And my mom was just like, "It's okay, calm down. You*

*will be fine. We are just trying to help you." But I was like bawling my eyes out. [Begins crying]*

*I: Why did that hurt you so much?*

*R: Because I thought I was smart and then I realized I wasn't. It just felt like a kick in the stomach, like you lifted me up and just dropped me.*

Maya received the help she needed in the mainstream course, and eventually worked her way back to advanced track courses before high school graduation. Her response to being removed from the program, Ian's insight on the term "gifted," and the social and physical separation between advanced track and mainstream coursework are all evidence of the role of K-12 tracking in developing beliefs about the need for and possession of talent in STEM. Furthermore, this separation often took on a racial or social class tone in students' experience.

**Being the Best: Tracking, Studying, and High Grades**

Despite most students believing advanced coursework was more difficult than mainstream work, there were many references to not having to study while in high school. The ability to do well in advanced coursework without the need to study was a meaningful way that students built a belief that they had innate ability. For instance, Alisha told me "When I was in high school, I didn't really have to study that hard. I remember I wasn't the type of person to do homework at home. And I would still get good grades." Similarly, Katerina said, "for the most part, high school work was little enough in volume and easy enough that I didn't really need to spend a lot of time externally." Specifically related to tracking, Gage related:

*I was one of those kids who never studied. I was always with the smart crowd. People kind of looked at us like, "Oh, those AVID[13] kids, those are the smart kids." I was doing well in my classes with minimal studying. I was doing really well-- really well in science. I guess I didn't really think over the math part too much. But, I guess, coming out of high*

[13] AVID stands for Advancement Via Individual Determination. This college prep program generally selects students with average standardized test scores. However, students in Gage's high school perceived their AVID program as an advanced placement program for "smart" kids.

*school, I thought I was way smarter than I actually was. So that's why I was like, "Oh, I can do this [laughter]. No problem."*

In this quote, Gage alludes to his attitude leaving high school. Many participants contrasted their experience studying in high school versus college. Casey said "It's been a learning experience for me being in college, because it's very different from what I was in before, where I didn't really have to study that much." Meredith's quote echoes Casey's:

*I was not studying too much [in high school]. I mean, I was a nerd, but you didn't have to study too much. You know what I mean? The difference between studying in high school and college was absurd. I was thinking I was studying, and I was looking at it and reading the textbook. And then, I wasn't making flashcards, and I wasn't outlining. I guess when you're a high schooler, that counts as studying. So I was studying. I just wasn't doing effective studying is a better way to put it.*

Participants described building a belief that they had innate ability through being selected for advanced coursework and not having to study for those courses or others. The reason that participants did not feel a larger incentive to study was because they were satisfied with their grades.

Earning good grades along with being selected for advanced coursework and not having to study supported students' perceptions of their innate ability. Alisha connected being chosen for advanced coursework and earning high grades in her interview:

*[…] so when you're in your gifted classes-- everyone had been told the same thing, our teachers would tell us we were the cream of the crop for the school, so we would just-- we were competitive amongst each other, because we already knew we were at the best, so now it's like, okay, who's smarter than who? […] So when we got to high school, everyone was like, "Oh, what number are you?" and I'm like, "What are you talking about, I have a number?" And they're like, "Yeah, on your report card or whatever, or your transcript it's supposed to say your rank." […] from that moment I learned about it, that was always looming over my head. I'm like, "I have to get good grades or so-and-so is going to be in front of me."*

For Katerina, her value towards good grades started with her family. "My parents always really pushed me to succeed," she told me. She continued:

> *And academics were like the only thing I was good at. I'm not a sporty person, I'm not a musical person, I'm not an artsy person, but I have been very good at taking tests and things like that all of my life. So I guess I eventually grew to base a lot of my perception of my own self-worth on how well I continued to maintain this good at tests thing.*

Katerina continued to struggle with defining her self-worth based on her grades throughout college. Similar to Katerina, Zachary also built an identity around academics supported by his admission to advanced coursework, value towards grades, and little need to study. He told me that in high school he believed that he was going to college to "be the best in the field [physics]" by "graduat[ing] with a 4.0 in physics, and […] go[ing] on and get[ting] a graduate degree in physics, and then […] go[ing] and be[ing] a physicist." Notably, Zachary made these plans before he understood what the work may be like. While he did well in his college physics courses, he realized he wasn't that interested in the topic. He simply believed he was supposed to achieve at this highest level in high school. He changed his major to a social science field after his second year in college.

Twenty-two of the 24 participants in this study reported being selected for gifted/honors tracks in elementary and middle school and/or AP/IB programs in high school. Two students were admitted to STEM-focused magnet programs. These programs—along with earning high grades and not feeling pressured to study for those grades—contributed to participants' beliefs that they were innately talented in mathematics and science courses.

**"This Isn't An Easy Major": College Weed-Out Cultures**

When students left high school, a final aspect of the educational experience further supported the belief that talent was necessary for success in STEM fields: weed-out cultures. The very first participant I interviewed mentioned weed-out courses, prompting me to ask about them during every interview unless the participant naturally brought the courses up. In their responses and throughout their interviews, participants discussed both weed-out courses and a general weed-out culture in their fields of study. Like discussions of difficult courses, participants had variable responses to my question about *which* courses were considered weed-out courses. However, almost all of them felt you could define a weed-out course. Some participants defined weed-out courses literally. For instance, Erick defined the course as those “designed to, honestly, be harder than they should be, so they *weed out* the people that don't really want to do the major.” Other participants defined the courses based on the percentage of students who changed majors during or after the course:

> *A weed-out class is a class that, by the end of the course, 50% of the people will change their major.* (Alan)
>
> *[W]hen I started taking the classes, I quickly realized that the professors kind of set them so that there was roughly a 50-60% pass rate for the classes, which made them really difficult and unnecessarily so.* (Casey)
>
> *I don't know. I mean, I didn't like it. It always upset me because I knew that they were just going to be super jerks about things, like completely go out of their way to make it so 20, 30% of the class isn't doing so hot.* (Meredith)
>
> *I've heard from a C[omputer] S[cience] adviser that told me, well, actually it was as CS faculty member told me that 33%, like a third of the class fails every semester out of this guy's class. That's just how hard it is.* (Josiah)
>
> *Weeding out the people, making sure that you're skimming the cream of the crop. You're only letting through the people who really have the drive to be a physics major, the people who are willing to put in the effort, people who are willing to dedicate their time to these assignments. Because, yeah, it happens. Our initial crop of physics majors was easily about a third as many as are now. Maybe more.* (Katerina)

Based on the data, participants perceived any course that resulted in a loss of one-third to one-half of the students who majored in their field of study as a weed-out course. They also described the courses as extremely (and sometimes overly) challenging. Some participants reported being told about weed-out courses by their faculty, and others said that it was just something they heard about from other students.

As alluded in the examples above, participants felt that these courses were intentionally developed by faculty or departments as some form of culling. For instance, Meredith told me, "I think that also universities set certain standards for how many students pass a course," and Haleigh (a White physics leaver) said that a weed-out course is one "that professors design to be very difficult, and only for students who are incredibly dedicated to the subject matter." From Gage's perspective, "the school or the college or whatever that would let these kids in don't want to waste their time. They want to kind of whittle it down to the best, so to do that pretty early on, they make the barrier of entry pretty tough." According to participants, weed-out courses serve multiple functions, including: reducing the faculty-to-student ratio in upper-level courses, protecting the investment of departments and colleges, identifying students willing to work extremely hard, forewarning students of the impending difficulty of upper-level courses, helping students recognize if they do not like the field of study, protecting the field of study from incapable practitioners, and to some, acting as a form of retribution or payback for faculty's own experience in difficult courses.

My discussion with Eva about weed-out courses illustrates most of these points:

*R: This is just a theory a lot of people have said, but it's because back in their day, it was so much harder to major in engineering, and I feel like they want the same to us, because now there's so many other resources we can use and you can do everything with a computer and stuff like that.*

*I: So they want it to be harder for you?*

*R: I feel like they do. […] they want to challenge you and if you can't handle that challenge, if you can't handle their standards, they don't want you in here. I think that's what it is.*

*I: Why do you think that's important to them, that you succeed past the challenges?*

*R: They just don't want to raise bad engineers. They don't want someone who isn't supposed to be an engineer to get a degree, while 30 years ago they got the same degree. It's not fair. That's what I think.*

*I: I was going to ask you what you think about weed-out courses and their function.*

*R: I think it's important to scare everyone, like jolt them awake. Like a wake-up call because this isn't an easy major. Same with medical school. I feel like they do that too. Because it's important to be a good doctor, same with being a good engineer. You're kind of like you're holding people's lives in your hands.*

Notably, despite the consistent reference to weed-out courses, musings on their purpose, and suggestion that faculty, departments, or colleges conspire to intentionally fail a certain percentage of students in some courses, there is no explicit policy to weed-out students from mathematics-intensive majors at this institution.

Beyond actual coursework, participants reported an overarching weed-out culture in physics, engineering, and computer science. This culture is expressed through implications that mathematics-intensive majors do not have any free time, feel a lot of pressure to work constantly, and that these characteristics are only chosen or managed by a select group of students. This oppressive atmosphere is communicated through a number of signals. Nessa described seeing a cartoon posted in the engineering library: “Simba asks Mufasa, ‘When are we going to have any playtime?’ and Mufasa says, ‘We're engineers. We don't do playtime.’” Multiple participants described faculty explicitly telling them that students would not have much free-time or sometimes the ability to enjoy holidays because of their work. Katerina described how she developed the belief that to be successful in physics, students had to be “chained to their desks”:

*I don't know that it would be communicated specifically, directly, that somebody meant to tell us that, but you see the people in the years above you, and they're working hard and pressing their heads against their desks and saying, “Oh, I never sleep.” Things like that. And that's just kind of the culture that you grow to expect. It's kind of this self-perpetuating sort of behavior, I guess.*

Sean (a Black man engineering swapper) directly imparts his impressions of the engineering workload to high schoolers that he mentors through a special program. This is what he reported saying to the students:

> *Like I said, there will be good and bad. You will reap all kinds of benefits. People will tell you "Not all super heroes wear capes." Girls might be more inclined to talk to you just because of your major or whatever. And it's cool to have. It's like a little license in the back of my pocket. Just, "Here you go." But at the same time, you're going to work for every second of it. And it's not a joke, it's not funny, it's not cute. I would tell an incoming engineering student, "Expect a lot of three straight days, two straight days, three straight days of hating your professors and not really knowing why, just because of the work load and things like that. Just expect a lot of mental and physical fatigue. Just expect it to get real. This is not a fairy tale deal. You're not just going to skate by."*

In this quote, Sean tries to recruit high school students by describing the type of social admiration that he perceives as an engineering major. However, he tries to inform them that there is a cost by way of the difficulty and weed-out culture of the field. Students are aware of and communicate to others that there is a weed-out atmosphere in college.

College weed-out cultures served to implicitly and explicitly exclude students from mathematics-intensive majors through perceived high fail rates and heavy workloads. The weed-out culture was communicated through the loss of students through introductory major courses, conversation between students, and a general atmosphere cultivated by both students and faculty. All together, these messages communicated that even after earning a place in a mathematics-intensive major through high school academic success, these fields of study are still exclusive spaces for only the most talented.

**Summary**

The qualitative study was designed to provide insight to the quantitative findings shared in Chapter 4 and explore research questions developed through the literature review shown in Chapter 2. This chapter of qualitative findings specifically described perceptions of difficulty and talent in STEM and mathematics-intensive science fields. Participants discussed several influences in the development of these beliefs.

First, they described informal methods of ranking majors or career fields against one another. Mathematics-intensive science fields were considered more socially relevant, economically stable, difficult, and filled with intelligent people than other fields. Ranking mathematics-intensive majors above others on these dimensions emphasized the importance of being talented to participate in these fields.

Second, teachers, family, and peers continued to reinforce the belief that talent is necessary to participate in mathematics-intensive science fields and that participants had the necessary talent to overcome the challenges in those fields. They communicated these ideas directly through encouragement. Participants also implied these ideas based on the reactions of others when they shared that they were majoring in a CEP field.

Third, K-12 tracking practices into advanced coursework, lack of need to study, and high-grade expectations further developed participants' perceptions. Because participants were selected for advanced coursework, they perceived themselves as separate and special compared to the wider population of their high schools. Earning high grades without studying further reinforced their belief that they had some special talent.

Last, when participants entered college they were confronted with a weed-out culture that continued to suggest that mathematics-intensive fields are exclusive spaces fit for only the most talented. These cultures were communicated directly or implied. Weed-out courses were the most obvious symbol of weed-out cultures.

In the next chapter, I describe how these established beliefs are shaped. The college experience and reflections on identity were the two main factors discussed by participants as shaping their beliefs. Finally, I will describe participants' reports of how difficulty and talent beliefs impacted them emotionally and educationally.

Table 5. Qualitative Participants

| Person | Gender | Race and Ethnicity | Qualifying Major | Persistence | Current Major |
|---|---|---|---|---|---|
| Alan | Man | White | Engineering | Leaver | Statistics |
| Alisha | Woman | Black | Engineering | Stayer | Biomedical Engineering |
| Antonio | Man | White and Latino | Computer Science | Stayer | Computer Science |
| Brooke | Woman | White | Physics | Stayer | Physics |
| Casey | Woman | White | Engineering | Stayer | Biomedical Engineering and Biology |
| Emil | Man | Black | Computer Science | Leaver | Information Technology |
| Erick | Man | Asian | Engineering | Swapper | Computer Criminology |
| Eva | Woman | White | Engineering | Swapper | Mechanical Engineering |
| Gage | Man | Black | Engineering | Leaver | Information Technology |
| Haleigh | Agender | White | Physics | Leaver | not enrolled at university |
| Ian | Man | White | Physics | Leaver | Mathematics |
| Josiah | Man | White | Computer Science | Stayer | Computer Science |
| Katerina | Woman | White | Physics | Stayer | Physics & Computational Science |
| Luis | Man | Latino | Physics | Stayer | Physics |
| Maya | Woman | Black | Computer Science | Stayer | Computer Science |
| Meredith | Woman | White | Physics | Leaver | Physical Science |
| Mia | Woman | Black | Computer Science | Stayer | Computer Science |
| Miguel | Man | Latino | Engineering | Swapper | Electrical Engineering |
| Morrison | Man | White | Engineering | Leaver | Biochemistry |
| Nessa | Woman | Black | Engineering | Stayer | Chemical Engineering |
| Sean | Man | Black | Engineering | Swapper | Industrial & Manufacturing Engineering |
| Stuart | Man | White | Engineering | Swapper | Environmental Engineering |
| Tien | Woman | Asian | Engineering | Stayer | Industrial & Manufacturing Engineering |
| Zachary | Man | White | Physics | Leaver | Classical Archeology |

Table 6. Reported Responses to Mathematics-Intensive Science Majors

| | |
|---|---|
| *Paraphrased Question: What did people say when you told them you were majoring in physics / engineering / computer science?* | |
| Alan | [T]he second you tell someone that you're an engineering, they automatically look at you differently, they think, you know [whispers] "Oh man, this kid's smart!" |
| Brooke | [T]hat physics is really hard. You know even people that don't know me, if you say that you're majoring in physics people will-- and there are often times I've got this response, "Wow, you must be really smart." And it's like, you know nothing else about me except that I'm majoring in physics and your response is "You must be really smart". |
| Casey | People always like, "Oh my gosh, its so hard. I don't know how you do it." |
| Gage | They were very impressed. They were like, "Oh my God, you're so smart. That sounds so hard, this and that." It felt good to hear that kind of stuff. |
| Ian | Well, the average person says, "Oh, wow, you must be so smart," or something like that. That's about it [laughter]. I mean, that's the average response. |
| Josiah | [W]henever I tell people I'm a computer science major, they're like, "Wow dude you must be smart. This is really hard. I couldn't do that." |
| Katerina | For the most part, if somebody would ask, I would tell them, and I'd usually get a response something along the lines of, "Oh, wow. That sounds so hard. You must be so smart." |
| Luis | [E]ven right now, if I tell a family member that I do-- that I'm a physics major, they're like "Woah," it's like, "that's really hard stuff." […] Kind of like, "Whoa, that's really hard." And obviously, since it's something really hard and it's really math related, you have to be really smart. |
| Miguel | They're always like, "Oh wow, you're really smart or something." Kind of like, "Oh, damn, that's too hard for me." That's their reaction. |
| Meredith | They would say, "Wow, that's so cool. Wow, you're so smart," which I liked. I'm not going to lie. |

Table 6 - continued

| | |
|---|---|
| Morrison | A lot of the responses were just like, "Wow, that sounds so hard" or "How can you do that?" Like, "How can you be an engineering double major, that doesn't make any sense." Like, "You must have no free time," like…That was pretty much about it. |

| | |
|---|---|
| Sean | [T]hey'd be like, you know, this little dude he's so smart. He'll be the one to do it. That's really cool. |
| Stuart | Well, obviously, you must be really smart [laughter]. |
| Tien | They're like, "Oh, my God. That's so hard," like, "Oh, my God. You must be so smart [chuckles]." I get that a lot. |

*Note*. *n* = 14 of 24 participants who provided direct quotes heard in response to the question "What did people say when you told them you were majoring in physics / engineering / computer science?" Data gathered during 2-hour interviews with each participant.

# CHAPTER 6

# CHANGES IN BELIEFS AND BEHAVIORS

## Introduction

The previous chapter illustrated the manner in which social ranking, communication from teachers, family, and peers, pre-college tracking, and weed-out culture established a two-sided belief. On one side, participants believed that talent was necessary to participate in mathematics-intensive science fields. These fields were also considered particularly difficulty or challenging. On the other side, participants also developed a belief that they had a special, innate ability. They believed that they were immune to or could overcome the difficulty or challenge in mathematics-intensive science fields.

In this chapter, I describe how these beliefs are shaped, first by the college experience and then through reflections on identity that primarily occurred during college. Participants reported struggling in their coursework, meeting other students who were talented within and outside of mathematics-intensive science fields, and being discouraged or supported by faculty. Some participants also reflected on their identities during college. Namely, gender, race/ethnicity, immigrant background, socio-economic status, and disability emerged as relevant to difficulty and talent beliefs. By the end of college, participants' ability beliefs—established and shaped by the college experience—had both emotional and educational outcomes. I describe these outcomes at the end of this chapter.

## The Role of the College Experience

In general, participants entered college believing that students in mathematics-intensive science fields must have innate ability to be successful in those fields. Further, they believed that they possessed this innate ability. Once they entered college, the participants had experiences that shaped these two basic beliefs. First, most participants found mathematics-intensive science courses more difficult than high school math and science courses. Second, participants met others in college who were more successful or talented, both in and out of mathematics-intensive science majors. Last, faculty discouraged or supported students' difficulty and talent beliefs.

**"Actually Having to Try": Experiencing Difficult College Coursework**

Participants generally believed that they were talented high schoolers in science and mathematics as a result of being told by their family and teachers, being selected for advanced coursework, earning high grades, and never needing to study (see Chapter 5). However, upon entry to college most participants experienced difficult coursework that prompted a shift in their perceived ability. This experience was surprising for most students. Alan (a White man engineering leaver) gave this part of his college experience its own title: "the brick wall of engineering." This is what he told me about his first year in college:

> *R: Not even, not even not understanding it at first, but actually having to try. That was… That was a big shock to me. […] Yeah, I thought I was just going to walk in, grab the golden goose and walk out, you know? […] Didn't think it would be difficult.*
>
> *I: So tell me about that first time that you experienced that, that you realized that this was different?*
>
> *R: Um, probably the first time that I took a circuits exam. I took it and I hadn't studied, never studied before in my life. Never studied for anything. Took it, you know, I'm like, Oooh, this isn't that bad. And I get it back and it was a 36 [out of 100 points]. Then that was the end of the year for me, and after that I was like, "You know what? It really was my fault. I'm going to try my hardest, I'm going to work really hard." I went into it that second semester after failing all these courses and I. Worked. Hard. And I still failed.*

As illustrated in this example, participants often defined the most difficult courses as those that required them to study for the first time in their lives. There were no specific courses that participants continually referenced, suggesting that any course could induce this experience of having to "really study" for the first time. Since many participants did not study frequently in high school, this was a transition they neither expected nor had resources to address.

For some, experiencing difficult coursework did not occur upon college entry, but after getting into their major coursework. Katerina's (a White woman physics stayer) experience is helpful to explain:

> *So I definitely, as soon as we got past my first semester in super easy physics classes and things started getting more difficult, I definitely had at least one panic attack per semester. You know, "Is this really what I want to do? I'm no good at this; how can I do this? Look at how my class mates they seem to be doing this effortlessly. How are they doing it? Do they have something I don't have?"*

Even occurring after the adjustment to college, experiencing difficult courses made participants like Katerina question their fit in the major. This questioning resulted from both their own performance and evaluating others' apparent comfort levels in class.

Despite the timing of encountering challenging classes, they often caused students to question their choice of a mathematics-intensive science major. Miguel (a Latino man engineering swapper) described his doubt in specializing in computer engineering when having a difficult time in those courses: "Man, I can't even pass the Intro to Programming, and my job is going to be based on programming." Whereas Miguel's experience with difficult courses contributed to his decision to change his specialization, Josiah (a White man computer science stayer) took a different lesson away from the experience. Through difficult coursework that required more than simply reading lecture notes or seeking help from instructors, he came to believe that innate ability is not required for his field of study:

> *And a lot of people in the real world, this is how it works. Like, professionals don't know the answer all the time. There are times when they don't know, they Google it, too, and see what someone else did and how they did it. [E]ven my professor, it was in programming II, he was like "you know, professionals still occasionally have to go to the books, still occasionally have to Google stuff - they don't know it all. This is a good [skill]-- they do it, and you should do it too to learn.*

Participants entered college with high expectations of their ability that they questioned when encountering challenging coursework. The result of this questioning led participants to believe either that they simply did not have a talent they needed, or that this talent wasn't truly required in the first place.

**"Everyone Here is Smart": Meeting Talented Peers**

The college experience also served to expose students to a wide range of others who were talented. For Alisha (a Black woman engineering stayer), this was a point of motivation, "[When] I came to college I was like, 'Okay everyone here is smart. That's how they got in. So you can't just do whatever you want and expect to get good results.'" Alisha recognized that although she was top of her class in high school, she entered a different pool of peers when she arrived at college. This observation served to motivate her to work harder and to adjust her expectations. Antonio (a White Latino man computer science stayer) compared himself to peers from different institutions.

> *I: Whenever you encountered those challenges [in college], what did it make you think?*
>
> *R: [A]re students at other colleges, in the same field, facing the same problems as I am in this field? [O]ne of my bosses right now at my job, he actually went to a different college than I am for the computer science field. And his wasn't as advanced as [the institution of interest's] is. So even though he knows the material, he had to do a lot on his own. He wasn't actually taught that.*
>
> *I: How did that make you-- hearing that from your boss, how did that make you feel about your course work?*
>
> *R: Partially relieved and partially scared. Because I attribute it to the fact that these courses are ridiculously difficult, but they also attribute it to the fact that I am learning what I should be learning. It's just I might not actually be learning the best way I can be, if that makes sense.*

For Alisha and Antonio, meeting others in their field of study helped put their struggle in context. Alisha felt that she was among similarly talented peers, and that she would need to work harder. Antonio realized that he may not be experiencing difficult work because he was unable, but because of different expectations.

Attending a large, public institution also allowed participants to meet others in a variety of majors. For instance, Erick (an Asian man engineering swapper) told me:

> *[T]he further I went into my major, the further my friends went into their major, and I was able to look at their coursework and they looked at mine. And things that were easy for them were not easy for me because they've been learning it for however long they've been in the course. And same went for me. So, there is no hierarchy of who is the smartest and whatnot. It's just only because you've studied that much longer that makes you smart in that, and that's it.*

Similarly, Miguel met friends through his girlfriend. He said that when he heard what they majored in, he thought "[I]f somebody tells me like, 'I'm a pre-law student.' And that's a lot of reading, a lot of writing, that's something I could never do. So I admire that too." Multiple participants shared similar stories of meeting people in different fields of study and realizing that they would not want to major in those fields or had low perceived innate ability in those fields. Meeting students in other majors helped them appreciate either a) that there are domain-specific abilities or b) that ability is not innate, but instead the result of practice, socialization, or interest. These experiences, therefore, started to refute the idea built before and during early college experiences that there is a deep connection between studying science and mathematics and having talent or being smart.

**"Do I Really Have What it Takes?" Faculty Discouragement and Faculty Support**

Many of the participants reported that faculty were either discouraging or supportive during students' college experiences, building up or dismantling beliefs around talent, difficulty, and challenge in STEM or mathematics-intensive science fields. Faculty could encourage the perception that science required innate ability in the way that they lectured and handled student questions. For instance, Alan (a White man engineering leaver) told me about how professors worked with students who had questions:

> *[T]hey get mad at you when you don't know stuff as quickly as they do and all that sort of stuff. They're not really willing to teach people if they're not picking it up as quickly as*

*they should be. […] And if you didn't reach that, it was your fault. Not anyone else's. Even if like… I had multiple times where couple subjects, I'd be like, "Wham bam, I got this immediately." And then there'd be one thing, "I just don't understand it. I don't understand it." And they didn't care. I'd talk to them, and they'd say, "Oh it's this." And "Oh, leave now." […] Yeah, they didn't really tolerate any sort of… failure to learn, I guess?*

For Alan and some of the participants I spoke with, their interactions with faculty could be negative and centered on professors' impatience and dismissiveness. The more impatience faculty showed toward students' learning process, the more students got the message that they should not be struggling in the coursework, suggesting to them that the topic required some level of innate ability that the student did not have.

Faculty could imply this one-on-one as described by Alan or in large groups. Meredith (a White woman physics leaver) described one of her professor's[14] strategies for eliciting questions:

*We were in a huge lecture hall, and he would always ask rhetorical questions. And no one's going to raise their hand in a lecture hall of 200 to answer a question that you didn't even really ask the class. You kind of just were like, "Does anybody know what this section of the [inaudible] blah, blah, blah?" And then nobody would answer in three seconds, and he would be like, "Oh, nobody? Well, why are you guys even in this class? Maybe I should just fail you all." And that was something he would actually say. So it was upsetting. So I just stopped going to class, and I just taught myself from the book.*

Meredith's example is in striking contrast to Mia's (a Black woman computer science stayer) experience:

*[B]efore she moves on, she's like, "Does anyone have any questions?" And then, even if no one asks questions, then she tries to say it another way, "Does anyone feel okay with the subject, or are you guys just bored?" So, a lot of times they'll just come ask you, "Does anyone have questions?" but no one will raise their hand because they don't want to feel stupid around the people that are in the class. So that's probably why I just-- that's how I feel sometimes. Even when she asks, "Does anyone have questions?" I'm like-- even though I have like a thousand questions [laughter], I'm like, "I'll meet you privately," because I don't want people to think I'm stupid [laughter].*

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[14] Unfortunately, I did not systematically gather data on the identities of faculty that participants referenced, so I cannot make inferences about the role of faculty identities on their approach to difficulty and talent in mathematics-intensive science fields. Where participants identified faculty members' rank or gender, I make note of this in the narrative. No participant discussed faculty's racial/ethnic identities. Some participants freely referred to faculty by name (redacted for privacy), but others intentionally chose to withhold names when they related their experiences.

Both Mia and Meredith point out why students may not want to answer their professors' request for questions: it's intimidating to ask a question that reveals a lack of understanding in front of others. In Meredith's example, the professor takes the silence to mean that students are not listening, and threatens to give the students a failing grade without regard to their actual performance on assessments. In contrast, the professor in Mia's example responds to the silence by asking different questions. Mia feels comfortable enough to ask this professor to meet in private, whereas Meredith's response to her professor's behavior in class is to no longer attend class. For Mia, her professor's patience sends the message that the material is difficult, questions are expected, and the professor is willing to be engaged in that process. For Meredith, the professor also acknowledges that the material should elicit questions, but instead of engaging those potential questions he signals his unwillingness to help.

Some professors spoke more directly about the difficulty in their field of study. Alisha described hearing from an advisor at orientation about the challenging nature of engineering:

> *[H]e basically said, "You're going to be at this for a long time, and you're-- everyone else is going to the party and you guys are going to be inside, studying. That's what engineers do." So, I felt like a lot of people were definitely scared. Of course we were all determined at the time, but I feel like his words definitely affected [inaudible]. I feel like people definitely started second-guessing, "Can I really do this? Do I even really understand what engineering is about? If an adult who's advising people in engineering is saying 'this is really hard,' do I really have what it takes to be in this major?"*

The individual in Alisha's story was not a professor, but as the first staff person they met in their major, he had a lot of influence on how the engineering students framed their experience. Alisha's story about directly discussing difficulty contrasts with Nessa's (a Black woman engineering stayer). She told me about a professor who shared his failures in class: "And so because he shared his failures, and you see how great he's doing, then it gives you permission to fail as well, somewhat, and not make you feel like, 'Okay, it's not the end of the world.'" For both women, the faculty or staff speaking framed their experience in the major. However, Nessa's professor was more intentional about controlling the message, and directing students to hear his experiences as "permission to fail" and learn from their mistakes.

Multiple participants described being individually mentored by faculty in their field. These mentoring relationships further shaped their perceptions of difficulty and talent in scientific fields. For instance, Ian (a White man physics leaver) works in the same space as an emeritus professor and has received advice from her about taking the difficulties in stride and trying not to focus on feeling bad when not doing well academically.

Similarly, Brooke (a White woman physics stayer) met a researcher at a national lab who completely changed her perspective on ability in physics. She described her experience:

> *[T]he scientist I was working with, he never liked math, and he'd never been good at it. I was just like, "Wow, this guy's a successful scientist, he has a PhD working with national labs, he has top security clearance and he's doing stuff I'm not even allowed to know about, and he doesn't like math." I guess that was the first big shock. And then I was like, "Huh, maybe math is important for getting through college, but once you're through--he's really good at what he's doing, but obviously you need to be good at math, but you don't necessarily need to be great at it."*

Prior to this experience, Brooke worried about her math ability and how it may limit her success as a physics student.

Sean (a Black man engineering swapper) was lucky to have two mentors in college—a man research supervisor who did not "cut [him] any slack" and a woman faculty member. The woman faculty member called Sean out on his misunderstanding of physics.

> *And so from then on out, she would sit me down in her office and teach me the fundamentals, and then in class I would see it again on a more advanced level, just to make sure I got it. And she talked about my social life a lot, and things I was doing, and just told me, "You have to study. You have to get your head on straight. You can't—" […] Like I said, I just realized that, again, like Dr. [redacted] was right. No matter how smart you are or how fast your mind works, or how fast you can piece things together, if you don't put in the work, you're not going to be successful.*

Both Sean and Brooke were mentored by more experienced faculty who spoke with them directly and honestly about the nature of ability in their fields of study. Both participants took away from these interactions that ability is not innate, and that working hard was expected and practiced by faculty in their field.

## The Role of Identity

At the beginning of this study, I endeavored to not only understand how college shaped perceptions of difficulty and talent in STEM and mathematics-intensive science fields, but also lay bare the role of gender and race/ethnicity identities in this process. In addition to race/ethnicity and gender, three other identities emerged from the data as meaningful: socio-economic status, immigrant experiences, and disability. For most participants, these identities did not become salient in relation to their major choice until they were thinking about attending college or in college. In this section, I first discuss gender and race/ethnicity identities, and then turn my attention to the other identities that participants described.

### "Guys Don't Have to Do That": Gender and Ability Beliefs

Just under half of the participants identified as women and one participant identified as agender[15]. These participants openly discussed their gender identities in relation to perceptions of difficulty and talent in STEM. For one participant, Eva (a White woman physics to engineering swapper), gender discrimination in college was overt and related to appearing intelligent. She told me:

> *Just people don't listen to my ideas sometimes, and I can tell it's not because they're not intelligent. It's not like they're unintelligent ideas or anything like that, it's just kind of like I can feel me being discriminated. […] I just feel like I'm never encouraged to speak my mind. I always have to plan ahead. I always have to say it in my head first and see if it's plausible, like does it improve? What does it do? And I feel like guys don't have to do that. I feel like they're so encouraged to speak, they're open, and even if they ask dumb questions, they're not chastised for it. But I feel like if I ask a question just because it*

[15] Haleigh (a White physics leaver) identifies as agender. Gender neutral pronouns they/their/them are used when referring to them. The use of they/their/them as a singular pronoun for transgender individuals has been widely embraced in academia and was recently added to the Associated Press' 2017 Stylebook (Easton, 2017). Furthermore, "Haleigh" (a traditionally feminine name) was chosen as their pseudonym as it reflects the feminine nature of their name.

*literally just popped into my head, I'm going to be—[…] what's the word called like they're going to focus on it more, or something like that. So I just always feel this constant pressure to always sound like I'm not stupid.*

Because Eva does not notice similar dismissive behavior toward men in her classes, she has concluded that she must police her interactions to avoid appearing "stupid." She implies that as a woman, it is automatically assumed that she has less to contribute and that she is less competent. Notably, Eva linked her struggle with these perceptions to developing anxiety that she was working through with a counselor.

Perceived gender also matters to how students are regarded in relation to their ability. Haleigh (a White physics leaver) identifies as agender but is perceived female. When I asked them a common response they heard when they shared that they were majoring in physics with others, they responded "With shock because I'm this tiny, little girl who works at a sandwich shop, and they didn't expect me to be majoring in something so brainy." Although they don't identify along the gender binary, Haleigh is perceived female and thus relegated to a category with stereotypes about their ability.[16]

Alisha theorized that girls were less interested in mathematics-intensive science fields than boys due to the fields' perceived difficulty. In addition to citing the lack of representation of women in engineering, she told me:

*I feel like everyone knows engineering is a really tough major as far as how much you have to know. […] I think maybe girls feel like guys will be intimidated by them if they have a major like that. Maybe girls just don't feel like they could do it because it's so intensive and so labor intensive with math, and physics, and chemistry, or if you're in chemical engineering.*

In this quote, Alisha mentioned girls' perceived ability as well as their potential fear that majoring in a perceived difficult field like engineering would "intimidate" boys, presumably

[16] See also Nicolazzo (2017) for an interesting discussion of how trans people are read along the gender binary based on the perceiver's own bias.

because heterosexual girls are romantically interested in boys. Eva, too, urged me to look into romantic relationships when I asked her about other important aspects of majoring in a mathematics-intensive science fields. A male respondent, Sean, also mentioned dating in relation to major choice. Therefore, simply being a woman had consequences for ability perceptions in STEM fields, as well as the potential role of the women as romantic partners.

There were only five women of color in this study, and only one referenced how her gender identity intersected with her racial identity. Alisha shared how her identity as a Black woman became more salient in college and related to her academic success:

> *R: Being a Black woman over there [in high school] it didn't really, it didn't really bother me […] everyone was minority there. […] I didn't really feel left out or the outlier or anything like that.*
>
> *I: Sure. It's cool that you went to such a diverse school. What about in college? Were there any experiences there you would like to share with me?*
>
> *R: You mean, what it was like being a black woman?*
>
> *I: Mm-hmm.*
>
> *R: Oh, here it is definitely more apparent even though we share the college with [a historically Black university] it's still not a lot of Black girls. I'm usually the only one most of the time. […] Yeah, and I don't know if I tend to gravitate towards other Black females, but usually when I do, that's when I do better in the class. […] But classes where I'm by myself and I can't find anyone else to relate to-- I don't know is just in college is really more apparent that like, "Oh, you're the only one in class."*

For Alisha, connecting with others like her helped her achieve higher scores in her courses. Yet, as Alisha pointed out there were also negative aspects: she felt that Black women were particularly underrepresented in college.

Alisha even described hearing a Black woman engineering faculty member describing her educational experience:

> *She was saying when she was in engineering in [redacted] a lot of people didn't want to work with her because she was a girl. Like, when they had to do group projects no one would ask her to join the group because she was a girl. She was also a Black person. I*

*ended up working for her, and I feel like she wanted to say "also because I was Black," but I think she would've got in trouble if she said that.*

Especially for Alisha and the White women I quoted in this section, gender played a role in perceived intelligence or interest in overcoming difficult or challenging work. Even being perceived feminine could lead to negative stereotypes, which for some participants like Eva made them negotiate their perceived and performed talent. As alluded to in Alisha's case, racial/ethnic identity also played a part in perceptions of talent, difficulty, and challenge in STEM fields.

**Defying Stereotypes: Race and Ethnicity**

Half of all participants were non-White or multi-racial/ethnic. Seven of these students identify as Black, two as Latino, and two as Asian. The multi-race/ethnicity student identifies as White and Latino. When women spoke about gender, it was generally to highlight negative stereotypes about intelligence or ability to deal with difficult material. Similarly, Antonio discussed his ethnic identity in relation to a negative stereotype:

*Well, so much of my identity is Hispanic[17]. […] There's a lot of jokes saying that the Hispanics or Mexicans would, in a sense, not be as intelligent as a - I don't know how to word this - but a standard student, I guess, a standard ethnicity, Caucasian male or something. And because of my ability to get good grades, ability to quickly move up through the classes, I kind of defied those stereotypes.*

Others initially perceived Antonio as less intelligent because of his Latino ethnic background, a stereotype that he was able to "defy," which became a source of pride for him. In contrast, Tien (an Asian woman engineering stayer) described hearing the model minority stereotype while in high school: "Of course, as you know it's like, 'Oh, you're Asian, you're just like super smart at

[17] In this dissertation, I use Latino to encompass all Latin American people, including groups traditionally referred to as Hispanic such as Mexicans

math and science.'" Unlike Antonio, she did not attempt to defy this stereotype, and she did not speak as if she believed it.

Mia and Maya (Black women computer science stayers) felt pressure to succeed from their family and broader ethnic identities. Twin sisters, Mia and Maya emigrated from Nigeria with their parents as children. They both reported that Nigerians highly value education and STEM fields. Mia said, "I think it's mainly my culture just because we see education as such a prized possession;" and Maya reported, "Yeah, and basically anything in STEM field, they'll love. My mom, she gloats about my brother being an engineer." In addition to family pride in STEM education, Maya cites her ethnicity as why she handles difficulty well:

> *I think it's because also probably because as a Nigerian it's super important to basically continue your education, and you can't stop just because something is too hard. Nothing is ever too hard. You are just making it too hard for yourself. You're just over thinking it. Everything can be attained, as long as you can continue on.*

These participants' stories illustrate that ethnic stereotypes exist, but they differ across groups and are based on perspective. Mia and Maya had a sense of pride that they come from strong people interested in doing well in school, while Tien did not necessarily associate with the model minority stereotype and Antonio deliberately defied the stereotype.

Sean also spoke about his identity, but he did so more extensively and about race. In fact, Sean spoke more extensively and clearly about this topic than any other Black men in the sample, so for brevity I share only portions of his interview. When I asked him about responses to his major in engineering, he told me that many people focused not on his major, but on his attendance at the institution of interest—a primarily White university: "if you're Black and you're going to [this university], that's kind of a big deal down here." The importance of Sean's college attendance was further emphasized when he talked about his family's positive response to his major and college choice: "a lot of my cousins fit the statistics, shall we say, […] I was the first one of my cousins to actually go to college, or for that matter, make it out of high school with honors and actually have a chance of doing something.” In contrast, some of Sean’s high school friends distanced themselves when they learned that he was attending college. Sean concluded that they felt he was leaving their community by attending postsecondary education.

Sean entered higher education with the pride of both being the first in his family to attend college and attending an institution that fewer people of his racial group had attended. Sean also highlighted his racial identity when he discussed his college peers:

> *[T]here are not a lot of minorities in STEM, or so they say. Personally, I don't see it, but--you know, a lot of the minorities I would talk to on campus when I first got here, […] they'd be like, “you know, this little dude he's so smart. He'll be the one to do it. That's really cool. That's what you want to do, and just keep fighting for it, keep going on. Don't give it up.”*

Although his family and hometown peers perceived the institution as more White, Sean found a community of racial/ethnic minority students who encouraged him while in college. Notably, like most participants’ reports, they perceived Sean as particularly intelligent because of his major choice.

Sean’s racial identity has remained significant throughout his college experience. Now that he is nearing graduation, his family has been giving him feedback on how to be a Black man with an engineering degree:

> *Even my mom sat me down and was just like, "Look, I don't want to talk at you like you're some up and coming rapper or the newest athlete." But she was like, "You've got to be careful about who you tell about yourself on that level because they see a young, Black, 21-year-old dude and some people out here are struggling. There are people twice your age who wish they had the opportunity you have right now and feel like they should have it versus you. They're going to feel some kind of way that you're doing this." So she's like, "You have to be careful about how you conduct yourself out there."*

No other participant—especially not White participants—discussed feeling the need to dampen their pride. In addition, if a White participant ever discussed having to tone down their intellectualism, it was never in reference to their racial group. The examples above illustrate that participants were aware of stereotypes or some relationship between their racial identities and ability perceptions. Other than some light mentions of difficulty, race/ethnicity is not discussed in relationship to the main constructs of interest in this paper.

### Other Identities

In addition to gender and race/ethnicity, immigrant experiences, socio-economic status, and disability were other dimensions that emerged in the data as relevant to the development of difficulty and talent perceptions.

**Trying A Lot Harder: Immigrant Experiences.** Related to race and ethnicity, the immigrant experience was discussed by some participants as a source of strength when dealing with difficulty. Following up on an example from the previous section, where Tien does not give much value to the model minority myth, she said:

> *Yes, a lot of Asian people are "good with math and science." But it's not always because they're Asian. It's because I understand the way they are, and a lot of them are immigrants. And I think coming from an immigrant family, you try a lot harder because you see what your parents went through. I think more being an immigrant I think impacted my life more than just being an Asian woman.*

A first-generation immigrant from Vietnam, this quote illustrates that Tien does not put stock into stereotyped innate ability based on her race or ethnicity. Instead, she feels that her ability to deal with difficulty was developed by understanding her parents' struggle to immigrate to the U.S.

Miguel, a first-generation immigrant from Peru, had similar thoughts:

> *I'm really smart because of the knowledge that I have accumulated, but that was only through, like I said discipline, and just being persistent, determination. It sounds like a little motivational poster, but that's all that it comes down to. Anybody can do anything. For me, I see my parents as an inspiration because in Peru, we came literally from nothing. And then now, we're in the U.S., they have a business, they're putting me through college.*

Miguel shows that he learned the following from his parents' immigrant experience: persistence, discipline, and determination. He feels these qualities are why he has the ability to do well in the sciences.

**Assuming Lower Intellect: Socio-Economic Status.** Miguel's quote mentions the next dimension of identity that emerged as relevant from the data: socio-economic status. He references that not only did he experience a difficult transition to a new country, but his family did this after coming "literally from nothing."

Multiple participants spoke to their awareness of growing up in low-income households. For instance, when I asked Luis (a Latino man physics stayer) why he felt there may be fewer people of color in STEM, he said:

> *I feel like it's not much color as it is much as economic status because-- just, people who are lower social classes have a tendency to care less about things like academics, and math and science. And if you want to do physics, you have to be good at math and science, and you really have to put forth a lot of effort in your academics. And if that's not something that-- well, if that's not one of your main values, your main priorities, then you're not going to go towards it.*

Luis himself came from a lower middle class family, but told me in his interview that he was more interested in academics due to growing up in a higher income area and having friends in that demographic. Notably, where Miguel felt inspired by coming from a lower-income family, Luis felt that it could be a detriment.

Haleigh (a White physics leaver) also discussed how perceptions of income level could be associated with perceived talent in STEM. They told me that customers at their work were "shocked" when they found out that Haleigh is majoring in physics. In a previous quote, they believed that this was because they can be perceived as feminine, but also because:

> *sandwich workers and fast food workers are generally considered to be liberal arts students by the population. We're pretty looked down upon by everybody in an upper-class position because everyone says, "Oh, I don't want to be burger flipping for the rest of my life." And phrases to that extent, which implies that fast food workers are somehow*

> *lower in intellect. So a lot of people just assume that I'm lower in intellect because I work in fast food.*

Based on these perspectives, it seems that there is a social perception that lower-income people do not have the innate ability or possibly the value towards academics to major in STEM fields. However, in reality some can be inspired by thriving in difficult circumstances to persist in mathematics-intensive science fields.

**"Even If I Can't Show It": Participating with Mental Disability.** The last dimension of identity that emerged from the data was disability. Some participants extensively discussed disability during the interview in reference to perceptions of difficulty and talent. Casey (a White woman engineering stayer) explained that she was diagnosed with attention deficit disorder and an anxiety disorder in college. In addition, she has multiple family members with mental health disorders. This is what she told me:

> *So actually mental illnesses are pretty big in my family and it's probably why I'm the first person to go to try to get a degree […]. I feel like that also gave me a perspective in doing what I'm doing too because everybody has their little hurdles and things they learn about themselves too. […]You can either lay down and give up or you can just keep going and it's up to you for who you are. [T]here have been professors who have told me that I can't do it and they're wrong because it's something that I do love even if I can't show it on a test. It's something that I love and something that my friends can see that I'm very informed about and that I plan to do research one day, hopefully, fingers crossed. So it's just something that I'm not going to give up on.*

Casey referred to her family's experience and her own disabilities as sources of strength when encountering difficulty and doubt during college. She recognized that her disabilities restricted her from being extremely successful at the highest levels of her field, but was able to use that knowledge to identify other motivations for pursuing the degree.

For some, their disabilities *did* restrict them from feeling capable of completing a degree in a mathematics-intensive science field. Haleigh experienced a traumatic brain injury during their first year in college. This event deeply impacted their ability to learn on a biological level compared to their capability in high school.[18] Where once Haleigh thought that math and science came easily to them, they no longer think this way: "I feel like I have to work a lot harder now in order to get to a place that I would have gotten to easily in the past, which is tragic for me, but I'm learning to cope with it." For Haleigh, coping means dropping out of college and building a new life in a new city as they adjust to their medication. They have plans to return to college, but not in the near future.

Identities including and beyond gender and race/ethnicity—immigrant experiences, socio-economic status, and disability—further informed participants' perceptions of difficulty and talent. Women generally felt that their talent was questioned by the men around them, and many connected with other women to find support. People of color experienced both positive and negative stereotypes, depending on their race/ethnicity identity and the context. Participants chose to either use these stereotypes as motivation or to ignore them. Immigrant students referred to their parents or their own journeys to the U.S. as inspiration during difficult or challenging coursework. Low-income students, like women, had their talent questioned by others. Like with some minority racial/ethnic groups, low-income students were also perceived as less intelligent, which most of the students felt compelled to prove wrong. Finally, students with a disability had to negotiate very real and meaningful limitations with their ability. Reflections on their identities in addition to their college experiences contributed to both mental well-being and educational outcomes.

## Mental and Emotional Health

Along with shaping difficulty and talent perceptions, the college experiences discussed in the previous sections had consequences for participants' mental and emotional health. In the

[18] In particular, they have been sleeping about 20 hours a day, which inhibits their ability to work. Also, they have empirical evidence that their processing speed is slower than it used to be.

following sections, I discuss how the evolution of students' perceptions impacted their self-worth, mental well-being, and resulted in the establishment of a new resolve.

**Being Enough: Impacts on Self-Worth**

The way that students experienced difficulty and perceived talent impacted their sense of self-worth. For some students, this struggle began before college. For instance, Katerina explained:

> *I'm not a sporty person, I'm not a musical person, I'm not an artsy person, but I have been very good at taking tests and things like that all of my life. So I guess I eventually grew to base a lot of my perception of my own self-worth on how well I continued to maintain this good at tests thing.*

Katerina went on to explain that the college experience threatened her sense of self-worth. "I thought that I was just going to run right into college physics and just be perfectly fine and maintain my top-of-the-class status," she told me: "Then I got to college and that was a big shock. And then the discovery that I wasn't all that good anyway at the more complicated stuff, that was another shock." Katerina very clearly linked her developing difficulty and talent beliefs to her sense of self-worth.

Nessa, like Katerina, measured herself based on her academic performance while in high school, when she thought of herself as "not good enough" as a result of her grades. However, she told me:

> *So for me, I [had] to learn that you're more than your GPA, and […] you're not going to understand everything. I'm not an art major. So when it comes to art, I shouldn't expect to get 100s on everything. […] So if I don't do well in art, then okay, I don't do well in art. But did I do my best? Yes, I did do my best. Then you're good, then you're fine. […] That's why I started to lean towards that concept - that way of looking at things - because it takes a lot off your plate. Because then, there's no pressure for you to always get the A. You just want to do your best and that's it.*

By meeting talented others and through faculty support, Nessa and Katerina both stopped letting their grades support their sense of well-being. Continually throughout the interviews, almost all participants described how their perceptions of talent, difficulty, and challenge impacted their sense of self-worth.

**Mental Well-Being**

When encountering difficulty and weed-out cultures in college, a number of participants reported serious mental health impacts. Alan's description of how his mental health deteriorated in relation to experiencing difficulty and questioning his innate ability was typical of reports from other participants. We got on the topic when he described having a particularly difficult semester:

> *I: Tell me about what strategies you used [to get through the class].*
>
> *R: [sigh] Sheer force of will I guess is the best way? I mean, I literally if I wasn't eating or sleeping or doing something, you know, I was, I had my head in a book. I think I lost, like, 30 lbs that semester.*
>
> *I: I'm sorry to hear that… That sounds awful.*
>
> *R: Yeah, it was pretty bad. […] Like I was suicidal. Um, I was going to therapy, and it wasn't stopping. Like I thought I was a failure, I thought I was all this other stuff.*

Alan's experience was so negative, he decided to change his major as an immediate result. For him, the challenges to his mental well-being were the result of experiencing difficulty in his courses and questioning his innate ability.

For others, difficulty and talent perceptions were just one element of a larger challenge in college. Stuart (a White man physics to engineering swapper), for example, described the source of his anxiety as "whether I was going to get the work done on time, whether I was going to get the A in the class," which are related to difficulty and talent perceptions, but also, "whether I was going to impress this person, whether I was going to get some resume references or stuff." Eva distinguished between developing depression and anxiety:

> *I feel like the depression was because of how hard it was of a major and the competitiveness. […] because it was head-on, it was at first when I started it, which was*

*sophomore year spring semester. But the anxiety I feel formed […] because of the whole gender discrimination. And now it continues.*

About half of the participants discussed receiving professional counseling while in college as a direct result of academic-related anxiety.[19] While the shaping of difficulty and talent perceptions in college were not the sole reason for mental and emotional crises, it definitely contributed to these participants' experiences.

**Fighting For It: Building a New Resolve**

In some instances, the reshaping of participants' perceptions of difficulty and talent resulted in building new skills. In other cases, the college experience helped participants understand that innate ability was not necessary for success in science fields. I name both of these outcomes "new resolve," because these themes seemed to act as new starting points for participants. Learning new skills helped some participants continue to their bachelor's degree, while breaking the stereotype that innate ability is necessary for success in STEM helped others better understand their objectives and others' passions.

Stuart's experience helped him build a new resolve by learning how to reframe his college course experiences: "It's not that I want to do well on a test. It's […] 'I'm taking this class. I want to get something out of it.'" For Alan, who struggled with depression and anxiety as a result of experiencing difficulty in engineering, he learned "to give [him]self a break" by telling himself "you can't control everything that happens in your life. You're going to have a bad day, you're going to have a day when you're taking a test when you're tired."

Similarly, Casey told me that college had taught her "that sometimes you have to fail in order to improve." She continued:

[19] The participants did not specify if this counseling occurred through the free on-campus clinic or through non-college practitioners.

> *I had 18 credit hours, and I had two jobs. And I was working a lot to pay all of my bills, and make sure I had money for food, and everything like that. And, yeah, my first semester didn't go so well. It wasn't an easy transition to go from a community college to university, so, yeah. There was a lot more studying required that I didn't know would be required initially, because I didn't have anybody to tell me that. […] And I had a couple of professors telling me that I wasn't cut out for sciences or things like that, because I wouldn't do well on the exams […]. But I didn't really have anybody to talk to, so I just kind of did a lot of self-reflecting, and decided that this is what I wanted. And I decided to fight for it. So that's why I'm here, and I've improved a lot.*

Unfortunately, the data is too variable to know exactly how students came to feeling a renewed sense of purpose. For Casey and Alan, self-reflection helped. However, some students were guided to this destination, such as Sean and Katerina who were both mentored by faculty. Despite this variability, it is important to highlight that not all students had negative self-worth or mental and emotional outcomes.

For other students, the college experience served to help them break the stereotype that scientific careers required innate ability. Zachary (a White man physics leaver) told me about both breaking the stereotype and focusing on learning over depending on his talent:

> *[T]he vanity disappeared when I started self-reflecting on the cult of STEM, because I started realizing the mindset with which I've been approaching things, and I wanted to make a particular effort not to be that way because I did not like the way it sounded. I didn't want to be the guy who thought he was the smartest person in the room anymore. But the actual change to not being, I don't think I'd recognized until probably this conversation simply because it's not what I look for anymore. I've switched to just trying to learn rather than trying to prove my intelligence.*

Notably, Zachary identified college as when he no longer wanted to rely on perceived intelligence, and instead focus on his actual learning. Related, Katerina told me that she no longer believes that intuition is necessary to do well in physics. "Instead of intuition," she told me:

> *You got to read what's written on the page, not what's happening in your head. And so I think that's more important now, the ability to just stare at something and follow through it, to find the error in your calculations to find the bug in your code. […] I think that's a tremendous problem in majors like this that are so much work, they're so hard,*

*and they have this perception of being so hard, but everyone still wants to seem smart because you're supposed to be smart to be in that major.*

Although many participants let go of the identity that they developed as high schoolers as having talent in science fields, they acknowledged that these perceptions of innate ability are prevalent in college. However, their growth in this area shows that these attitudes can be adjusted over time. In addition, there was not a clean correlation between developing a new resolve and students' decisions to stay or leave mathematics-intensive field of study. Although there may not be direct educational outcomes to this shift in perceptions, the positive benefits to students' mental and emotional health is notable.

## Educational Outcomes

Perceptions of difficulty and talent are also directly related to students' decisions to stay or leave mathematics-intensive science fields. Of the 24 participants in the study, 46% (n = 11) stayed, 33% (n = 8) left, and 21% (n = 5) swapped between mathematics-intensive science fields. In the sections below, I describe how perceptions of difficulty and talent were directly linked to these persistence patterns.

### Pick an "Easier Major": Choosing to Leave Mathematics-Intensive Science Fields

Of the 8 participants who left mathematics-intensive science fields, perceived difficulty of the field was a significant factor in the decision to leave for 5 of the participants. For instance, Meredith emphasized ease when I asked her what she would tell her younger self about college: "Honestly, I would say start in an easier major. You know what I mean? Start with something where I can get a higher GPA." Because she changed her prospective career from becoming involved in space exploration to medicine, a high GPA was important to Meredith for admission to medical school. Similarly, Gage (a Black man engineering leaver) was thinking of difficulty when he discussed other major options with a friend: "my best friend's girlfriend […] was in IT and she was like, 'Gage, you got to do IT. The requirements aren't as hard. […] And it's just so easy.' At the time I was like, 'I don't want to do IT, that sounds too easy. That sounds like a joke, or whatever.'" Gage ultimately did change his major to IT, which he came to enjoy more than his initial engineering major.

Two of the 5 participants who swapped from one mathematics-intensive science field to another did so also out of perceived difficulty of the fields. For instance, Sean changed his specialty from mechanical to industrial and manufacturing engineering because he thought he could achieve the same goals with a little less effort in the second major. Erick changed his major from engineering to computer criminology, because he felt he could achieve similar goals in an "easier" major. In contrast to Sean—who isn't sure exactly what he wants to do in engineering—Erick's goal was to build his character in college through a broad, co-curricular experience, which he felt was more possible in a major that required less effort.

**"You Just Can't Stop": Persisting in Mathematics-Intensive Science Fields**

Stayers were distinct from leavers in this study in many ways. They were most distinct from leavers in that they were less likely to believe that innate ability was required for success in STEM fields before college. For instance, Stuart initially majored in physics believing that he was going to go to graduate school. However, as he progressed through college, he began to really think about his values:

> *[A]s I thought more recently, it's just been very—[…] "Yeah, I really just don't want to go to grad school." I really just want to get into the real world, like those internships, and forge my own path of learning […] I'm just tired of the system. I don't think it's done a good job. I feel like I've only learned because of A) Montessori school and B) because I somehow kept this little string of wanting to love to learn throughout the whole thing.*

Stuart referred to his open learning experiences at Montessori school multiple times in his interview, and referred to perceptions of talent as something that others had, not something he felt he personally possessed. Stuart went on to explain how he changed his major from physics to engineering out of an interest of one day entering urban and regional planning. He was not struggling in his physics courses; he simply had a different interest.

Nessa and Josiah also did not enter college believing that they had innate ability in mathematics-intensive science fields. Both students declared an exploratory major when they matriculated. Through their first year, they were provided with structured learning and reflection sessions around career choice. These sessions eventually led them to select fields that they knew they enjoyed, not necessarily fields that they felt destined to select due to their talent.

Barring the themes already described in this chapter which positively impacted participants' perceptions of difficulty and talent, some participants simply decided to stay. For instance, when Tien encountered an experience in the classroom that challenged her, she persisted because she "just knew I had to do it because it's on a contingency that in order to get my job, I have to have a degree." Similarly, Miguel told me that he wished he could go back to tell his younger self, "It gets harder, and you just can't stop. You've got to keep going. The end is almost here, and I'm already three years in, so I got two more, but you'll start to reap the benefits because you know try hard, and they'll help you out." In this quote, Miguel highlights that resigning himself to difficulty early on—with an emphasis on why the upcoming challenging is worth the effort—would have helped him.

**Summary**

Most of the 24 participants in my study entered college believing that mathematics-intensive science fields required innate ability and that they possessed this type of ability. Through the college experience, they encountered difficult coursework like never before, met others who had unique talents, and received support or discouragement from faculty. Participants' identities—gender, race/ethnicity, immigrant background, socio-economic status, and disability—also became salient during college in relation to their experiences with difficulty and ability perceptions. During these educational experiences and through reflection, students had a number of mental and emotional health outcomes, including negative impacts to their self-worth and mental well-being, as well as positive impacts such as developing a new resolve. Participants also chose to leave or stay in mathematics-intensive science fields as a result of shaping difficulty and talent perceptions.

# CHAPTER 7

# HYPOTHESIZED THEORETICAL FRAMEWORK & DISCUSSION

In this dissertation I presented two studies with the purpose of better understanding difficulty and talent beliefs. In the quantitative study, I used nationally-representative ELS data to measure difficulty orientations by gender and race/ethnicity. I also estimated the relationships between these variables and postsecondary outcomes in mathematics-intensive science fields. I sought to clarify the findings from the quantitative study through qualitative interview data of 24 diverse seniors, sampled using a robust, two-stage process. This study illuminated how difficulty and talent perceptions were established and shaped by the educational experience as well as identity. Below, I summarize the findings from these studies. Then, I present the framework that emerged from those findings. Next, I discuss the framework and findings, limitations of the framework, and planned research. Finally, I describe implications for educational researchers, practitioners, and policy makers.

## Summary of Findings

Shared in Chapter 1, five overarching research questions framed this dissertation:

1. Do specific beliefs about difficulty and talent in STEM exist?
2. How are these beliefs developed through the educational experience?
3. What are the associations between perceived difficulty and postsecondary mathematics-intensive science outcomes?
4. How do postsecondary experiences shape perceptions of difficulty and talent in STEM fields?
5. How does gender and race/ethnicity relate to beliefs about difficulty and talent in mathematics-intensive science fields?

Based on the findings shared in Chapters 4-6, I respond to each question below.

**Do Specific Beliefs About Difficulty and Talent in STEM Exist?**

Findings indicate that there are specific ability beliefs about difficulty and talent in STEM fields. The first pieces of evidence that specific beliefs exist came from previous literature. Namely, resilience, grit, and flow theories all describe how people overcome and thrive in the face of difficulty or challenge (Csíkszentmihályi, 1990; Duckworth et al., 2007; Fletcher & Sarkar, 2013). Mindset theory explains that beliefs about the nature of innate ability, or talent, influence students' persistence and success (Dweck, 2000, 2006). Linking these ideas to STEM, field-specific ability beliefs show that there are social beliefs that "brilliance" is required for mathematics-intensive science fields (Leslie et al., 2015; Meyer et al., 2015). This dissertation expanded and enhanced previous research by focusing on difficulty and talent beliefs in mathematics-intensive science fields.

The quantitative study confirmed that perceived difficulty is consequential for CEP outcomes and vary by demographic identity (more specific discussion of these findings addressed in the sections below). Notably, mathematics difficulty orientations were positively associated with CEP outcomes while verbal difficulty orientations were negatively associated, indicating domain-specific beliefs. The qualitative study provided more insight on specific difficulty and talent beliefs. First, participants described a broad social belief that these fields are difficult, and therefore one must be talented to participate. Many participants also believed that they had this requisite talent because they were successful in difficult science and mathematics courses. These ability beliefs were specific to mathematics-intensive science fields.

**How Are These Beliefs Developed Through The Educational Experience?**

The qualitative study provided the most insight into how educational experiences establish beliefs about difficulty and talent. Findings from Chapter 5 primarily address this research question. The belief that some fields of study were more socially valuable than others was implied through school conversations about and independent internet searches on career fields. Teachers, parents, or peers also told participants that they were smart and therefore should major in a mathematics-intensive science field. Belief in one's innate ability was also confirmed through selection for special academic programs, considered more difficult than mainstream courses. These programs included gifted, honors, AP, IB, and magnet programs. Tracking was particularly problematic for students because it separated them from those with average or below-average academic achievement, inflating their talent beliefs. In addition, when students were not challenged and did not feel pressed to study even in their advanced coursework, they built an even stronger belief in their innate ability. This strong belief in innate ability is at the heart of the difficulty orientation measure from the quantitative study.

**What are the associations between perceived difficulty and postsecondary mathematics-intensive science outcomes?**

High school mathematics difficulty orientation—belief that one can understand the most difficult or complex mathematics material presented by teachers or in texts—was positively associated with participation in mathematics-intensive science fields at the postsecondary level. A one standard deviation increase in mathematics difficulty orientation was associated with a 45% and 32% increased risk of majoring and earning degrees, respectively, in a computer science, engineering, or physics (CEP) field net of all other variables. Mirroring these results, verbal difficulty orientation was associated with a 24% and 28% decreased risk of majoring and earning degrees, respectively, in these fields. Increasing mathematics difficulty orientation is a meaningful way to encourage participation in CEP fields.

The qualitative findings added depth to the quantitative results. Participants articulated the belief that mathematics-intensive science fields were more difficult than other fields. This perceived difficulty was related to these fields' social value, higher pay, and high concentration of intelligent people. Before college, many participants believed that they had a innate ability in mathematics and science domains, so these subjects were not difficult for them. The college experience shifted both the belief that mathematics-intensive science fields are particularly difficult and that participants had special talent in these fields.

**How do postsecondary experiences shape perceptions of difficulty and talent in STEM fields?**

The quantitative study lacked robust measures of the college experience or perceptions of difficulty and talent in college. Further, the drop-off in significant findings for the most distal postsecondary outcome, CEP degree completion, could indicate meaningful, unmeasured college experiences. The qualitative study's main purpose, therefore, was to understand how the postsecondary experience shaped perceptions of difficulty and talent established before college.

The college experience and identity shaped established beliefs about the need for talent in mathematics-intensive science fields and participants' possession of that talent. Once participants declared a major in a mathematics-intensive science field, responses from peers indicated perceptions that those majors were difficult and particularly suitable for smart people. College weed-out cultures further perpetuated the belief that mathematics-intensive science fields were exclusive to only those with the most talent. Difficult college coursework caused many participants to question their innate ability. Meeting talented others led some to continue to question their talent, others to adjust expectations, and still others to realize that the smartest students do not necessarily select STEM fields. Faculty could discourage participants by making them feel that they should not find material difficult and that they were not fit for the field. However, supportive faculty were those who shared their experiences with difficulty, helped students find positive coping mechanisms, or emphasized the importance of hard work rather than talent for success.

**How does gender and race/ethnicity relate to beliefs about difficulty and talent in mathematics-intensive science fields?**

Mathematics difficulty orientation and CEP participation varied by gender and race/ethnicity. Women's difficulty orientations were, on average, 0.3 standard deviations lower than men's. Thus, it naturally follows that women had 10 and 9 percentage points lower predicted probability to major and earn degrees, respectively, in CEP fields given mathematics difficulty orientation. Women or female-passing qualitative participants reported being treated as less intelligent than male peers in their major, but more intelligent than non-majors and therefore intimidating to potential romantic partners. Some female participants reported that women chose perceived less difficult STEM majors. Women exclusively spoke about gender when describing their experiences.

Turning to race/ethnicity, there were multiple quantitative findings. Whereas Latinos and Asians had significantly different mathematics difficulty orientations compared to White students, they did not significantly differ from White students in CEP outcomes. Black students had higher gains in their predicted probabilities to declare and earn degrees in CEP fields given increases in mathematics difficulty orientations, despite not significantly differing from White students on this measure. Similar to women, Black and Latino qualitative participants reported hearing negative stereotypes about their intelligence. One Asian participant described hearing model minority stereotypes, especially around mathematics ability. All of these students discounted these stereotypes, and at least one Latino participant actively sought to prove the stereotype wrong. Related to race, ethnicity and immigrant experience as a separate but intersecting identities emerged in the qualitative study. Some participants described ethnic pride for doing difficult things, while immigrant participants referred to previous difficult experiences as inspiration to overcome current challenges.

Although there were no significant interaction results in the quantitative study, there were some notable intersectionality findings. For instance, Black women at the highest mathematics difficulty orientations were more likely than all but Black men to declare CEP majors. All Black students had higher gains in probability to declare a CEP major compared to all other groups, but Black men were more highly advantaged than Black women. Only one qualitative participant discussed gender and race/ethnicity intersectionality directly. She stated that her identity as a Black Woman was more obvious to her in college, and that she actively sought others like her to support her learning.

Although I initially endeavored to understand the role of gender and race/ethnicity, other identities emerged as relevant to difficulty and talent beliefs. In addition to immigrant experiences described above, socio-economic status and disability were relevant to difficulty and talent beliefs. Low SES students described both negative stereotypes about intelligence and lack of role models. Last, participants with a disability described overcoming difficulties and persisting through objective evidence of being differently abled. These findings are described in more detail in Chapter 5.

## Resulting Hypothesized Theoretical Framework

A hypothesized theoretical framework for understanding beliefs about difficulty and challenge in mathematics-intensive science fields emerged from the findings summarized above. In addition, over a period of about a year that I was working on this dissertation, I consulted with the data, interview participants, researcher memos, a peer reviewer, my dissertation chair, and received feedback through conference participation on the framework. This framework shows the role that pre-college experiences, college experiences, and reflections on identity had in the shaping of ability beliefs. These beliefs—specifically about difficulty and talent—were associated with educational as well as mental and emotional outcomes.

There are five main parts to the model: pre-college experiences, college experiences, identity reflection, ability beliefs, and outcomes. All of the themes discussed in the qualitative study plus one additional factor from the quantitative study ("Can understand most difficult / complex math material") are illustrated using squares, whereas the beliefs are distinguished using circles. Within some squares are dimensions of the overall theme, such as "Social Value, Pay/Employment Benefits, Difficulty, Concentration of Intelligent People" under "Ranking Majors". One- or two-sided arrows illustrate relationships between each part of the model.

On the far left of the figure are four themes of the pre-college experience. Three of the themes—ranking majors, being told by parents/teachers, and K-12 advanced programs—were described in Chapter 5 of the qualitative findings about ability belief development. The last aspect—"Can understand most difficult/complex math material"—is a paraphrasing of the survey items that made up the mathematics difficulty orientation scale in the quantitative study. Pre-college experiences has four arrows leading to additional parts of the model. The middle arrows point to the two ability beliefs of interest. Specifically, these pre-college factors established the dual belief that mathematics-intensive science fields require talent and that participants had this talent based on their ability to handle difficult material. Next, pre-college experiences led students to enroll in college and select mathematics-intensive science fields of study. Last, for some participants pre-college experiences led to a reflection on their identity, be it gender, race/ethnicity, immigrant experiences, disability, or socio-economic status.

Once in college, six themes continued to shape the two ability beliefs about needing and having talent. As described in Chapter 5, peer responses to major and weed-out cultures further supported the beliefs that talent was necessary to participate in mathematics-intensive sciences, that those fields of study are particularly difficult, and that participants had the innate ability to be successful in those fields. Difficult coursework, meeting talented others, faculty discouragement, and faculty support all either increasingly or decreasingly supported these beliefs depending on the exact experience (Chapter 6). In turn, students' reckoning of difficulty and talent perceptions influenced their decisions to take more difficult courses, how they socialized with talented others, and their interactions with faculty. College experiences also prompted identity reflection for some, as students were in a more diverse environment than ever before. Reflecting on one's gender or race/ethnicity identities, and immigrant, disability, or socio-economic statuses also shaped and were shaped by students' perceptions of their innate ability or ability to overcome challenge (Chapter 6).

The ability beliefs that were shaped by pre-college experiences, college experiences, and identity reflection had specific mental and emotional as well as educational outcomes. Both the perception that mathematics-intensive science fields required talent and the belief that one had (or did not have) talent impacted students' self-worth, mental well-being, and the development of a new resolve to continue their studies (Chapter 6). These beliefs could have also informed students' decisions to stay or leave a mathematics-intensive science major or to complete college (Chapter 6). The quantitative findings additionally illustrated an independent relationship between some gender and race/ethnicity identity groups and educational outcomes (Chapter 4).

## Framework Discussion

Although it was not the intent, the process presented in Figure 12 follows the structure of many identity developmental theories (Sanchez, n.d.), lending support for the validity of the model. Specifically, the framework begins with students in a state of conformity, when participants follow a pathway prescribed by the idea that one must have talent to participate in mathematics-intensive science fields. They additionally accept the black and white belief that they are simply able to understand difficult material, or that they have innate ability. Participants experience dissonance, a crisis, or encounter in college, resulting in deep reflection and a more complex understanding of talent and difficulty in STEM fields. Finally, participants use this reflection and refer to their other identities to act or not act as a result of their newfound understanding of talent and difficulty.

Other aspects of this framework are notable. I use the term identity "reflection" versus "development" intentionally. Participants spoke referentially to their identities or identity was examined statically in the quantitative study. Therefore, this model does not integrate more complex identity development models. Also, to achieve model parsimony and show passage of time, I condensed themes under the headers "Pre-College Experiences," "College Experiences," etc. Original versions of this model showed lines from each theme to each belief and outcome individually. This created an overly complex model. Discussion with other scholars helped me condense the model into its current form in hopes that it would be more effectively used.

This framework was designed to synthesize findings from the two studies in this dissertation. Therefore, while it looks holistically at the educational experience, it is not comprehensive. There are many aspects of the educational experience that may be missing to informed readers. For instance, objective measures of academic achievement (standardized test scores, GPA, etc.) and hands-on learning experiences such as undergraduate research are not explicitly listed in the framework. This framework was developed using a grounded theory approach, and therefore uses only those themes that arose from the data. In sum, it is not my intent to replace other theories describing ability beliefs or participation in STEM fields. Instead, I present one potential process that may be relevant to college students.

Student perspectives and student-level data built this framework; therefore, it can be misconstrued as placing the onus of ability belief development solely on students. However, my intent is to illustrate the role that structural inequities can play in the development of students' talent and difficulty beliefs, especially for women and underrepresented racial/ethnic minorities. For instance, the model explicitly includes several stakeholders as influential to belief development: parents, high school teachers, college professors, and peers. Participants further discussed structural aspects of their educational experiences that played a role in their ability belief development, including K-12 tracking practices and difficult coursework. Implicit in the model are issues such as access to high quality schools with advanced programs, equity in testing practices, and implicit bias on the part of educators. These issues negatively impact students, and are at least partially within the control of the stakeholders named in the implications section below.

## Significance of the Findings

This dissertation adds to the literature in multiple ways. First, the findings presented here more explicitly link previous ability belief concepts such as mindset theory (Dweck, 2000, 2006) and field-specific ability beliefs (Leslie et al., 2015; Meyer et al., 2015) to the major choice-making process. Specifically, this dissertation shows that when students believe that talent is necessary for participation in mathematics-intensive science fields and that they possess this talent, they are motivated to select a CEP major in college. When they begin to question one or both of these beliefs, their motivation to continue in these majors is at stake. Second, this dissertation engages the concept of difficulty in this process. Perceived difficulty of mathematics-intensive science fields was cited as a reason that participation in these majors required talent. Furthermore, students believed that their success in the most advanced mathematics and science coursework with little difficulty was an indicator of their innate ability. Students who believed that they could understand the most difficult or complex mathematics material or texts (difficulty orientations) were more likely to select majors in mathematics-intensive science fields.

Third, this dissertation describes how these beliefs are established. Congruent with mindset theory (Dweck, 2000, 2006) and expectancy-value theory (Eccles, 1987, 1994; Wigfield & Eccles, 2000) research, significant others like parents and teachers can influence students' beliefs about their own talent in mathematics-intensive science fields. This dissertation makes more explicit the link between K-12 tracking practices and perceptions of difficulty and talent in STEM. The perspectives shared also illustrate beliefs that some fields are ranked more highly than others on overlapping dimensions: social value, economic benefits like pay, difficulty, and concentration of intelligent people. Therefore, the general social atmosphere is partially culpable for the development of these beliefs.

Fourth, this dissertation illustrates how the college experience can shape beliefs about difficulty and talent in mathematics-intensive science fields. Although previous research showed relationships between the college experience and STEM outcomes (Chang et al., 2014; Cole & Espinoza, 2008), there has not yet been a study of how postsecondary experiences can influence difficulty or talent beliefs for students in mathematics-intensive science fields. The quantitative study showed that the college experience may be particularly important for women—gender differences were widest on CEP degree outcomes. The qualitative study provided rich data on the role of difficult college coursework, weed-out culture, meeting talented others, and faculty encouragement and discouragement in further shaping beliefs about difficulty and talent.

The framework shared here does not provide clear pathways for the direction of these beliefs given influences in college. Most importantly, difficulty and talent beliefs were not reported as binary states. Participants spoke about these beliefs as if they fell on a spectrum. Furthermore, the quantitative study measures difficulty orientations at one time period—there is no opportunity to observe change. At this time, participants' experiences are too diverse and there is insufficient data to support pathways from college experiences to ability beliefs to outcomes.

The last way that this dissertation is meaningful is that it engages identity as a vital aspect of the STEM difficulty and talent perception development process. Gender and race/ethnicity differences in STEM-related ability beliefs have been widely documented, though it is more common with on gender (Litzler et al., 2014; OECD, 2015; Sax, Kanny, et al., 2015; Van de Gaer et al., 2012). The findings in this dissertation illustrate how gender and race/ethnicity together and separately relates to difficulty and talent beliefs. Both women and minorities faced negative stereotypes about their talent. Some minority participants referred to their racial or ethnic identities as reasons to persist even in the face of difficulty. Black students in particular were advantaged in their probability to participate in CEP fields given increases in their mathematics difficulty orientations. Black women were less advantaged than Black men in increases in difficulty orientations, but at their most confident they were more likely to participate in CEP fields compared to all other men and women. Notably, other identities emerged in the research as meaningful to difficulty and talent beliefs: immigrant status, socio-economic status, and disability.

## Future Research

As it is a nascent explanation of the difficulty and talent belief development process, this framework can be improved through future research. Immediate research plans include quantitative and qualitative research. First, I plan to return to the ELS sample and test parts of the framework through the estimation of structural equation models. This study would allow me to first test variables that emerged as meaningful in the qualitative study that were not accounted for in the quantitative study. Secondly, a structural equation model would illuminate moderating effects for individual postsecondary experiences. In addition to this quantitative study, the model can be validated using other datasets, including the most recent national datasets, if appropriate measures exist. If not, additional research can culminate in the creation of an original survey. This survey would provide an opportunity to validate specific questions and scales to measure difficulty and talent beliefs.

Additional qualitative research is needed. In attempting to establish the existence of these specific ability beliefs for multiple gender and racial/ethnic populations, the qualitative study included a diverse sample on these dimensions. Future qualitative data collection can focus on a more limited sample to better understand the experiences of specific groups. This may be particularly illuminating for the identities that emerged from the qualitative study as relevant: immigrant students, low-income students, and students with a disability. Furthermore, institutional policies and college faculty/staff were influential to shaping students' difficulty and talent perceptions. An additional qualitative study investigating their beliefs about difficulty and talent in mathematics-intensive science fields would be illuminating, especially related to weed-out cultures and courses that are perceived as especially difficult.

## Implications

The belief that mathematics-intensive science fields are for the especially talented is pervasive. Participants reported that this belief was implicit or was made explicit throughout their educational experiences. In the following sections, I describe what researchers, practitioners, and policy makers can do to develop positive difficulty and talent perspectives to encourage participation in mathematics-intensive science fields.

### Researchers

Research on gender and race/ethnicity variation in STEM is prominent and highly funded. This study's findings, however, illustrate that other dimensions of identity can impact students' ability beliefs and subsequent decisions to participate in mathematics-intensive science fields. Immigrant experiences, socio-economic status, and disability were additional frames to understanding how perceptions of talent and difficulty were shaped throughout educational experiences. The existence of these additional frames suggests that research from an intersectionality perspective (Cho et al., 2013; Crenshaw, 1989, 1991) can help further illuminate processes that impact students' decisions to participate and persist in STEM fields. As emphasized by Beddos and Borrego (2011), looking at gender and race/ethnicity in STEM research is a start, but it's not enough. Intersectionality research in this domain needs to expand to include other identities.

Researchers can also do more to examine STEM participation patterns for students with low or middle ability beliefs and standardized test scores. By focusing our research on only those with the highest scores in both of these dimensions, we limit our findings and implications to those already served by the elementary and secondary school tracking system. We unintentionally perpetuate the idea that STEM fields are only for those with some demonstrated level of ability, rather than help educators identify the potential in students performing at the middle or lower levels.

Qualitative participants in this dissertation described some majors within mathematics-intensive science fields as easier than others (for instance, industrial engineering vs. mechanical engineering). There is already strong support by scholars to disaggregate the "STEM umbrella" of majors (Corbett & Hill, 2015; Sax, Perez-Felkner, Gaston Gayles, Trautvetter, & Wang, 2015). Studying similar majors for differences in difficulty and talent perceptions may be of interest to researchers.

Finally, one quantitative finding is worth further investigation. Verbal difficulty orientations were consistently negatively related to CEP outcomes in the quantitative study, measured in isolation or with other scales. Verbal difficulty orientations were associated with both CEP declared and degree major, while mathematics difficulty orientation was only associated with CEP declared major. Furthermore, verbal difficulty orientation *increased* Black students' predicted probabilities to declare a CEP major, beyond the effect for mathematics difficulty orientation. On the qualitative side, many participants described pre-college interest in activities that used their verbal skills, such as analyzing literature and creating art. However, these interests or aptitudes clearly did not outweigh students' decisions to major in a mathematics-intensive science field. Future researchers may continue to explore verbal difficulty orientations to understand if and how they may discourage participation in CEP fields for some, but encourage participation for Black students.

**For Practitioners**

From the postsecondary education perspective, administrators, faculty, and staff can increase participation in reflection of this dissertation's findings. Qualitative participants provided helpful accounts of faculty behaviors that encouraged or discouraged them. One helpful comparison was Mia's and Meredith's description of faculty members eliciting questions at the end of a lesson. One faculty member takes silence to mean that students are not engaged with the material, the other to mean that students are too intimidated to ask a question. This simple difference in regard toward students' ability meant a lot to Mia's and Meredith's next actions: Mia asked her question, albeit privately, to the professor while Meredith decided to stop going to class. Throughout the qualitative findings, participants reported building their difficulty and talent beliefs through the influence of their instructors. Faculty would do well to interrogate their own perceptions of students' talent.

Related, postsecondary education practitioners and policy makers may also have to directly address weed-out courses in a productive manner. Some participants reported hearing about weed-out courses directly from faculty, even though there are no official weed-out policies in place. Faculty and departments need to reconcile their undergraduate teaching philosophies, come to consensus about the openness of the program to students who may struggle with the coursework, and then address these perspectives in the classroom and advising sessions. Further, university departments can do more to provide access to students who may not enter with calculus credit or prior coursework in specific fields of study, such as computer programming. Summer bridge programs or different course modalities may be options for these departments to better engage students with objective skills deficits from high school.

Students who did not receive one-on-one mentoring were either supported or discouraged simply from faculty's attitude about innate ability in STEM during lectures. Individual faculty members should feel empowered to positively impact students' ability perceptions simply by encouraging them that failure is expected, learning can be difficult, and that talent is not a requirement for success in the classroom. Practical actions also include checking for understanding in multiple ways, rather than asking once "Does everyone understand?" Faculty can also openly share their own failures or experiences learning the material, to highlight that they also had a difficult time, but were still able to achieve a prestigious position in the academy and conduct impactful scientific research. Engaging industry leaders and non-academic researchers to attend classes and discuss the same topics could help students see that a variety of careers are open to them even if they currently find a topic or class difficult. If faculty do not foreshadow struggle through their academic program, they can inadvertently suggest that difficulty is not a necessary aspect of learning advanced material.

**For Policy Makers**

A central finding of this study is that participants perceived STEM fields as exclusionary as a result of perceived difficulty and a belief that innate ability was at least partially required to participate. These perceptions are barriers to students' entry into science careers. It is possible that in trying to promote these fields of study, past policies and casual discussion implied that only the particularly talented could be engaged in these majors. Take, for instance, that the

National Defense Education Act (NDEA)—the foundation of much of the scientific research and science educational structure in the U.S.—also included a significant amount of funding for gifted programs (Fleming, 1960; Jolly, 2009). The effects of the NDEA are still felt today, through the development of specialized STEM schools (Thomas & Williams, 2009) and discussions of "Big Science" and "Best Science," which focus on how the majority of grant funding is allocated to a small number of prestigious, highly selective postsecondary institutions (Thelin, 2011).

As reported by participants, these policies are replicated within individual schools through tracking practices. The students with the highest test scores are selected for gifted/honors programs in elementary and middle school and then AP/IB courses in high school. In the liberal arts and social science fields, this has few repercussions, as AP and IB English and history courses generally grant credit for core curricular courses that are required for every major. In contrast, AP and IB mathematics and science courses often lead to college course credit in gateway courses for mathematics-intensive science fields. In the case of the institution of interest, for instance, on-time completion of a CEP major can hinge on being granted or earning calculus credit within the first year, as it is a pre-requisite for major coursework. If the student does not enter the institution with calculus credit, they must complete two courses prior to enrolling in the first of the four-course calculus sequence. In addition, once in college students perceive continuing tracking practices through weed-out cultures. Classes that result in one-third to one-half loss of students in the major, and implications from faculty, staff, and older students that these majors require innate ability or extreme effort create an exclusionary atmosphere.

Therefore, in order to increase participation in STEM fields, policy makers and practitioners across the P-16 educational pipeline should acknowledge and work to dismantle the insinuation that only the innately talented can eventually become successful scientists. This can be achieved in many ways. First, teachers and administrators can engage the suite of mindset interventions currently available to schools to encourage students at an early age to regard math and science learning as flexible (Dweck, 2017). Teachers and parents may additionally frame students' entry into or exclusion from advanced coursework as rewards for hard work or opportunities to continue building knowledge, respectively, rather than signals of innate ability. Further, curricula should be more flexible to allow more students to engage in advanced coursework in high school that would expose them to college-level mathematics and science material.

## Conclusion

This dissertation built upon previous research on ability beliefs and participation in STEM. The framework presented here shows connections between perceived need for talent in STEM, perceived innate ability in science and mathematics domains, participation in these fields, and identity. These factors shape and are shaped by the educational experience. The findings presented here provide one aspect of the major choice-making process, illuminating how perceptions of ability and talent influence decisions to participate in STEM.

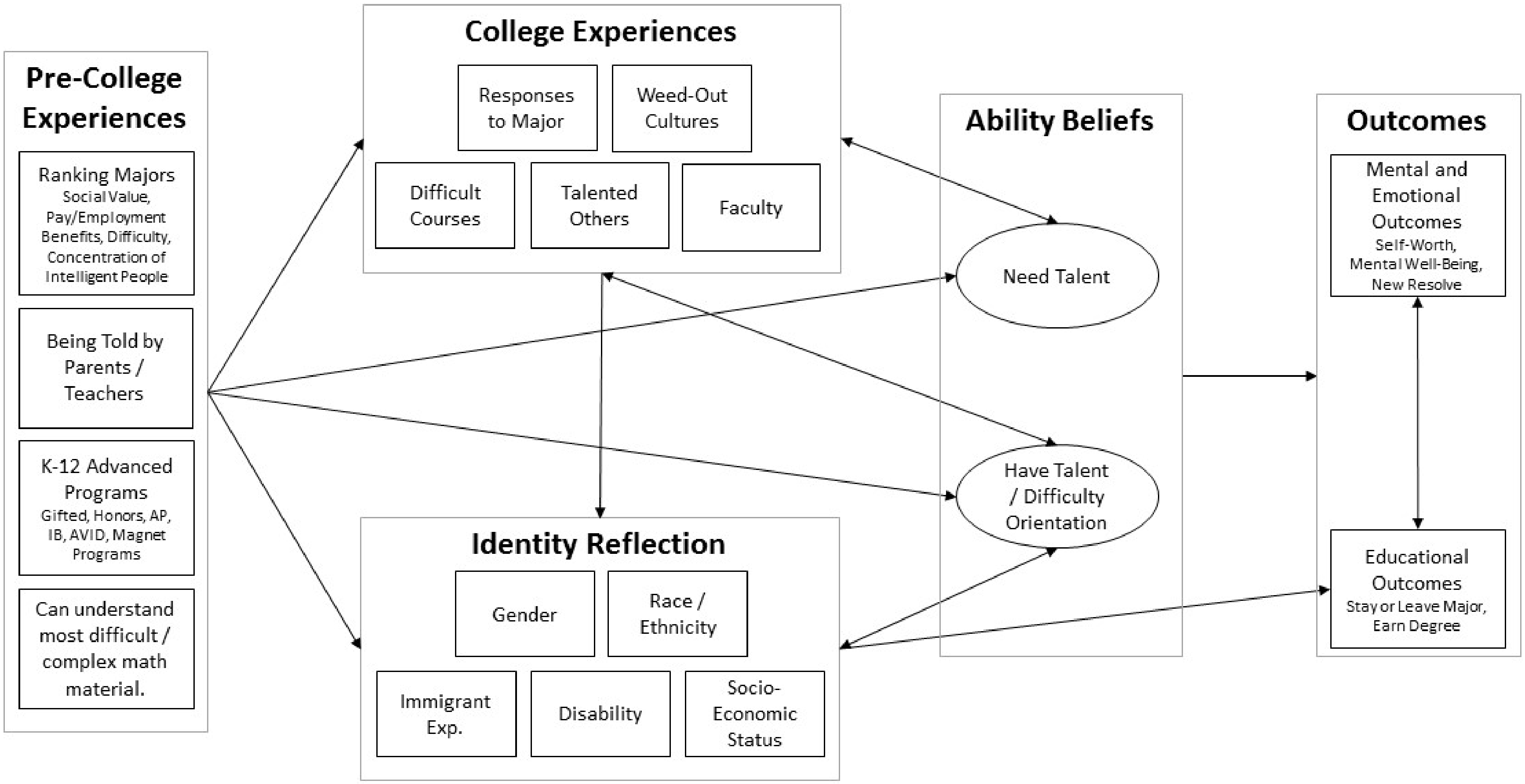


Figure 12. Hypothesized Theoretical Framework of Difficulty and Talent Beliefs that Emerged from the Two Dissertation Studies

# APPENDIX A

# HUMAN SUBJECTS BOARD APPROVAL & CONSENT FORM

Florida State
UNIVERSITY

Office of the Vice President For Research
Human Subjects Committee
P. O. Box 3062742
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

RE-APPROVAL MEMORANDUM

Date: 08/21/2017

To: Samantha Nix

Address: 4452

Dept.: EDUCATIONAL LEADERSHIP

From: Thomas L. Jacobson, Chair

Re: Re-approval of Use of Human subjects in Research:
Exclusivity Through Challenge: Perceptions of Difficulty in Mathematics-Intensive STEM Fields at the Intersection of Race/Ethnicity and Gender

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 08/20/2018 , you are must request renewed approval by the Committee.

If you submitted a proposed consent form with your renewal request, the approved stamped consent form is attached to this re-approval notice. Only the stamped version of the consent form may be used in recruiting of research subjects. You are reminded that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report in writing, any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chairman of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc:
HSC No. 2017.21692

**Interview Consent Form**

**Information and Purpose:** Some studies have suggested that there is a social belief that mathematics and science fields are overly challenging and require innate talent or brilliance. The overarching purpose of this study is to understand how college students perceived mathematics and science fields in adolescence and in college. Participating students in this study are seniors in any field, but who spent at least two semesters in a physics, engineering, and/or computer science major. The first interview will focus on experiences before college and the second interview will focus on college experiences. This consent form will be read and signed at each interview.

**Your Participation**: Participation in the study entails two, one-hour or one, two-hour interviews focused on pre-college and college experiences with science and mathematics. Participation in the research is voluntary and you may refuse to answer a question at no penalty to you.

**Benefits and Risks:** There is minimal risk associated with participation in this study. Your participation could help advance understanding of how students perceive mathematics and science fields. If you do choose to participate, you will additionally receive a $10 Amazon gift card for each interview hour to compensate you for your time.

**Confidentiality:** The interview will be recorded for analysis, but your name will not be recorded or associated with any written report of the research. I will only record your name and contact information so I can send you a transcript of the interview for your approval. I will keep your private information confidential to the extent allowed by law.

**Contact:** If you have questions, you can contact me at ________ or ____________. You may also contact my research advisor, Dr. Lara Perez-Felkner at ________________. If you have questions and you do not feel comfortable asking me or Dr. Perez-Felkner, you may contact the Florida State University Institutional Review Board at 850-644-8633 or at humansubjects@magnet.fsu.edu.

**By signing below, you acknowledge that we spoke about the project, its risks and benefits, and my efforts to protect your privacy.** Participation in this study is voluntary and you may refuse to answer a question at no penalty to you. In addition, you may discontinue your participation in this research at any time at no penalty to you.

Signature: ________________________________________ Date: _________________

Print Name: ____________________________________________

# APPENDIX B

# APPENDIX TABLES

Table 7. Sample Missingness

| | Estimated Frequency |
|---|---|
| *Demographic Characteristics* | |
| Gender | 0 |
| Race-Ethnicity | 0 |
| Parent Education | 1,570 |
| Family Income | 2,880 |
| *High School Experiences* | |
| 10th Grade Standardized Math Test Scores | 660 |
| 10th Grade Standardized Reading Test Scores | 760 |
| Science Pipeline | 940 |
| High School GPA | 960 |
| Values Mathematics | 2,870 |
| *High School Characteristics* | |
| Free and Reduced Price Lunch | 3,080 |
| Region | 0 |
| Urbanicity | 0 |
| *College Experiences and First Post-Secondary Institutional Characteristics* | |
| Research with Faculty Outside of Class | 3,280 |
| Control of First Attended Institution | 1,730 |
| Type and Selectivity of First Attended Institution | 1,730 |
| *Difficulty Orientations* | |
| General Academic Scale | 3,610 |
| Verbal Scale | 3,330 |
| Mathematics Scale | 3,460 |
| *Major and Degree Outcomes* | |
| Declared Major | 4,470 |
| Degree Major | 5,880 |

*Note*. $n$ = 11,540 respondents from the National Center for Education Statistics' Education Longitudinal Study 2002/2012 restricted data. Restricted-use NCES data requires rounding all unweighted sample descriptive statistics to the nearest 10.

Table 8. Items, Factor Loadings, and Scoring Coefficients Used to Develop Difficulty Orientation Scales

| Question | Factor Loadings | Scoring Coefficients |
|---|---|---|
| *General Scale* | *Eigenvalue = 0.8* | |
| When I sit myself down to learn something really hard, I can learn it. | 0.6 | 0.4 |
| When studying, I keep working even if the material is difficult. | 0.6 | 0.4 |
| *Verbal Scale* | *Eigenvalue = 1.4* | |
| I'm certain I can understand the most difficult material presented in English texts. | 0.8 | 0.5 |
| I'm confident I can understand the most complex material presented by my English teacher. | 0.8 | 0.5 |
| *Mathematics Scale* | *Eigenvalue = 1.4* | |
| I'm certain I can understand the most difficult material presented in math texts. | 0.8 | 0.5 |
| I'm confident I can understand the most complex material presented by my math teacher. | 0.8 | 0.5 |

*Note*. $n$ = 11,540 respondents from the National Center for Education Statistics' Education Longitudinal Study 2002/2012 restricted data. Scales were estimated using factor analysis without rotation. Stata 14's regression method provides both factor loadings and scoring coefficients. Items were chosen based on its domain-specific expression of participants' perceived ability with challenging or difficult material.

Table 9. Sample Descriptive Statistics

| | % or Mean | SE | Min | Max |
|---|---|---|---|---|
| *Demographic Characteristics* | | | | |
| Gender | | | | |
| Men | 48.4% | 0.7% | 0.0 | 100.0 |
| Women | 51.6% | 0.7% | 0.0 | 100.0 |
| Race-Ethnicity | | | | |
| White | 63.8% | 1.1% | 0.0 | 100.0 |
| Asian/Pacific Islander | 5.0% | 0.3% | 0.0 | 100.0 |
| Black | 13.0% | 0.7% | 0.0 | 100.0 |
| Latino | 13.6% | 0.8% | 0.0 | 100.0 |
| Other | 4.6% | 0.4% | 0.0 | 100.0 |
| Parent Education | | | | |
| High School or Less | 21.2% | 0.8% | 0.0 | 100.0 |
| Some College | 31.9% | 0.8% | 0.0 | 100.0 |
| Bachelor's Degree | 28.0% | 0.7% | 0.0 | 100.0 |
| More Than a Bachelor's Degree | 18.9% | 0.7% | 0.0 | 100.0 |
| Family Income | | | | |
| Up to $25,000 | 16.6% | 0.7% | 0.0 | 100.0 |
| $25,001-$50,000 | 27.5% | 0.7% | 0.0 | 100.0 |
| $50,001-$75,000 | 25.1% | 0.8% | 0.0 | 100.0 |
| $75,001-$100,000 | 14.6% | 0.6% | 0.0 | 100.0 |
| $100,0001 or more | 16.2% | 0.7% | 0.0 | 100.0 |
| | | | | |
| *High School Experiences* | | | | |
| 10th Grade Standardized Test Scores | | | | |
| Math (mean) | 53.2 | 0.2 | 19.4 | 86.7 |
| Reading (mean) | 53.0 | 0.2 | 23.6 | 78.8 |
| Science Pipeline | | | | |
| Chemistry I or Physics I and Below | 59.6% | 1.0% | 0.0 | 100.0 |
| Chemistry I and Physics I | 19.8% | 0.9% | 0.0 | 100.0 |
| Chemistry II and Physics II | 20.6% | 0.9% | 0.0 | 100.0 |
| High School GPA (mean) | 2.8 | 0.0 | 0.0 | 4.0 |
| Values Mathematics (mean) | 2.5 | 0.0 | 1.0 | 4.0 |
| Growth Mindset | 3.0 | 0.7 | 1.0 | 4.0 |
| | | | | |
| *High School Characteristics* | | | | |
| Free and Reduced Price Lunch | | | | |
| 0-5% | 21.1% | 1.5% | 0.0 | 100.0 |
| 6-20% | 25.2% | 1.6% | 0.0 | 100.0 |
| 21-50% | 37.2% | 1.7% | 0.0 | 100.0 |
| 50-100% | 16.5% | 1.2% | 0.0 | 100.0 |
| Region | | | | |

Table 9 - continued

| | % or Mean | SE | Min | Max |
|---|---|---|---|---|
| Northeast | 19.9% | 0.9% | 0.0 | 100.0 |
| Midwest | 24.7% | 0.8% | 0.0 | 100.0 |
| South | 33.7% | 0.9% | 0.0 | 100.0 |
| West | 21.7% | 0.9% | 0.0 | 100.0 |
| Urbanicity | | | | |
| Urban | 31.0% | 0.9% | 0.0 | 100.0 |
| Suburban | 50.4% | 1.0% | 0.0 | 100.0 |
| Rural | 18.7% | 0.8% | 0.0 | 100.0 |
| *College Experiences and First Post-Secondary Institutional Characteristics* | | | | |
| Research with Faculty Outside of Class | 12.5% | 0.5% | 0.0 | 100.0 |
| Public Institution | 76.6% | 0.7% | 0.0 | 100.0 |
| Type and Selectivity | | | | |
| 2-year or Less Institution | 38.0% | 1.0% | 0.0 | 100.0 |
| 4-year Institution, Inclusive | 16.6% | 0.7% | 0.0 | 100.0 |
| 4-year Institution, Moderately Selective | 25.0% | 0.7% | 0.0 | 100.0 |
| 4-year Institution, Highly Selective | 20.3% | 0.8% | 0.0 | 100.0 |

*Note*. *n* = 11,540 respondents from the National Center for Education Statistics' Education Longitudinal Study 2002/2012 restricted data. Restricted-use NCES data requires rounding these descriptive results to the nearest tenth.

Table 10. Sample Descriptive Statistics on Dependent Variables by Gender

| | Men | Women | Min | Max |
|---|---|---|---|---|
| *Declared Major* | | | | |
| Undecided | 29.1% | 23.3% | 0.0 | 100.0 |
| | (1.4%) | (1.1%) | | |
| Non-STEM | 39.3% | 45.0% | 0.0 | 100.0 |
| | (1.4%) | (1.1%) | | |
| Mathematics-Intensive Sciences | 13.4% | 3.2% | 0.0 | 100.0 |
| | (0.7%) | (0.4%) | | |
| Biological Sciences | 4.1% | 4.2% | 0.0 | 100.0 |
| | (0.5%) | (0.4%) | | |
| Health Sciences | 3.3% | 12.3% | 0.0 | 100.0 |
| | (0.4%) | (0.8%) | | |
| Other Sciences | 10.8% | 11.9% | 0.0 | 100.0 |
| | (0.7%) | (0.6%) | | |
| *Degree Major* | | | | |
| Non-STEM | 63.2% | 62.9% | 0.0 | 100.0 |
| | (1.6%) | (1.4%) | | |
| Mathematics-Intensive Sciences | 12.4% | 2.9% | 0.0 | 100.0 |
| | (0.9%) | (0.4%) | | |
| Biological Sciences | 5.4% | 4.6% | 0.0 | 100.0 |
| | (0.7%) | (0.5%) | | |
| Health Sciences | 2.7% | 10.3% | 0.0 | 100.0 |
| | (0.5%) | (0.7%) | | |
| Other Sciences | 16.2% | 19.3% | 0.0 | 100.0 |
| | (1.3%) | (1.0%) | | |

*Note*. $n$ = 11,540 respondents from the National Center for Education Statistics' Education Longitudinal Study 2002/2012 restricted data. Restricted-use NCES data requires rounding these descriptive results to the nearest tenth. Mathematics-intensive sciences includes the physical sciences, engineering, and computer sciences.

Table 11. Sample Descriptive Statistics on Dependent Variables by Race/Ethnicity

| | White | Asian/Pacific Islander | Black | Latino | Other | Min | Max |
|---|---|---|---|---|---|---|---|
| *Declared Major* | | | | | | | |
| Undecided | 24.6% | 27.7% | 25.0% | 33.2% | 26.6% | 0.00 | 100.00 |
| | (1.2%) | (1.9%) | (2.0%) | (3.1%) | (3.6%) | | |
| Non-STEM | 44.0% | 31.2% | 41.8% | 39.3% | 40.8% | 0.00 | 100.00 |
| | (1.2%) | (2.0%) | (2.1%) | (2.8%) | (4.5%) | | |
| Mathematics-Intensive Sciences | 7.8% | 12.0% | 10.7% | 5.8% | 8.1% | 0.00 | 100.00 |
| | (0.5%) | (1.4%) | (1.4%) | (1.3%) | (2.3%) | | |
| Biological Sciences | 4.3% | 8.3% | 3.5% | 2.9% | 3.7% | 0.00 | 100.00 |
| | (0.4%) | (1.1%) | (0.7%) | (0.7%) | (1.8%) | | |
| Health Sciences | 7.4% | 9.2% | 10.2% | 7.8% | 8.8% | 0.00 | 100.00 |
| | (0.5%) | (1.2%) | (1.1%) | (1.3%) | (2.3%) | | |
| Other Sciences | 11.9% | 11.6% | 8.8% | 11.1% | 12.0% | 0.00 | 100.00 |
| | (0.6%) | (1.5%) | (1.3%) | (1.5%) | (2.5%) | | |
| *Degree Major* | | | | | | | |
| Non-STEM | 64.1% | 50.1% | 63.9% | 62.3% | 61.6% | 0.00 | 100.00 |
| | (1.3%) | (2.2%) | (2.6%) | (2.8%) | (4.4%) | | |
| Mathematics-Intensive Sciences | 8.0% | 11.4% | 6.7% | 5.3% | 5.5% | 0.00 | 100.00 |
| | (0.6%) | (1.5%) | (1.2%) | (1.0%) | (1.6%) | | |
| Biological Sciences | 4.8% | 11.4% | 3.9% | 4.0% | 5.8% | 0.00 | 100.00 |
| | (0.5%) | (1.3%) | (1.0%) | (0.9%) | (2.2%) | | |
| Health Sciences | 6.7% | 7.2% | 7.5% | 5.5% | 6.6% | 0.00 | 100.00 |
| | (0.7%) | (1.1%) | (1.3%) | (1.2%) | (2.5%) | | |
| Other Sciences | 16.4% | 19.8% | 18.0% | 22.9% | 20.5% | 0.00 | 100.00 |
| | (0.9%) | (2.1%) | (1.9%) | (2.8%) | (3.4%) | | |

*Note. n* = 11,540 respondents from the National Center for Education Statistics' Education Longitudinal Study 2002/2012 restricted data. Restricted-use NCES data requires rounding these descriptive results to the nearest tenth. Mathematics-intensive sciences includes the physical sciences, engineering, and computer sciences.

# APPENDIX C

# QUALITATIVE INTERVIEW PROTOCOL

GROWING UP

- Where did you grow up?
- What was math and science like for you growing up?
- What did you like about math and science? Did you like one over the other? Why?
- Tell me about the math and science courses you took? What did you think of those courses?

PRE-COLLEGE BELIEFS

- When you thought about a successful scientist, what was the image that came to mind? What about in your current field of study?
- What qualities did you think was necessary to be a successful student in these fields?
- What made you interested in science?

IDENTITY

- Was your race/ethnicity and gender identity relevant growing up? In what ways?

CHOOSING A MAJOR

- What major did you choose when you entered FSU? Why?
- What did people say when you told them that was your major choice?
    - Did this differ based on who you talked to? How?
    - What did you think when they said these types of things?
    - Did you agree or disagree? Has that changed?
- Have you changed your major since starting at FSU? What factors led to that?

COLLEGE EXPERIENCES AND BELIEFS

- STEM experiences in general…
    - What was most helpful?
    - What was least helpful?
    - Who did you have connections with? Why?

- Tell me about your department. What type of people are in the major? What about the professors?
    - What qualities do you think people value in your major?
    - What about your friends or peers in the major. What do they value?
    - What do you like most about your major? Least?

- How do you measure success in your major? Failure? Why, how did that develop?

CHALLENGE

- Challenging courses:
    - According to others
    - According to you

- What did people say about the math courses?

- Tell me about a time when you felt challenged in your major
    - What was challenging / how was it challenging?
    - What did you think about it and yourself?
    - What did you know about yourself, what did you worry about?
    - What did you do?

- Tell me about a time when you felt overwhelmed in your major
    - Does it differ from simply feeling challenged? Why?
    - (Ask questions above)

CULTURAL STEREOTYPES

- Hierarchy of majors…

- Pointing out people of different majors.

CLOSING OUT

- Did you feel connected to the campus while at the university?
    - In what ways?
    - Was that important to your studies?
    - Did that differ from your feeling of connection to your department? Why?

- Looking back, what would you tell your younger self about your college experience in general? In your major?

- Is there anything about your college experiences with math and science that you'd like me to know?

# REFERENCES

AAPA. (1996). Statement on Biological Aspects of Race. *American Journal of Physical Anthropology, 101*, 569-570.

Adelman, C. (2006). *The toolbox revisited: Paths to degree completion from high school through college*. Washington, D.C.: U.S. Department of Education Retrieved from http://www2.ed.gov/rschstat/research/pubs/toolboxrevisit/toolbox.pdf.

Anderson, E. L., & Kim, D. (2006). *Increasing the success of minority students in science and technology*: American Council on Education Washington, DC.

Augustine, N. R. (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215. doi:http://dx.doi.org/10.1037/0033-295X.84.2.191

Bazelais, P., Lemay, D. J., & Doleck, T. (2016). How does grit impact college students' academic achievement in science? *European Journal of Science and Mathematics Education, 4*(1), 33-43.

Beddos, K., & Borrego, M. (2011). Feminist Theory in Three Engineering Education Journals: 1995–2008. *Journal of Engineering Education, 100*(2), 281-303.

Beilock, S. L. (2008). Math Performance in Stressful Situations. *Current Directions in Psychological Science, 17*(5), 339-343. doi:10.1111/j.1467-8721.2008.00602.x

Berryman, S. E. (1983). *Who Will Do Science? Trends, and Their Causes in Minority and Female Representation among Holders of Advanced Degrees in Science and Mathematics. A Special Report*. Retrieved from New York: http://www.eric.ed.gov/ERICWebPortal/detail?accno=ED245052

Bonous-Hammarth, M. (2000). Pathways to success: Affirming opportunities for science, mathematics, and engineering majors. *Journal of Negro Education, 69*(1-2), 92-111.

Brint, S., Cantwell, A. M., & Hanneman, R. A. (2008). The two cultures of undergraduate academic engagement. *Research in Higher Education, 49*(5), 383-402.

Brown, S. C., Stevens, R. A., Troiano, P. F., & Schneider, M. K. (2002). Exploring complex phenomena: Grounded theory in student affairs research. *Journal of College Student Development, 43*, 173-183.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187-1218. doi:10.1002/tea.20237

Ceci, S. J., Williams, W. M., & Barnett, S. M. (2009). Women's underrepresentation in science: Sociocultural and biological considerations. *Psychological Bulletin, 135*(2), 218-261. doi:10.1037/a0014412

Chang, M. J., Eagan, M. K., Lin, M. H., & Hurtado, S. (2011). Considering the Impact of Racial Stigmas and Science Identity: Persistence among Biomedical and Behavioral Science Aspirants. *The Journal of Higher Education, 82*(5), 564-596. doi:10.1080/00221546.2011.11777218

Chang, M. J., Sharkness, J., Hurtado, S., & Newman, C. B. (2014). What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. *Journal of Research in Science Teaching, 51*(5), 555-580. doi:10.1002/tea.21146

Charles, M. (2011). A world of difference: international trends in women's economic status. *Annual review of sociology, 37*, 355-371.

Charles, M., & Bradley, K. (2009). Indulging Our Gendered Selves? Sex Segregation by Field of Study in 44 Countries. *American Journal of Sociology, 114*(4), 924-976.

Charleston, L. J., Adserias, R. P., Lang, N. M., & Jackson, J. F. L. (2014). Intersectionality and STEM: The Role of Race and Gender in the Academic Pursuits of African American Women in STEM. *Journal of Progressive Policy and Practice*, *2*(3), 273-293.

Charleston, L. J., George, P. L., Jackson, J. F. L., Berhanu, J., & Amechi, M. H. (2014). Navigating underrepresented STEM spaces: Experiences of Black women in U.S. computing science higher education programs who actualize success. *Journal of Diversity in Higher Education, 7*(3), 166-176. doi:10.1037/a0036632

Chen, X. (2009). Students Who Study Science, Technology, Engineering, and Mathematics (STEM) in Postsecondary Education. Stats in Brief. NCES 2009-161. *National Center for Education Statistics*.

Cheryan, S., Master, A., & Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: increasing girls' interest in computer science and engineering by diversifying stereotypes. *Frontiers in Psychology, 6*, 49. doi:10.3389/fpsyg.2015.00049

Cheryan, S., Plaut, V. C., Davies, P. G., & Steele, C. M. (2009). Ambient belonging: How stereotypical cues impact gender participation in computer science. *Journal of personality and social psychology, 97*(6), 1045-1060. doi:10.1037/a0016239

Cho, S., Crenshaw, K., & McCall, L. (2013). Toward a Field of Intersectionality Studies: Theory, Applications, and Praxis. *Signs*, *38*(4), 785-810.

Cole, D., & Espinoza, A. (2008). Examining the academic success of latino students in science technology engineering and mathematics (STEM) majors. *Journal of College Student Development*, *49*(4), 285-300.

Cole, E. R. (2009). Intersectionality and research in psychology. *American Psychologist, 64*(3), 170-180. doi:10.1037/a0014564

Corbett, C., & Hill, C. (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Retrieved from AAUW: http://www.aauw.org/files/2015/03/Solving-the-Equation-report-nsa.pdf

Corbin, J., & Strauss, A. (2015). *Basics of Qualitative Reserach: Techniques and Procedures for Developing Grounded Theory* (Vol. 4). Los Angeles: Sage.

Correll, S. J. (2001). Gender and the Career Choice Process: The Role of Biased Self-Assessments. *The American Journal of Sociology, 106*(6), 1691-1730.

Cowan, C. D., Hauser, R. M., Kominski, R. A., Levin, H. M., Lucas, S. R., Mogan, S. L., . . . Chapman, C. (2012). *Improving the Measurement of Socioeconomic Status for the National Assessment of Educational Progress: A Theoretical Foundation*. Retrieved from

Cox, B. E., McIntosh, K., Reason, R. D., & Terenzini, P. T. (2014). Working with Missing Data in Higher Education Research: A Primer and Real-World Example. *The Review of Higher Education, 37*(3), 377-402. doi:10.1353/rhe.2014.0026

Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *The University of Chicago Legal Forum*, 139-167.

Crenshaw, K. (1991). Mapping the Margins: Intersectionality, Identity Politics, and Violence against Women of Color. *Stanford Law Review, 43*(6), 1241-1299.

Creswell, J. W. (2013). Steps in Conducting a Scholarly Mixed Methods Study. *DBER Spekaer Series, 48*.

Creswell, J. W., & Clark, V. L. P. (2007). *Designing and Conducting Mixed Methods Research* (2nd ed.). Los Angeles: mHochschle Liechtenstein Bibliothek.

Cribbs, J. D., Hazari, Z., Sonnert, G., & Sadler, P. M. (2015). Establishing an Explanatory Model for Mathematics Identity. *Child development, 86*(4), 1048-1062. doi:10.1111/cdev.12363

Csíkszentmihályi, M. (1990). *Flow: The psychology of optimal experience: Steps toward enhancing the quality of life*. New York: Harper & Row.

Csíkszentmihályi, M., & Csikszentmihályi, I. S. (Eds.). (1988). *Optimal experience: Psychological studies of flow in consciousness*. New York: Cambridge University Press.

Csíkszentmihályi, M., & Schneider, B. L. (2000). *Becoming adult: How teenagers prepare for the world of work*. New York: Basic Books.

Cunningham, B. C., Hoyer, K. M., & Sparks, D. (2015). *Gender Differences in Science, Technology, Engineering, and Mathematics (STEM) Interest, Credits Earned, and NAEP Performance in the 12th Grade*. (NCES 2015-075). Washington, D.C.: National Center for Education Statistics Retrieved from http://nces.ed.gov/pubs2015/2015075.pdf.

Dalton, B., Ingels, S. J., Downing, J., & Bozick, R. (2007). *Advanced Mathematics and Science Coursetaking in the Spring High School Senior Classes of 1982, 1992, and 2004: Statistical Analysis Report*. Retrieved from National Center for Education Statistics, Institute for Education Sciences:

Deboer, G. E. (1984). Factors related to the decision of men and women to continue taking science courses in college. *Journal of Research in Science Teaching, 21*(3), 325-329. doi:10.1002/tea.3660210309

DeCaro, M. S., Rotar, K. E., Kendra, M. S., & Beilock, S. L. (2010). Diagnosing and alleviating the impact of performance pressure on mathematical problem solving. *The Quarterly Journal of Experimental Psychology, 63*(8), 1619-1630. doi:10.1080/17470210903474286

DeNavas-Walt, C., & Proctor, B. D. (2014). *Income and Poverty in the United States: 2013*. (P60-249). Washington, D.C.: U.S. Government Printing Office Retrieved from http://www.census.gov/content/dam/Census/library/publications/2014/demo/p60-249.pdf.

Denissen, J. J. A., Zarrett, N. R., & Eccles, J. S. (2007). I Like to Do It, I'm Able, and I Know I Am: Longitudinal Couplings Between Domain-Specific Achievement, Self-Concept, and Interest. *Child development, 78*(2), 430-447. doi:10.1111/j.1467-8624.2007.01007.x

Duckworth, A. L. (2016). *Grit: The Power of Passion and Perseverance*. New York: Scribner.

Duckworth, A. L., & Gross, J. J. (2014). Self-Control and Grit: Related but Separable Determinants of Success. *Curr Dir Psychol Sci, 23*(5), 319-325. doi:10.1177/0963721414541462

Duckworth, A. L., Peterson, C., Matthews, M. D., & Kelly, D. R. (2007). Grit: perseverance and passion for long-term goals. *J Pers Soc Psychol, 92*(6), 1087-1101. doi:10.1037/0022-3514.92.6.1087

Duckworth, A. L., & Quinn, P. D. (2009). Development and validation of the short grit scale (grit-s). *J Pers Assess, 91*(2), 166-174. doi:10.1080/00223890802634290

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality, and development*: Psychology Press.

Dweck, C. S. (2006). *Mindset: The new psychology of success*: Random House LLC.

Dweck, C. S. (2007). Is Math a Gift? Beliefs that Put Females at Risk. In S. C. Ceci & W. M. Williams (Eds.), *Why Aren't More Women in Science? Top Researchers Debate the Evidence* (pp. 47-55). Washington, D.C.: American Psychological Association.

Dweck, C. S. (2008). *Mindsets and math/science achievement*. Retrieved from New York, NY:

Dweck, C. S. (2017). Mindset. Retrieved from https://mindsetonline.com/

Eccles, J. S. (1987). Gender Roles and Women's Achievement-Related Decisions. *Psychology of Women Quarterly, 11*(2), 135-172. doi:10.1111/j.1471-6402.1987.tb00781.x

Eccles, J. S. (1994). Understanding Women's Educational and Occupational Choices. *Psychology of Women Quarterly, 18*(4), 585-609. doi:10.1111/j.1471-6402.1994.tb01049.x

Eccles, J. S. (2005). Studying gender and ethnic differences in participation in math, physical science, and information technology. *New Directions for Child and Adolescent Development, 2005*(110), 7-14. doi:10.1002/cd.146

Eccles, J. S. (2011). Understanding educational and occupational choices. *Journal of Social Issues, 67*(3), 644-648.

Eccles, J. S. (2015). *Gendered Socialization of STEM Interests in the Family*. Paper presented at the 2nd Network Gender & STEM Conference, Berlin, Germany.

Eccles Parsons, J., Adler, T. F., & Kaczala, C. M. (1982). Socialization of Achievement Attitudes and Beliefs: Parental Influences. *Child development, 53*(2), 310-321.

Eisenhart, M. A., & Finkel, E. (1998). *Women's science: Learning and succeeding from the margins*. Chicago, IL: University of Chicago Press.

Else-Quest, N. M., Mineo, C. C., & Higgins, A. (2013). Math and Science Attitudes and Achievement at the Intersection of Gender and Ethnicity. *Psychology of Women Quarterly, 37*(3), 293-309. doi:10.1177/0361684313480694

Evans, N. J., Forney, D. S., Guido, F. M., Patton, L. D., & Renn, K. A. (2010). *Student Development in College* (2nd ed.). San Francisco, CA: Jossey-Bass.

Ferguson, D. M., Cawthorne Jr, J. E., Ahn, B., & Ohland, M. W. (2013). Engineering Innovativeness. *The Journal of Engineering Entrepreneurship, 4*(1), 1-16. doi:10.7814/jeen5v3p1fcah

Fleming, A. S. (1960). The philosophy and objectives of the National Defense Education Act. *Annals of the American Academy of Political and Social Science, 327*, 132-138.

Fletcher, D., & Sarkar, M. (2013). Psychological resilience: A review and critique of definitions, concepts, and theory. *European Psychologist, 18*(1), 12-23. doi:10.1027/1016-9040/a000124

Fletcher, J., & Tienda, M. (2010). Race and Ethnic Differences in College Achievement: Does High School Attended Matter? *The ANNALS of the American Academy of Political and Social Science, 627*(1), 144-166. doi:10.1177/0002716209348749

Gable, S. L., & Haidt, J. (2005). What (and why) is positive psychology? *Review of General Psychology, 9*(2), 103-110. doi:10.1037/1089-2680.9.2.103

Good, C., Aronson, J., & Harder, J. A. (2008). Problems in the pipeline: Stereotype threat and women's achievement in high-level math courses. *Journal of Applied Developmental Psychology, 29*(1), 17-28. doi:http://dx.doi.org/10.1016/j.appdev.2007.10.004

Good, C., Aronson, J., & Inzlicht, M. (2003). Improving adolescents' standardized test performance: An intervention to reduce the effects of stereotype threat. *Journal of Applied Developmental Psychology, 24*(6), 645-662. doi:http://dx.doi.org/10.1016/j.appdev.2003.09.002

Griffith, A. L. (2010). Persistence of women and minorities in STEM field majors: Is it the school that matters? *Economics of Education Review, 29*(6), 911-922. doi:10.1016/j.econedurev.2010.06.010

Guay, F., Marsh, H. W., & Boivin, M. (2003). Academic self-concept and academic achievement: Developmental perspectives on their causal ordering. *Journal of Educational Psychology, 95*(1), 124-136. doi:10.1037/0022-0663.95.1.124

Hall, R. M., & Sandler, B. R. (1982). *The Classroom Climate: A Chilly One for Women?* (HE 014 909). Washington, D.C.: Association of American Colleges.

Hall, R. M., & Sandler, B. R. (1984). *Out of the Classroom: A Chilly Campus Climate for Women?* (HE 017 963). Washington, D.C.: Association of American Colleges.

Hanson, S. L. (2004). African American Women in Science: Experiences from High School through the Post-Secondary Years and Beyond. *NWSA Journal, 16*(1), 96-115. doi:10.1353/nwsa.2004.0033

Harper, S. R., Wardell, C. C., & McGuire, K. M. (2011). Man of Multiple Identities: Complex Individuality and Identity Intersectionality among College Men *Masculinities in Higher Education: Theoretical and Practical Considerations* (pp. 81-96): Taylor and Francis.

Hedges, L. V., & Nowell, A. (1995). Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science, 269*(5220), 41.

Hill, C., Corbett, C., & St Rose, A. (2010). *Why So Few? Women in Science, Technology, Engineering, and Mathematics*: ERIC.

Hirschman, C. (2004). The Origins and Demise of the Concept of Race. *Population and Development Review, 30*(3), 385-415.

Hu, T., Zhang, D., & Wang, J. (2015). A meta-analysis of the trait resilience and mental health. *Personality and Individual Differences, 76*, 18-27. doi:10.1016/j.paid.2014.11.039

Hurtado, S., Cabrera, N. L., Lin, M. H., Arellano, L., & Espinosa, L. L. (2009). Diversifying Science: Underrepresented Student Experiences in Structured Research Programs. *Research in Higher Education, 50*, 189–214. doi:10.1007/s11162-008-9114-7

Hurtado, S., Eagan, M. K., Tran, M. C., Newman, C. B., Chang, M. J., & Velasco, P. (2011). “We Do Science Here”: Underrepresented Students’ Interactions with Faculty in Different College Contexts. *Journal of Social Issues, 67*(3), 553-579. doi:10.1111/j.1540-4560.2011.01714.x

Hurtado, S., Newman, C. B., Tran, M. C., & Chang, M. J. (2010). Improving the rate of success for underrepresented racial minorities in STEM fields: Insights from a national project. *New Directions for Institutional Research, 2010*(148), 5-15. doi:10.1002/ir.357

Hyde, J. S. (2005). The Gender Similarities Hypothesis. *American Psychologist, 60*(6), 581-592. doi:10.1037/0003-066X.60.6.581

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science, 321*(5888), 494-495.

Ingels, S. J., Pratt, D. J., Wilson, D., Burns, L. J., Currivan, D., Rogers, J. E., & Hubbard-Bednasz, S. (2007). *Education Longitudinal Study of 2002 (ELS:2002): Base Year to Second Follow-up Data File Documentation*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Jacobs, J. E., Lanza, S., Osgood, D. W., Eccles, J. S., & Wigfield, A. (2002). Changes in Children’s Self-Competence and Values: Gender and Domain Differences across Grades One through Twelve. *Child development, 73*(2), 509-527. doi:10.1111/1467-8624.00421

Jahn, J. L. S., & Myers, K. K. (2014). Vocational Anticipatory Socialization of Adolescents: Messages, Sources, and Frameworks That Influence Interest in STEM Careers. *Journal of Applied Communication Research, 42*(1), 85-106. doi:10.1080/00909882.2013.874568

Johnson, D. R. (2011). Women of color in science, technology, engineering, and mathematics (STEM). *New Directions for Institutional Research, 2011*(152), 75-85. doi:10.1002/ir.410

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher, 33*(7), 14–26.

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a Definition of Mixed Methods Research. *Journal of Mixed Methods Research, 1*(2), 112-133.

Jolly, J. L. (2009). The National Defense Education Act, current STEM initiative, and the gifted. *Gifted Child Today, 32*(2), 50-53.

Kerr, B., & McKay, R. (2013). Searching for Tomorrow's Innovators: Profiling Creative Adolescents. *Creativity Research Journal, 25*(1), 21-32. doi:10.1080/10400419.2013.752180

Klein, D. (2016). MIMRGNS: Stata module to run margins after mi estimate: IDEAS, Research Division, Federal Reserve Bank of St. Louis. Retrieved from https://ideas.repec.org/c/boc/bocode/s457795.html

Lane, T. B. (2016). Research Environments as Counterspaces? Examining Spaces that Inhibit and Support Science Identity Development for Black Students in STEM. *Urban Education Research and Policy Annuals, 4*(1), 160-169.

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). STEM: Good Jobs Now and for the Future. ESA Issue Brief# 03-11. *US Department of Commerce*.

Lazarus, R. S. (1991). Progress on a cognitive-motivational-relational theory of emotion. *American Psychologist, 46*(8), 819.

Leggon, C. B. (2006). Women in Science: Racial and Ethnic Differences and the Differences They Make. *The Journal of Technology Transfer, 31*(3), 325-333. doi:10.1007/s10961-006-7204-2

Leslie, S.-J., Cimpian, A., Meyer, M., & Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science, 347*(6219), 262-265. doi:10.1126/science.1261375

Liber, E., & Weisner, T. S. (2010). *Meeting the Practical Challenges of Mixed Methods Research* (C. Teddlie & A. Tashakkori Eds.). Thousand Oaks, CA: SAGE Publications, Inc.

Linley, P. A., Joseph, S., Harrington, S., & Wood, A. M. (2006). Positive psychology: Past, present, and (possible) future. *The Journal of Positive Psychology, 1*(1), 3-16. doi:10.1080/17439760500372796

Litzler, E., Samuelson, C., & Lorah, J. (2014). Breaking it Down: Engineering Student STEM Confidence at the Intersection of Race/Ethnicity and Gender. *Research in Higher Education, 55*(8), 810-832. doi:10.1007/s11162-014-9333-z

Lundy-Wagner, V. C., & Gasman, M. (2011). When gender issues are not just about women: reconsidering male students at historically Black colleges and universities. *Teachers College Record, 113*(5), 934-968.

Lundy-Wagner, V. C., Vultaggio, J., & Gasman, M. (2013). Preparing Underrepresented Students of Color for Doctoral Success: The Role of Undergraduate Institutions. *International Journal of Doctoral Studies, 8*.

Lutfey, K., & Mortimer, J. (2006). Development and Socialization through the Adult Life Course. In J. Delamater (Ed.), *Handbook of Social Psychology* (pp. 183-202): Springer US.

Ma, Y. (2011a). College major choice, occupational structure and demographic patterning by gender, race and nativity. *The Social Science Journal*, *48*(1), 112-129. doi:10.1016/j.soscij.2010.05.004

Ma, Y. (2011b). Gender differences in the paths leading to a STEM baccalaureate. *Social Science Quarterly*, *92*(5), 1169-1190.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education, 95*(5), 877-907. doi:10.1002/sce.20441

Mangels, J. A., Good, C., Whiteman, R. C., Maniscalco, B., & Dweck, C. S. (2012). Emotion blocks the path to learning under stereotype threat. *Social cognitive and affective neuroscience, 7*(2), 230-241.

Margolis, J., & Fisher, A. (2002). *Unlocking the Clubhouse: Women in Computing*. Cambridge, MA: The MIT Press.

Markus, H., & Wurf, E. (1987). The dynamic self-concept: A social psychological perspective. *Annual Review of Psychology, 38*, 299-337.

Marsh, H. W. (1986). Verbal and Math Self-Concepts: An Internal/External Frame of Reference Model. *American Educational Research Journal, 23*(1), 129-149. doi:10.3102/00028312023001129

Marsh, H. W. (1990). A multidimensional, hierarchical model of self-concept: Theoretical and empirical justification. *Educational Psychology Review, 2*(2), 77-172. doi:10.1007/BF01322177

Meyer, M., Cimpian, A., & Leslie, S.-J. (2015). Women Are Underrepresented in Fields Where Success is Believed to Require Brilliance. *Frontiers in Psychology, 6*. doi:10.3389/fpsyg.2015.00235

Museus, S. D., & Griffin, K. A. (2011). Mapping the margins in higher education: On the promise of intersectionality frameworks in research and discourse. *New Directions for Institutional Research, 2011*(151), 5-13. doi:10.1002/ir.395

Myers, K. K., Jahn, J. L. S., Gailliard, B. M., & Stoltzfus, K. (2010). Vocational Anticipatory Socialization (VAS): A Communicative Model of Adolescents' Interests in STEM. *Management Communication Quarterly, 25*(1), 87-120. doi:10.1177/0893318910377068

Nakamura, J., & Csikszentmihalyi, M. (2002). The concept of flow. In C. R. Snyder & S. J. Lopez (Eds.), *Handbook of positive psychology* (pp. 89-105). New York, NY: Oxford University Press.

Nix, S., Perez-Felkner, L. C., & Thomas, K. (2015). Perceived Mathematical Ability under Challenge: A Longitudinal Perspective on Sex Segregation among STEM Degree Fields. *Frontiers in Psychology, 6*. doi:10.3389/fpsyg.2015.00530

NSB. (2014). *Science and Engineering Indicators 2014* (NSB 14-01). Retrieved from Arlington, VA: http://www.nsf.gov/statistics/seind14/

NSF. (2011). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2011*. Retrieved from Arlington, VA: http://www.nsf.gov/statistics/wmpd/

NSF. (2013). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013* (Special Report NSF 13-304). Retrieved from Arlington, VA: www.nsf.gov/statistics/wmpd/

NSF. (2015). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015*. Retrieved from Arlington, VA: http://www.nsf.gov/statistics/wmpd/

O'Brien, L. T., Blodorn, A., Adams, G., Garcia, D. M., & Hammer, E. (2015). Ethnic variation in gender-STEM stereotypes and STEM participation: an intersectional approach. *Cultur Divers Ethnic Minor Psychol, 21*(2), 169-180. doi:10.1037/a0037944

Obama, B. (2013). Remarks by the President in the State of the Union address. Washington, D.C.: The White House.

OECD. (2015). Girls' lack of self-confidence *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence* (pp. 63-95). Paris: OECD Publishing.

Olitsky, N. H. (2014). How Do Academic Achievement and Gender Affect the Earnings of STEM Majors? A Propensity Score Matching Approach. *Research in Higher Education, 55*(3), 245-271. doi:10.1007/s11162-013-9310-y

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research, 66*(4), 543-578.

Pangallo, A., Zibarras, L., Lewis, R., & Flaxman, P. (2015). Resilience through the lens of interactionism: a systematic review. *Psychol Assess, 27*(1), 1-20. doi:10.1037/pas0000024

Parsons, T. (1951). *The Social System*. London: Routledge.

Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Newbury Park, CA: Sage.

PCAST. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. Retrieved from https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf

Perez-Felkner, L. C. (2013). Socialization in Childhood and Adolescence. 119-149. doi:10.1007/978-94-007-6772-0_5

Perez-Felkner, L. C., McDonald, S.-K., Schneider, B., & Grogan, E. (2012). Female and male adolescents' subjective orientations to mathematics and the influence of those orientations on postsecondary majors. *Developmental psychology, 48*(6), 1658-1673. doi:10.1037/a0027020

Perna, L., Gasman, M., Gary, S., Lundy-Wagner, V., & Drezner, N. D. (2010). Identifying strategies for increasing degree attainment in STEM: Lessons from minority-serving institutions. *New Directions for Institutional Research, 2010*(148), 41-51.

Perna, L., Lundy-Wagner, V., Drezner, N. D., Gasman, M., Yoon, S., Bose, E., & Gary, S. (2009). The contribution of HBCUs to the preparation of African American women for STEM careers: A case study. *Research in Higher Education, 50*(1), 1-23.

Rattan, A., Good, C., & Dweck, C. S. (2012). “It's ok—Not everyone can be good at math”: Instructors with an entity theory comfort (and demotivate) students. *Journal of Experimental Social Psychology, 48*(3), 731-737.

Reilly, D., Neumann, D. L., & Andrews, G. (2015). Sex differences in mathematics and science achievement: A meta-analysis of National Assessment of Educational Progress assessments. *Journal of Educational Psychology, 107*(3), 645-662. doi:10.1037/edu0000012

Riegle-Crumb, C. (2006). The Path through Math: Course Sequences and Academic Performance at the Intersection of Race-Ethnicity and Gender. *American Journal of Education, 113*(1), 101-122. doi:10.1086/506495

Riegle-Crumb, C., & King, B. (2010). Questioning a White Male Advantage in STEM. *Educational Researcher, 39*(9), 656-664. doi:10.3102/0013189x10391657

Riegle-Crumb, C., King, B., Grodsky, E., & Muller, C. (2012). The more things change, the more they stay the same? Prior achievement fails to explain gender inequality in entry into STEM College majors over time. *American Educational Research Journal, 49*(6), 1048-1073.

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education, 95*(3), 458-476.

Rittmayer, M. A., & Beier, M. E. (2009). Self-efficacy in STEM. *Applying Research to Practice (ARP) Resources.* Retrieved from http://www.engr.psu.edu/AWE/ARPresources.aspx

Ro, H. K., & Loya, K. I. (2015). The Effect of Gender and Race Intersectionality on Student Learning Outcomes In Engineering. *The Review of Higher Education, 38*(3), 359-396. doi:10.1353/rhe.2015.0014

Rubin, D. B. (2004). *Multiple imputation for nonresponse in surveys* (Vol. 81): John Wiley & Sons.

Rubin, M., Denson, N., Kilpatrick, S., Matthews, K. E., Stehlik, T., & Zyngier, D. (2014). "I Am Working-Class". *Educational Researcher, 43*(4), 196-200. doi:10.3102/0013189x14528373

Saldana, J. (2009). An introduction to codes and coding, Chapter 1 *The Coding Manual for Qualitative Researchers* (pp. 1-31): Sage Publications.

Sanchez, C. (n.d.). *Commonalities Among Identity THeories*. Higher Education and Student Affairs, Educational Leadership & Policy Studies, College of Education, University of Iowa. Retrieved from http://www.uiowa.edu/~epls/faculty/pascarel/papers/sanchez.pdf

Sax, L. J. (1994). Mathematical self-concept: How college reinforces the gender gap. *Research in Higher Education, 35*(2), 141-166. doi:10.1007/BF02496699

Sax, L. J., Kanny, M. A., Riggers-Piehl, T., Whang, H., & Paulson, L. (2015). "But I'm Not Good at Math": The Changing Salience of Mathematical Self-Concept in Shaping Women's and Men's STEM Aspirations. *Research in Higher Education*, 1-30. doi:10.1007/s11162-015-9375-x

Sax, L. J., Perez-Felkner, L. C., Gaston Gayles, J., Trautvetter, L., & Wang, X. (2015). *A "World Café" on the Nuanced Experiences of Women Across STEM: Theoretical and Methodological Considerations of Disciplinary Differences and Intersectionality in Computer Science and Engineering*. Paper presented at the Association for the Study of Higher Education Annual Meeting, Denver, CO.

Schneider, B., Milesi, C., Perez-Felkner, L. C., Brown, K., & Gutin, I. (2015). Does the gender gap in STEM majors vary by field and institutional selectivity? *Teachers College Record*.

Seligman, M. E. P., & Csikszentmihalyi, M. (2000). Positive psychology: An introduction. *American Psychologist, 55*(1), 5-14. doi:10.1037/0003-066x.55.1.5

Shavelson, R., J. , Hubner, J., J. , & Stanton, G., C. . (1976). Self-Concept: Validation of Construct Interpretations. *Review of Educational Research, 46*(3), 407-441. doi:10.3102/00346543046003407

Silverman, D. (2011). *Interpreting qualitative data: Methods for analyzing talk, text and interaction* (4th ed.). Thousand Oaks, CA: Sage Publications.

Smedley, A., & Smedley, B. D. (2005). Race as biology is fiction, racism as a social problem is real: Anthropological and historical perspectives on the social construction of race. *American Psychologist, 60*(1), 16-26. doi:10.1037/0003-066X.60.1.16

Smith, D. G. (2009). *Diversity's promise for higher education: Making it work*. Baltimore, MD: Johns Hopkins University Press.

Snow, C. P. (1961). *The Two Cultures and the Scientific Revolution*. New York, NY: Cambridge University Press.

Sonnert, G., Fox, M. F., & Adkins, K. (2007). Undergraduate Women in Science and Engineering: Effects of Faculty, Fields, and Institutions Over Time*. *Social Science Quarterly, 88*(5), 1333-1356.

Spelke, E. S. (2005). Sex Differences in Intrinsic Aptitude for Mathematics and Science?: A Critical Review. *American Psychologist, 60*(9), 950-958. doi:10.1037/0003-066X.60.9.950

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype Threat and Women's Math Performance. *Journal of Experimental Social Psychology, 35*(1), 4-28. doi:http://dx.doi.org/10.1006/jesp.1998.1373

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist, 52*(6), 613-629. doi:10.1037/0003-066x.52.6.613

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of personality and social psychology, 69*(5), 797-811. doi:10.1037/0022-3514.69.5.797

Stets, J. E., Brenner, P. S., Burke, P. J., & Serpe, R. T. (2017). The science identity and entering a science occupation. *Soc Sci Res, 64*, 1-14. doi:10.1016/j.ssresearch.2016.10.016

Strauss, V. (2016). The problem with teaching 'grit' to poor kids? They already have it. Here's what they really need. *The Washington Post*. Retrieved from https://www.washingtonpost.com/news/answer-sheet/wp/2016/05/10/the-problem-with-teaching-grit-to-poor-kids-they-already-have-it-heres-what-they-really-need/?utm_term=.77042a316f22

Strayhorn, T. L. (2013). What Role Does Grit Play in the Academic Success of Black Male Collegians at Predominantly White Institutions? *Journal of African American Studies, 18*(1), 1-10. doi:10.1007/s12111-012-9243-0

Strayhorn, T. L. (2015). Factors Influencing Black Males' Preparation for College and Success in STEM Majors: A Mixed Methods Study. *Western Journal of Black Studies, 39*(1), 45-63.

Summers, L. H. (2005). *Remarks at NBER Conference on Diversifying the Science & Engineering Workforce*. Paper presented at the NBER Conference on Diversifying the Science & Engineering Workforce, Cambridge, MA. http://www.harvard.edu/president/speeches/summers_2005/nber.php

Tampio, N. (2016). Teaching 'grit' is bad for children, and bad for democracy. *aeon*. Retrieved from https://aeon.co/ideas/teaching-grit-is-bad-for-children-and-bad-for-democracy

Teddlie, C., & Tashakkori, A. (2010). Overview of Contemporary Issues in Mixed Methods Research *Handbook of Mixed Methods in Social & Behavioral Research.*

Thelin, J. (2011). *History of American Higher Education* (2nd ed.). Baltimore, MD: Johns Hopkins University Press.

Thiry, H., Laursen, S. L., & Hunter, A.-B. (2011). What Experiences Help Students Become Scientists?: A Comparative Study of Research and Other Sources of Personal and Professional Gains for STEM Undergraduates. *The Journal of Higher Education, 82*(4), 357-388. doi:10.1353/jhe.2011.0023

Thomas, J., & Williams, C. (2009). The history of specialized STEM schools and the formation and role of the NCSSSMST. *Roeper Review, 32*(1), 17-24. doi:10.1080/02783190903386561

Urquhart, C. (2013). *Grounded THeory for Qualitative Research: A Practical Guide*. Washington, D.C.: SAGE.

Van de Gaer, E., Grisay, A., Schulz, W., & Gebhardt, E. (2012). The Reference Group Effect: An Explanation of the Paradoxical Relationship Between Academic Achievement and Self-Confidence Across Countries. *Journal of Cross-Cultural Psychology, 43*(8), 1205-1228. doi:10.1177/0022022111428083

Wang, M.-T., Eccles, J. S., & Kenny, S. (2013). Not Lack of Ability but More Choice Individual and Gender Differences in Choice of Careers in Science, Technology, Engineering, and Mathematics. *Psychological Science, 24*(5), 770-775.

Watt, H. M. G. (2006). The role of motivation in gendered educational and occupational trajectories related to maths. *Educational Research and Evaluation, 12*(4), 305-322. doi:10.1080/13803610600765562

Wie-Cheng, M. (2003). Factors that influence persistence in science and engineering career aspirations. *The Career Development Quarterly, 51*(3), 234-243.

Wigfield, A., & Eccles, J. S. (2000). Expectancy-Value Theory of Achievement Motivation. *Contemp Educ Psychol, 25*(1), 68-81. doi:10.1006/ceps.1999.1015

Yeh, C. (2017). Forget Grit. Focus on Inequality. *Education Week*. Retrieved from https://www.edweek.org/ew/articles/2017/04/14/forget-grit-focus-on-inequality.html

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary educational psychology, 25*(1), 82-91.

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