REIMAGINING DIVERSITY IN STEM: USING AN ASSETS-BASED CAPITAL FRAMEWORK MODEL TO EXPLORE THE CAREER TRAJECTORY OF SCIENTISTS FROM UNDERREPRESENTED GROUPS

By

Patricia Jaimes

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Geological Sciences—Doctor of Philosophy
Environmental Science and Policy—Dual Major

2021

ABSTRACT

REIMAGINING DIVERSITY IN STEM: USING AN ASSETS-BASED CAPITAL FRAMEWORK MODEL TO EXPLORE THE CAREER TRAJECTORY OF SCIENTISTS FROM UNDERREPRESENTED GROUPS

By

Patricia Jaimes

An emerging approach to diversity and inclusion initiatives within the sciences is to consider the assets and resources (in the form of capitals) held by individuals from underrepresented groups. In Chapter 1 of this dissertation, we performed a systematic literature review to explore the secondary types of capital that exist within the STEM education literature, in relation to the five primary forms of capital: cultural, economic, human, social, and symbolic. We identified 184 scholarly documents using systematic literature review procedures. To qualify, documents needed to pertain to STEM, careers and education, and capital and explicitly define capital. We extracted the capital types that were found in the retained documents and recorded their definitions. Thirty-six forms of capital emerged from these studies, and 27 were retained in our final model. Five of these capitals were primary capital categories (cultural, economic, human, social, and symbolic); twenty-one were secondary capitals. Using a deductive thematic coding approach, we sorted the secondary capitals into the five primary capital categories based on their definitions. Three secondary capitals that did not align with any of the primary capitals were sorted into a "other" category. These three capitals were then analyzed inductively and were sorted into a newly developed intrinsic capital primary category. The final Capital Framework Model CFM) was developed.

To test the CFM, we performed an exploratory study in Chapter 2 looking at how the CFM could be used to explain the educational and career persistence of scientists from

underrepresented groups and determine which capitals were most useful to scientists from underrepresented groups for their educational and career persistence. Fifteen semi-structured interviews were conducted with scientists who identified as a racial/ethnic minority or disabled or queer. Interview transcripts were coded through a deductive thematic analysis, using the CFM model as a codebook. Findings illustrate that participants from underrepresented groups accessed social capital, cultural capital, economic capital, and intrinsic capital to persist in STEM careers. Scientists of color engaged with capitals differently than white scientists. A new intrinsic capital type- critical consciousness capital- was added to the CFM model.

The third chapter of this dissertation builds off the work of Yosso (2005) and Chapters 1 and 2, to explore how the CFM, with the inclusion of critical consciousness capital, explains the career trajectories of Latinx scientists. Semi-structured interviews were conducted with 10 Latinx scientists and were coded deductively using the updated CFM as a codebook. Findings reveal that while traditional initiatives that provide social and cultural capital in order to broaden the participation of underrepresented students in STEM are effective, it is the strengths and resources - in the form of capital- derived from their communities, that empower and enable Latinx scientists to persist in scientific careers. Most importantly, we found that Latinx scientists are drawn to the social justice implications of a scientific career and strive towards helping their communities combat the oppressive systems that hold them back. Efforts to broaden participation in STEM could be improved by embedding the cultural and intrinsic strengths found among Latinx communities into their programming with a focus on applying scientific principles into social justice work.

ACKNOWLEDGEMENTS

The completion of this PhD would not have happened if it were not for the support of my community. My parents instilled in me a hard work ethic and a love for education. It is those values that allowed me to persevere through all the obstacles and hardships I encountered during my educational journey. It is because of them that I am a dreamer, always strive to do my best and push forward in my goals and dreams. As a first-generation college student, I had no knowledge about graduate school when I first entered college. Thank you to my undergraduate advisors, mentors, and work supervisors for guiding me and teaching me about the educational and career possibilities that existed beyond the bachelor's degree. Thank you for helping me access scholarships and research opportunities. Those supports and resources forever changed my life and influenced the way that I approach my own work with students. I intend to pay it forward to future generations of students.

Thank you to my advisor, Dr. Julie Libarkin, for being the most amazing advisor any graduate student could ask for. Your unique approach to advising and mentoring was instrumental to my being able to complete this dissertation. Thank you for cultivating a positive, healthy, and safe lab environment. I would not have survived my doctoral program without your support. Completion of my doctoral program would not have been possible without my fellow lab-mates and friends: Caitlin Kirby, Eleanor Rappolee, and Amanda Lorenz. Together we navigated the graduate school and dissertation process. We applied to many of the same funding opportunities and always helped each other along the way. We celebrated each other's successes and supported each other through all the rejections. I could not have asked for better lab-mates or friends these past six years. Thank you to my committee for their guidance and support and for

making me a better researcher and scholar: Drs. Carmen McCallum, Leslie Gonzales, and Tyrone Rooney. Thank you to my friends and family near and far who always sent me words of encouragement and support.

I am grateful for my spouse Areli Diaz Adan for the incredible amount of support he provided me during the last six years. He has been the most amazing co-parent and life partner and a key component in my being able to finish this degree. Thank you for all the support you provided me during the entire PhD process and for making sure I take breaks and am well-rested. Also, thank you for all the delicious meals you have cooked for our family over the last six years- I don't know that I would have made it through graduate school on just my cooking! To my child- I became a parent at the young age of 18 and have been in school during the entirety of your eleven years of life. Thank you for being so patient with me and for always encouraging me to "do my homework". Thank you for always cheering me on. This degree is for you!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Broadening the participation of individuals from underrepresented groups in STEM (Science, Technology, Engineering, and Math) has long been a national priority within the United States (Leggon, 2018; Means et al., 2018; Saw, 2020). Although broadening participation efforts initially focused on increasing the participation of individuals from underrepresented racial/ethnic groups, over time they have expanded to include women, and individuals from the disabled and queer communities (Leggon, 2018; National Science Foundation, 2019; Yoder & Matheis, 2016). However, despite decades of efforts, individuals from underrepresented groups continue to be underrepresented in the sciences (Byars-Winston et al., 2010; Cech & Pham, 2017; National Science Foundation, 2019; Pew Research Center, 2018).

Initiatives that seek to broaden participation in STEM have evolved from focusing on the quantitative dimension (increasing numbers), to also focusing on the qualitative dimension (i.e. quality of education, training, and research) (Leggon, 2018). The research used to inform broadening participation efforts in STEM has historically focused on the qualities and characteristics that individuals from underrepresented groups lacked (Harper, 2010; Leggon, 2018; Stolle-McAllister, 2011). As such, individuals from underrepresented groups have been portrayed as having deficits that impede their participation in STEM (Leggon, 2018; Stolle-McAllister, 2011). Therefore, broadening participation in science initiatives have often focused on "fixing" those perceived deficits and providing individuals with the tools and knowledge perceived to be necessary to succeed in a STEM career (Ackerman, 1991; O'Connell, 2011; Stolle-McAllister, 2011). These approaches are considered deficit-based models (Harper, 2010; Leggon, 2018).

The concepts that are often used in initiatives and science education programming that seek to broaden the participation of individuals from underrepresented groups in STEM, are often grounded in capital theories (Archer et al., 2012; Bourdieu, 1986; Ovink & Veazey, 2011; Saw, 2020; Stolle-McAllister, 2011; Turnbull et al., 2020). In this study, capital is defined as the financial and non-financial resources that individuals use to succeed in life (Jaimes et al., unpublished work, Ch.1). Within the context of STEM, social and cultural capitals are the primary capital concepts used to explore the persistence of individuals from underrepresented groups (Callahan et al., 2015; Cole & Espinoza, 2008; Martin et al, 2013; Ovink & Veazey, 2011; Stolle-McAllister, 2011). Social capital can be understood as the networks of people that lead to resources and opportunities to benefit individuals and networks. Cultural capital can be understood as having familiarity with the dominant culture of a society (Bourdieu, 1986; Bourdieu & Passeron, 1977). Broadening participation efforts often aim to provide students from underrepresented groups with social capital and cultural capital to enable them to pursue a scientific career path. Within STEM, social capital is often discussed in the form of mentoring relationships and cultural capital is discussed through the gaining of scientific knowledge and how to conduct research through college bridge programs or undergraduate research experiences.

Unfortunately, the lack of diversity in STEM continues to be a problem (Cech & Pham, 2017; National Science Foundation, 2019; Pew Research Center, 2018). As such, scholars have called for the use of an assets-based research approach that explores the strengths and resources that individuals use in order to navigate scientific careers (Harper, 2010). That is, instead of focusing on what inhibits individuals from underrepresented groups from participating in STEM careers, scholars should explore the factors that help them persist. Broadening participation in STEM requires an understanding of the different factors that support student persistence in

STEM and figuring out what works for different groups of students. In this study, we shift away from the deficit-based model and use an asset-based approach to explore the factors that contribute to the persistence of individuals from underrepresented groups in STEM.

An assets-based model that has been applied to higher education research and is now being applied to STEM education research is Dr. Tara Yosso's Community Cultural Wealth (CCW) model (Yosso, 2005). CCW provides an expanded understanding of cultural capital through the lens of Critical Race Theory (CRT). CRT explains how the social, educational, and legal structures of society are grounded in the values of the white, Western, and dominant culture and how those structures are complicit in the oppression of non-white and marginalized groups (Delgado & Stefanic, 2001). In her CCW model, Yosso (2005) critiques traditional interpretations of cultural capital that is the foundation of the deficit-based model and argues that students of color and with other marginalized identities bring their own cultural assets to schools. CCW consists of six capitals: aspirational capital, familial capital, linguistic capital, navigational capital, social capital, and resistant capital. These assets help students of color to survive and thrive in those spaces. In an effort to shift away from the traditional deficit-based model that is used to help individuals from underrepresented groups persist in STEM careers, science educators have begun applying Yosso's CCW model to explore the factors that enable participants to successfully pursue a scientific career path (Braun et al., 2017; Burt & Johnson, 2018; Samuelson and Litzler, 2016).

In this dissertation, I utilize qualitative research methods to explore the factors that contribute to the career persistence of scientists from underrepresented groups. In the first chapter of this dissertation, I performed a systematic literature review, following Borrego et al.'s (2014) recommendations, exploring the types of capital that exist in the STEM education literature relating to education and career. Thirty-six forms of capital emerged from this study, and twenty-seven were retained in a final Capital Framework Model (CFM). Five of these capitals were primary capital categories (cultural, economic, human, social, and symbolic); twenty-one were secondary capitals, most of which stemmed from the five primary capitals. Three secondary capitals did not align with any of the primary capitals and were sorted into an "other" category. After analytical discussions among the three authors, these three capitals were then sorted into a newly developed intrinsic capital primary category. The final Capital Framework Model (CFM) included six primary capital categories with twenty-one secondary capitals being sorted into one of those primary categories (Table 2); cultural capital (N=11), economic capital (N=0), human capital (N=1), social capital (N=5), symbolic capital (N=1), and intrinsic capital (N=3).

The second chapter of this dissertation evaluates the Capital Framework Model to utilize an asset-based research approach and explore the types of capital that scientists from underrepresented groups used to persist in their academic and scientific endeavors. This chapter explored how the Capital Framework Model could be applied to explore the educational and career persistence of scientists from underrepresented groups. Fifteen semi-structured interviews were conducted with scientists who identified as belonging to one or more underrepresented groups (e.g. racial/ethnic minority or disabled or queer). Interview transcripts were coded through a deductive thematic analysis, using the CFM model as a codebook. Findings illustrate that participants from underrepresented groups accessed social capital, cultural capital, economic capital, and intrinsic capital to persist in STEM careers. Scientists of color engaged with capitals differently than white scientists. A new intrinsic capital type- critical consciousness capital- emerged from the interview transcripts of participants of color and was added to the CFM model.

The third chapter of this dissertation explored how the Capital Framework Model, with the addition of critical consciousness capital, explains the career trajectories of Latinx scientists. Semi-structured interviews were conducted with 10 Latinx scientists and were coded deductively using a pre-determined CFM codebook. Findings reveal that while traditional initiatives to broaden the participation of underrepresented students in STEM are effective, it is the cultural and intrinsic strengths (i.e. in the form of capital), derived from their communities, that empower and enable Latinx scientists to persist in scientific careers. Most importantly, we found that Latinx scientists are drawn to the social justice implications of a scientific career and strive towards helping their communities combat the oppressive systems that hold them back in life.

These asset-based explorations of the educational and career persistence of scientists from underrepresented groups can help improve broadening participation efforts in STEM. Each chapter of this dissertation provides further details into the background, methods, and findings of each study.

CHAPTER 1

RETHINKING INITIATIVES TO INCREASE DIVERSITY IN STEM: A NEW CAPITAL FRAMEWORK MODEL

Introduction

Despite the decades of diversity and inclusion initiatives that seek to broaden the participation of scientists from traditionally marginalized groups within the United States (U.S.), ethnic/racial minorities, queer, and disabled scientists continue to remain underrepresented in the scientific workforce (Byars-Winston et al., 2010; Cech & Pham, 2017; National Science Foundation, 2019; Pew Research Center, 2018). These diversity initiatives are often grounded in capital theories – considerations of what underrepresented groups need in order to be successful (Luedke, 2019; Ovink & Veazey, 2011; Stolle-McAllister, 2011). For example, many of these initiatives include providing students with scholarships or financial aid (economic capital), connecting them with mentors (social capital), or teaching them how to perform science (cultural capital).

Although some efforts have been beneficial at recruiting individuals into scientific majors (Eagan et al., 2013; Hernadez et al., 2018; Nagda et al., 1998; Schultz et al., 2011), the lack of diversity further along the academic pipeline (e.g. graduate school to workforce) makes clear that retention of these individuals is a problem. Certainly, the scientific workforce is not representative of the U.S. population (National Science Foundation, 2019; U.S. Census, 2011). As stated by Denton et al., (2020), science educators need to utilize different approaches to diversity and inclusion initiatives in order to create a more inclusive and representative scientific workforce. Historically, traditional efforts have been grounded in a deficit-based interpretation of capital which implies that marginalized communities lack assets needed for success (Harper, 2010). However, scholars have called for changing these approaches towards an asset-based mindset (Denton et al., 2020; Harper, 2010; Samuelson & Litzler, 2016) where we look at the resources (i.e. capitals) that are available among these communities and which could be useful for success in science.

In this paper, we define capital as financial and non-financial resources that individuals utilize to succeed in life. The STEM education literature has expanded to include multiple forms of capital that help scientists succeed in their education and careers. We explore the many forms of capital that exist in the STEM education literature, evaluate the nature of these capitals relative to longstanding primary forms of capital described in the literature, and build a model that encompasses all forms of capital that have been identified as important for STEM success. Through this work, we build new understanding about how we can shift away from deficit interpretations of capital toward a more asset-based understanding of how to apply these theories in scientific spaces.

Theoretical Background

Five forms of primary capital have long dominated the literature on capital (Becker, 1964; Bourdieu, 1986; Coleman, 1988; Putnam, 1993; 1995). We review these five forms and further consider alternative views of capital, particularly the concept of Community Cultural Wealth as articulated by Yosso (2005; 2006).

Cultural Capital

Cultural capital is a concept that embodies the social assets of an individual that promote social mobility (Bourdieu & Passeron, 1977; Bourdieu, 1986). Cultural capital encompasses an individual's accumulated knowledge, behaviors, and skills that demonstrate familiarity with the norms that dominate in a particular society (Bourdieu & Passeron, 1977; Bourdieu, 1986). Cultural capital is acquired through the process of socialization, often through one's family or through formal schooling (Bourdieu, 1986; Lee & Bowen, 2006; Longden, 2004; Vryonides, 2007). Bourdieu (1986) describes cultural capital as being manifested in three ways: the cultural objects that one owns such as books or art (objectified), an individual's acquired attributes and behaviors through socialization (embodied), and an individual's credentials or qualifications (institutionalized).

Although cultural capital is not necessarily connected to an individual's social status (Reay, 1998), the norms and behaviors of the more privileged social groups in society often constitute the cultural capital that is reinforced in educational and other social institutions (Bourdieu, 1990). Bourdieu (1990) argues that cultural capital and its transmission across generations between families can lead to an unfair education system that favors students from more privileged homes. As such, the concept of cultural capital has been used to explain the educational disparities between privileged and less privileged social groups (Goldenburg, 2014; Gonzales, 2012; Leese, 2010). Students from less privileged homes are often perceived as "lacking" the necessary cultural capital that is needed to experience academic success. The educational system is therefore set up to assimilate those students into the culture of the privileged groups (Cole & Espinoza, 2008; Goldenburg, 2014). This approach to education is considered a deficit-based model because it fails to consider the cultural assets and resources that these students bring from their own communities (Yosso, 2005).

Economic Capital

Economic capital is perhaps the most familiar of all forms of capital as "capital" is often used interchangeably with "financial resources". Economic capital refers to material assets that are 'immediately and directly convertible into money and may be institutionalized in the form of property rights' (Bourdieu 1986, p. 242). The value of economic capital comes from its exchange value. For example, within the context of education, students from wealthier families are able to purchase laptops, books, and other school materials that help them advance in their educational pursuits. In this example, those with economic capital (i.e. financial resources) are able to purchase “goods” that help them access the cultural capital embedded in the education system (i.e. non-financial resources). Research has shown that wealth and family income are large predictors of academic success (Blanden & Gregg, 2004; Shapiro et al., 2013). Recognizing that gaps in educational achievements can be associated with socioeconomic status, the National Science Foundation has invested financially into efforts that seek to broaden the participation of underrepresented groups in STEM (James & Singer, 2016). For students who come from low-income backgrounds, these efforts often come in the form of fellowships, scholarships, or paid internships, given them the economic capital that is necessary to be able to access to a college or graduate education.

Human Capital

Human capital consists of the accumulated skills and knowledge an individual has which is of value to an employer. Gary Becker (1994, p. 11), described human capital as activities that influence future monetary and psychic income by increasing resources in people. It can be understood as “what you know” that is necessary to be able to perform labor. That knowledge and skillset are viewed in relation to their value to an organization or company. For example, a university’s human capital would be its employees.

Symbolic Capital

Symbolic capital is synonymous with honor or prestige (Bourdieu, 1986; Archer et al., 2014). Symbolic capital refers to "the form that the various species of capital assume when they are perceived and recognized as legitimate" (Bourdieu, 1989, p. 17). In other words, it is the value that is placed on an asset or attribute (i.e. capital) within a specific context or discipline. Olsson et al. (2019, p. 245) succinctly clarify: "*what is recognised as important within a specific field evolves to constitute symbolic capital and indicates prestige or high status for those within that field*". For example, a scientist who is perceived to be successful or recognized as "top in their field" is someone who has symbolic capital within the scientific community. This recognition of "top" can emerge from an individual receiving grants or awards, and vice versa, having symbolic capital can lead an individual such as obtaining more grants or awards (Brosnan, 2011).

Social Capital

Social capital is a concept that is widely used in higher education and other disciplines to explain the benefits derived from social networks (Callahan et al., 2015; Dike & Martin, 2018; Saw, 2020). Though no single definition exists, scholars often use one of three main definitions conceptualized by the three most influential writers of social capital, Bourdieu, Coleman, or Putnam (Field, 2003; McCallum, 2012). Though all three writers offer various perspectives, they agree that social capital is a resource that is embedded in social relationships that individuals can access in order to succeed in their endeavors. Putnam describes social capital as "*the features of social life—networks norms and trust—that enable participants to act together more effectively to pursue shared goals*" (Putnam, 1995, p. 56). Putnam's conceptualization of social capital refers to the collective value of all social networks and the norms of reciprocity that derive from these networks.

Bourdieu defines social capital as *"the aggregate of the actual potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition"* (Bourdieu, 1986, p.248). He primarily focuses on the resources and benefits available to individuals as a result of their social connections, suggesting that members of the more privileged or elite social classes have access to more resources than individuals that were not part of the privileged.

Coleman (1988, p. S98) defines social capital as "*not a single entity but a variety of different entities, with two elements in common: they all consist of some aspect of social structures, and they facilitate certain actions of actors-whether persons or corporate actors-within the structure. Like other forms of capital, social capital is productive, making possible the achievement of certain ends that in its absence would not be possible"* . Coleman saw social capital as a resource that exists among groups that helps them achieve an end-goal that would not be possible without it. Coleman's interpretation of social capital considered individuals, organizations, and communities as beneficiaries of social capital, while Bourdieu's version implied that social capital only exists between individuals to benefit those individuals (McCallum, 2012; Tzanakis, 2013; Rogošić and Baranović, 2016).

Community Cultural Wealth

Community Cultural Wealth (CCW; Yosso, 2005) provides an expanded understanding of cultural capital through the lens of Critical Race Theory (CRT). CRT explains how the social, educational, and legal structures of society are grounded in the values of the white, Western, and dominant culture and how those structures are complicit in the oppression of non-white and marginalized groups (Delgado & Stefanic, 2001). In her CCW model, Yosso (2005) critiques traditional interpretations of cultural capital that is the foundation of the deficit-based education model and argues that students of color and with other marginalized identities bring their own cultural assets to schools. These assets in turn help students to survive and thrive in those spaces. Yosso (2005) categorized cultural assets that make up the CCW model into six different forms of capital: aspirational, familial, linguistic, navigational, social, and resistant. “These capitals are not mutually exclusive or static, but rather are dynamic processes that build on one another as part of community cultural wealth” (Yosso, 2005, p. 77). Yosso argues that schools need to shift away from the deficit-model towards an asset-based model that utilizes the cultural wealth of marginalized students. This means recognizing and validating the cultural wealth that students bring with them to schools and incorporating those strengths into the educational curriculum. CCW has been studied widely within higher education scholarship (Espino, 2014; Mobley & Brawner, 2019; Saenz et al., 2018) and has also been applied in STEM education research. STEM education scholars are applying the CCW model in their research to understand how individuals from underrepresented groups persist in scientific careers (Braun et al., 2017; Denton et al., 2020; Rincon & Dueñas, 2020).

This Study

Five foundational forms of capital (cultural, economic, human, social, and symbolic) are used in education literature. Yosso introduced five additional forms of capital in her conceptualization of Community Cultural Wealth: aspirational capital, familial capital, linguistic capital, navigational capital, and resistant capital. These capital concepts have been used previously to explore and explain how students navigate the educational system (Espino, 2014; Saenz et al., 2018). These concepts have also been used in the sciences to develop efforts to broaden the participation of individuals from underrepresented groups in STEM (Braun et al., 2017; Denton et al., 2020; Rincon & Dueñas, 2020; Samuelson & Litzler, 2016). However, the number of capitals that have been developed beyond the traditional forms and Yosso's additions are overwhelming and not clearly organized. A systematic literature review is a useful tool for synthesizing the current knowledge that exists on a given topic or phenomena (Borrego et al., 2014; Newman & Gough, 2020; Denton et al., 2020). Performing systematic literature reviews can help scholars identify gaps in the literature, inform them about new research that needs to be undertaken, and provide specific recommendations for practice (Borrego et al., 2014; Newman & Gough, 2020). This study seeks to fill a critical gap in our understanding of the capital framework by performing a systematic literature review to explore the various types of capitals that exist in the STEM education and career literature and the relationships between those different capitals. The following are the research questions addressed in our study, following the systematic literature review steps recommended by Borrego et al., (2014).

1. In the context of STEM education and careers, what forms of capital exist in the literature?
2. How are those capitals defined?
3. What model emerges to encapsulate and organize all forms of capital?

Methods

This study followed the systematic literature review guidelines detailed by Borrego et al. (2014) and Pettigrew and Roberts (2006) for engineering education and other social science disciplines. After developing our research questions, Two of the authors, P.J. and J.L, developed a protocol detailing the databases that would be used to conduct the search and the inclusion and exclusion criteria for the documents that would be analyzed in this study. Per Borrego et al.'s

(2014) recommendations, P.J. consulted with a librarian to discuss the protocol and search procedure.

Search Strategy

The databases searched were electronic and concerned areas of education and STEM. The exact databases used in this search were: Scopus (General), Proquest Library (ERIC), and Web of Science (Core Collection). The following search string was used to search each database: *Capital AND (science OR STEM OR engineering) AND (education OR career)*. All searches were made against peer-reviewed articles, book chapters, conference papers or proceedings, and abstracts.

Inclusion Criteria

Inclusion criteria (IC) developed at the start of the search process were applied to the retrieved documents. Documents that did not meet the IC were excluded. To be considered in the systematic literature review, the documents needed to:

- IC1: be peer-reviewed
- IC2: be available in full-text
- IC3: pertain to STEM education or careers
- IC4: include capital as defined in the general definition
- IC5: include a definition for capital
- IC6: contain capital definitions that do not combine multiple theories (e.g. cognitive load theory + capital theory)
- IC7: be published between 1973 and January 15, 2020 (date of search)
- IC8: be in the English language

Search results were screened using Covidence, an online systematic review (SR) tool (Harnke, Knight, and Kellermeyer, 2018). Results from each database were imported to Covidence for 1) deduplication and 2) abstract screening. Duplicate articles and any articles covering topics outside of STEM were excluded from the study. Remaining citations were then extracted out of Covidence. A second round of screening was conducted on full-text. Articles that did not meet the inclusion criteria were further excluded from the study (Figure 1). For example, we excluded documents that did not define capital (per inclusion criteria). Finally, types of capital and definitions used in included articles were recorded in an EXCEL workbook for further consideration.

Data Analysis

Throughout this process, P.J. and J.L met regularly to discuss findings and refine the analytical strategy for this study. In order to answer research questions 1 and 2, P.J. read the documents that were retained after the second screening stage and recorded the forms of capitals and definitions included in those documents.

Most of the capitals that were found in the retained documents had multiple definitions. For example, definitions for social capital varied depending on whether researchers used Bourdieu's (1986), Coleman's (1988), or Putnam's (1995) definitions of social capital. Definitions were verbatim transcribed from documents. PJ synthesized definitions and developed a single definition for each capital. All three authors reviewed definitions, considered published definitions where applicable, and revised definitions until consensus was reached.

To further investigate research question 2, capitals with near-identical definitions were combined. First, the researchers discussed the definitions for each of the capitals. Capitals that were found to have nearly identical definitions were combined into a single capital category in order to reduce redundancy.

To answer research question 3, types of capitals and definitions were then coded using thematic analysis (Boyatzis, 1998; Braun & Clark, 2006; Clark & Braun, 2014). This analytical method has been used in research as a way to identify, analyze, organize, describe, and report meaningful patterns and themes found in a qualitative dataset (Nowell et al., 2017). Coding of the data occurred in two stages. In the first stage of coding, a deductive thematic analysis was performed on the data (Braun & Clark, 2006; Crabtree & Miller, 1999; Fereday & Muir-Cochrane, 2006), meaning that we coded each capital using a predetermined codebook. The predetermined codebook was made up of "primary capitals" as defined by foundational works in capital theory (Table 1): cultural capital (Bourdieu, 1986), economic capital (Bourdieu, 1986), human capital (Becker, 1964; 1994), social capital (Coleman, 1988; Putnam, 1993; 1995), and symbolic capital (Bourdieu, 1986). First, capitals were coded as belonging into one or more of these capitals based on definitions. Capitals that were explicitly defined as combinations of primary capitals were removed from further analysis. All other capitals were sorted, based on their definitions, into these five primary capitals. Any capitals that did not fit these primary capitals were sorted into an "other" category.

Several steps were taken to ensure trustworthiness during the coding process. First, capital definitions were articulated via a synthesis conducted by P.J. These definitions were reviewed by J.L. to ensure clarity. All three authors subsequently discussed and reviewed definitions further to ensure other researchers would understand definitions as written. Second, all three authors collaborated on the process of identifying and merging like capitals together. This ensured no capital was lost in the coding process. Finally, all three authors coded secondary capitals as a group. While most codings were in strong agreement, discrepancies were easily resolved through discussion.

Once the deductive coding was completed, capitals in the "other" category were analyzed inductively (Fereday & Muir-Cochrane, 2006; Nowell et al., 2017; Roberts et al., 2019) to determine if these "other" capitals shared any characteristics in common. The three authors conducted this inductive analysis together and reached agreement about the addition of new primary capitals to the capital model.

Results

Search Results

The search [Capital AND (science OR STEM OR engineering) AND (education OR career)] yielded 5,386 results: Scopus (3,152), ProQuest (677), and Web of Science (1,557). After deduplication in Covidence, 1,067 duplicate articles were removed, and 4,319 article abstracts were screened. After abstract screening, 3,874 articles were excluded for not being about STEM or engineering topics. This resulted in 445 articles being retained for full-text screening. Of the articles that received full-text screening, only 184 were retained for analysis after applying the inclusion and exclusion criteria (Figure 1). Most of the exclusion occurred because studies did not focus on STEM and capital within the context of STEM education. A smaller subset of documents did not clearly define the specific form of capital being discussed. The remainder of this paper focuses on the 184 retained articles.

Types of Capital

We identified thirty-six different types of capital in analyzing the 184 articles. Five of these capitals were the primary capital categories defined by Bourdieu (1986), Coleman (1988), Putnam (1993;1995), and Becker (1964; 1994): cultural, economic, human, social, and symbolic capital. Thirty-one additional secondary capitals were thus identified as secondary capital types. One secondary capital was ambiguously defined, and with agreement among the three authors, it was excluded. Thus, thirty secondary forms of capital were retained for further analysis in relation to the five primary capitals.

The five forms of primary capital were defined based upon their original definitions and current usage (Bourdieu, 1986; Coleman, 1988; Putnam, 1993; Becker, 1994). The remaining thirty capitals were defined by P.J. through synthesis across definitions used in analyzed documents. For example, academic capital was defined in four different ways: 1) supporting college-going (e.g. concerns about college costs, networking, trust, information, cultural capital, habitus patterns; (Hadinger, 2016), 2) curricular choices and subsequent credentials (Adamuti-Trache & Andres, 2008), 3) accumulation of one's educational and academic experiences that allow one to become a successful scientist in academia (Braun et al., 2017), and 4) prior academic preparation and access to academic support services (Enriquez, 2014). These were synthesized into a single definition that incorporated all the necessary elements: the accumulation of an individual's educational and academic experiences that makes them knowledgeable about academic norms, practices, and resources and allows them to be academically successful. Table 1 provides all synthesized definitions for the thirty secondary capitals.

The first step in our analysis was combining like-forms of capital as determined by their definitions (Table 1). Four forms of capital were removed during this analysis due to redundancy. First, economic capital is defined as "*Having money or financial resources that benefit an individua*l", while financial capital is defined as "*Economic and financial resources*" and physical capital is defined as "*money and other material assets*". Since these three definitions are nearly identical to each other, the authors agreed that these were like-forms of capital and made the decision to combine them into a single category of economic capital (Bourdieu, 1986). Second, STEM social capital and science-related social capital were defined as knowing people who work in STEM (science-related social capital) or having access to resources and networks within STEM (STEM social capital). After discussing these two definitions, the authors agreed that these were like-forms of capital and made the decision to combine them into a single category of STEM social capital. Finally, engineering transfer capital and transfer capital were also combined into a single "transfer capital" category since both capitals were defined as being knowledgeable about the academic transfer process; "engineering transfer capital" was simply discipline-specific. With the combination of these seven secondary capitals into three, twenty-six secondary capitals remained for further analysis.

Next, a deductive analysis was applied to the twenty-six secondary forms of capital. Each researcher individually read the definition for each secondary capital in order to familiarize themselves with the data (Braun & Clark, 2006). We then coded each secondary form of capital as aligning with one or more of the primary forms of capital. For example, as can be seen in Table 2, academic capital was coded as aligning with the definition of cultural capital. After coding individually, the three authors regrouped to discuss how we coded each secondary capital and our reasoning. Three forms of capital (aspirational, identity, and psychological) did not fit into any primary capital category and were sorted into "other". An additional five forms of secondary capital were sorted into more than one primary form of capital (*italics in Table 2*). These secondary capitals were all combinations of primary capitals and were already represented by those primary forms and/or other secondary forms. These five capitals did not contribute new insight to the capital model and were therefore removed. Thus, twenty-one secondary capitals were retained for further analysis. Below we discuss these secondary capitals and their relationship to primary capital.

Deductive Thematic Groupings

The remaining twenty-one secondary capitals were included in our final model (Figure 2). In this section, we will discuss the results of the deductive coding and specifically the forms of secondary capital grouped within primary capital categories.

Cultural Capital

Cultural capital is defined as "being knowledgeable about societal or cultural norms and values and having the ability to reproduce and replicate those values and norms in order to be an active, welcome, and successful member of that society or culture". Secondary capitals that were coded as aligning with the definition of cultural capital all had definitions pertaining to being knowledgeable about academic spaces or discipline-specific skills and norms, having cultural knowledge or the ability to successfully navigate unfamiliar environments, and promoting knowledge. There are eleven secondary capitals that were sorted into the cultural capital category (Figure 2).

Academic capital, hidden capital, and transfer capital all have definitions pertaining to academic knowledge. For example, academic capital is defined as an accumulation of an individual's academic experiences, making them knowledgeable about academic norms (Table 1). Hidden capital is defined as having intrinsic knowledge about mathematical and scientific concepts that are not recognized by a traditional educational system, such as using the design of cornrow hairstyles to explain the Cartesian coordinate system (Drazan et al., 2015; Englash & Bennett, 2009). Finally, transfer capital is defined as being knowledgeable about the transfer process between academic institutions in higher education. During our discussions, we determined that “academic knowledge” was the theme that emerged from these secondary capitals, which aligns with the definition of cultural capital. As such, these three capitals were sorted into the cultural capital category.

Community capital, credential capital, experimental capital, and linguistic capital all have definitions pertaining to having cultural knowledge, which also aligns with the general definition of cultural capital. For example, community capital was defined as the support of the community, the benefits of language and culture, and the mores and cultural life of a community. Credential capital refers to a sense of mutual membership or “in-group identity” such as a cultural interest that is mutually shared between student and teacher (Drazan et al., 2015). A student and teacher having a mutual interest in a scientific issue is an example of both individuals having “credential capital” which leads to a positive educational experience for both. Experimental capital is defined as a resource that can be utilized to intrinsically motivate students to engage with material, which is dependent on having cultural ownership over a domain of knowledge that is not yet known (Drazan et al., 2015). An example of experimental capital, as seen in Drazan et al., (2015), is an educator using a students' intrinsic interest in sports performance (i.e. sense of cultural ownership) to teach them how to apply STEM concepts to explore the physical phenomena that enhances an athlete’s performance (unknown knowledge). Linguistic capital is defined as the skills learned through communication experiences in more than one language and/or style and having the ability to code-switch between communities or environments. Linguistic capital, a concept introduced in Yosso’s (2005) Community Cultural Wealth model, describes the multiple language and communication skills that Students of Color arrive to school with, which are derived from their own cultural experiences. “Cultural knowledge" was the theme that emerged from these secondary capitals. As such, we sorted these capitals into the cultural capital category.

Discipline capital and technical capital both have definitions pertaining to disciplinary knowledge. Discipline capital refers to discipline-specific paradigms related to conducting research, while technical capital refers to general knowledge, skills, and abilities. The theme that emerged from these two secondary capitals was "discipline-specific knowledge or skills". As such, we sorted these two secondary capitals into the cultural capital category.

Two capitals that stood on their own were navigational capital and resistant capital. Navigational capital is a specific form of capital that refers to the skills and knowledge an individual has, which allows them to successfully maneuver unfamiliar social spaces. The skills and knowledge component of its definition is why we sorted navigational capital into the cultural capital category. Resistant capital is defined as "promoting knowledge and skills through behaviors that challenge inequality" (Yosso, 2005) and was also sorted as aligning with the general definition of cultural capital. However, though we agreed that resistant capital should be sorted into the cultural capital category, through several discussions, we categorized resistant capital as being its "antithesis". We will discuss the implications of this categorization in the discussion.

Economic Capital

Economic capital is defined as having money, financial resources, or material assets that benefit an individual. There were no explicit forms of secondary economic capital that emerged in this study. Economic capital can take many forms, from physical money to loans to scholarships, although ultimately the ability to access financial resources to support oneself in education and careers is an important form of capital for STEM.

Human Capital

Human capital is defined as “the accumulated skills and knowledge an individual has which is of value to an employer”. There is only one secondary capital that was sorted into the human capital category (Figure 2). This was decisional capital, defined as “the capacity to make sound decisions in situations where there are no fixed rules or evidence to rely on for guidance and can only be developed through years of experience”. The theme that emerged from this capital was “accumulation of professional experience”. As such, we sorted decisional capital into the human capital category.

Social Capital

Social capital is defined as the networks of people that lead to resources and opportunities to benefit individuals and networks. There are five secondary capitals that were sorted into social capital (Figure 2). These are college social capital, familial capital, parental social capital, peer-related social capital, STEM social capital. College social capital refers to the utilization of counselors for learning about college entrance information. The theme that emerged from this capital was “relying on academic networks” which aligns with the definition of social capital. The theme that emerged from familial capital and parental social capital was “family or community networks”. Peer-related social capital refers to the “networks of peers” that an individual relies on, while STEM social capital refers to an individual's “scientific network”. All five of these capitals describe different forms of networks, thus we sorted them into the social capital category.

Symbolic Capital

Symbolic capital is defined as an individual’s accumulated honor or prestige and the recognition that derives from them. There is one specific form of capital that was sorted into the symbolic capital category- scientific capital. Scientific capital was defined as "a symbolic capital based on knowledge and recognition within STEM that allows an individual to obtain more grants, bigger labs, etc". The theme that emerged from this capital was "recognition of scientific qualifications" and therefore we sorted scientific capital into the symbolic capital category.

Inductive Thematic Grouping

Three secondary types of capital – aspirational capital, identity capital, and psychological capital – did not align with any of the general capital types and were sorted into an "other" category. Aspirational capital is defined as "the ability to maintain hopes and dreams for the future alive despite real and perceived barriers and challenges". Identity capital is defined as "having the ability to build pre-professional identity and demonstrate alignment between emergent identities and future performance within a specific working context". This means having an understanding of the several elements that shape one as an individual and the ability to draw on past experiences to articulate a personal narrative that aligns to the employment domains one seeks to enter (Tomlinson, 2017, p. 345). Finally, psychological capital was defined as "developing dispositions such as resilience, risk tolerance, adaptability and 'mindsets around flexibility and career malleability". Through several discussions and rounds of coding, the theme that emerged from these capitals was "intrinsic strengths and resources". We created a new primary capital category which we named "intrinsic capital". Therefore, we defined intrinsic capital as the internal, self-authored strengths of an individual.

Discussion

Our systematic literature review exploring the forms of capital that are found in STEM education and career literature identified 184 qualifying documents that were included in our study (Figure 1). Thirty-six forms of capital emerged from these studies, and twenty-seven were retained in our final model. Five of these capitals were primary capital categories (cultural, economic, human, social, and symbolic); twenty-two were secondary capitals. Using a deductive thematic coding approach, we sorted the secondary capitals into the five primary capital categories. Three secondary capitals that did not align with any of the primary capitals were sorted into a "other" category. These three capitals were then analyzed inductively. We developed a new primary capital category to sort these three capitals into- intrinsic capital. The final Capital Framework Model (CFM) included six primary capital categories with twenty-one secondary capitals being sorted into one of those primary categories (Figure 2); cultural capital (N=11), economic capital (N=0), human capital (N=1), social capital (N=5), symbolic capital (N=1), and intrinsic capital (N=3).

We found that most of the secondary capitals that were identified in our systematic literature review could be sorted into the primary capital categories of cultural, economic, human, social, and symbolic capital – with the exception of the three secondary capitals that were sorted into the intrinsic capital category (aspirational, identity, and psychological). During our search, we discovered inconsistencies in how scholars defined and explained these secondary capitals. For example, as discussed in our methods section, academic capital was defined in four different ways. Although the definitions were similar, creating our model required developing a synthesized, single definition for academic capital, as well as all the secondary capitals with multiple definitions. When reading the various documents in which academic capital was found, we found that while some scholars provided detailed and explicit explanations of their interpretation of academic capital and how they applied it in their work, other scholars provided a few vague sentences about the concept. We noticed this same pattern for nearly all the other secondary forms of capital. We also noticed redundancies in secondary capital types, which necessitated our combination of like-forms of capital, such as STEM social capital and science-related social capital.

In a few studies, capitals were described with ambiguous definitions that were unclear or confusing to understand. These ambiguities perhaps reflect inconsistent understanding among the STEM education community about these capital concepts. This results in the production of confusing scholarship on these concepts. For STEM educators who seek to learn about these capitals and how to apply them in improving science education initiatives, these inconsistencies in explanations and definitions, as well as the redundancies in the creation of new secondary forms of capital, can make it challenging for them to fully grasp these concepts and inhibit intellectual progress.

Emerging from the lens of Critical Race Theory and through critiquing traditional interpretations of cultural capital, Yosso's (2005) introduction of the Community Cultural Wealth model was a first step in explaining how secondary capitals stem from primary forms of capital (e.g. cultural). For example, Yosso explains how the six capitals that create the CCW model are a representation of the array of skills, knowledge, abilities, and contacts that are cultivated among Communities of Color to resist and survive social oppressions. In her paper, (2005), she explains how she conceptualized the forms of capital that make up the CCW model and how they connect back to cultural capital (through a CRT lens) and the strengths and resources that are found among communities of color. In this study, we wanted to build off of this work and develop a model to provide the STEM education community an understanding of how the secondary capitals that are used in scholarly research often stem from primary forms of capital. The capitals found in our search include those that are in the CCW model, as well as others.

Five secondary capitals were included in our social capital model. These capitals all consisted of various types of networks: family, peers, and academic or scientific relationships. These secondary capitals provide insight into network types that go beyond the traditional mentoring-mentee relationships that are often discussed in STEM education literature (Callahan et al., 2015; Dike & Martin, 2018; Saw, 2020). Perhaps, most insightful is the finding of Yosso's familial capital in our search. This capital symbolizes the family, kinship, and community networks that impart intergenerational cultural knowledge and wisdom and the importance of these connections among communities of color and other marginalized communities. This differs from traditional interpretations of social capital which are perceived as being the networks and resources available to the elite and dominant members of society (Bourdieu, 1986), a resource that helps members of a group reach an end-goal (Coleman, 1988), or the norms of reciprocity and trustworthiness that exist in social networks (Putnam, 1993). These are the interpretations of social capital that are discussed in higher education circles, including STEM education. Familial capital, and the cultural knowledge that is learned from these networks, is a type of social capital that has not been recognized or deemed valuable within the dominant scientific community. When students of color are recruited into STEM majors, they are encouraged to establish relationships with scientific mentors who teach them how to assimilate into the dominant culture, sometimes at the expense of their own familial capital. An example of this phenomena is when Indigenous students are told that their cultural knowledge (e.g. traditional ecological knowledge) is not "real science", despite its societal contributions and have to learn to "code-switch" between communicating about their cultural knowledge (derived from their familial networks) and Western science knowledge (Snively & Corsiglia, 2000). Finding the use of familial capital in our search suggests that science educators are acknowledging the importance of students' families within the context of STEM education, specifically the families of students of color and other marginalized groups.

Almost half (N=11) of the twenty-one secondary capitals that were included in our final model were specific forms of cultural capital. All eleven capitals described knowledge needed to be successful in a specific area of STEM or STEM engagement. While the secondary capitals that we found in our search included capitals that reflected the norms and values of Western society (e.g. academic capital), we also found capitals that stem from the cultures of communities of color or other marginalized groups. Examples of these capitals include some of those found in CCW such as navigational capital and linguistic capital, as well as others such as hidden capital. These capitals are grounded in the cultural knowledge, assets, and historical experiences of communities of color and other marginalized groups. For example, the knowledge that goes into the designing of cornrows, a cultural practice in the African American community, is an example of hidden capital, one of the secondary forms of capital that were included in our cultural capital model (Eglash & Bennett, 2009). Finding these secondary capitals in our search of STEM education literature provides insight into how the concept of cultural capital has expanded since Bourdieu's initial inception, to recognize the value of the knowledge embedded in the cultures of non-dominant communities. As reflected in our search, these new conceptualizations are being applied within the context of STEM education to explore and understand how to better support students of color and other marginalized communities who are interested in science (Braun et al., 2017; Denton et al., 2020; Drazan et al., 2015; Eglash & Bennett, 2009; Rincon et al., 2020).

This brings us to resistant capital, which was one of the secondary capitals included in our cultural capital model. We sorted this into the cultural capital category because of the "promoting knowledge" component of its definition. However, in our discussions of this definition, we also interpreted resistant capital as being the "antithesis" of traditional interpretations of cultural capital. The conceptualization of resistant capital is rooted in the historical resistance to subordination and oppression exhibited by communities of color and their resistance of racism through maintaining and passing on their cultural knowledge (Yosso, 2005). Within the context of higher education and STEM education, resistant capital is exhibited through pushing against and challenging systemic inequities embedded in our educational systems and advocating for structural and cultural change (Revelo & Baber, 2018; Yosso, 2005). This contradicts the traditional interpretations of cultural capital which implies the need for less privileged groups to assimilate into the culture of the dominant (elite) group in order to succeed in life (Bourdieu, 1986; Yosso, 2005).

We did not have any secondary capitals within the economic capital category. While economic capital can be represented in many forms (e.g. money, real estate, investments) ultimately, the concept is simple- having financial resources.

Our human capital and symbolic capital models each contained only one secondary form of capital. Scientific capital was identified as a type of symbolic capital within the context of science. Based on honor and recognition, having scientific capital allows a scientist to obtain additional scientific resources (Brosnan, 2011). When reflecting on symbolic capital within the sciences, it is important to consider how honor and prestige are given. Often, it is based on an individual's ability to replicate the valued cultural capital within STEM, which is reflective of the merits valued by a white, western, culture (Wilson et al., 2019). It is common knowledge that within the sciences, obtaining grant funding and publishing are important milestones for career advancement. Yet scientists of color get funded and are published at lower rates than white scientists (Hoppe et al., 2019; Prescod-Weinsten, 2019; Roberts et al., 2020), thus limiting their career advancement opportunities. Therefore, we argue that in order to foster an inclusive and diverse scientific workforce, the scientific community needs to look past the merits of a white, western, scientific culture and expand their recognition of merit, honor, and prestige to be inclusive of the capitals held by scientists from traditionally underrepresented groups.

Human capital can be understood as the accumulated skills and knowledge an individual has which is of value to an employer (Becker, 1964;1994). In this study, decisional capital was grouped into the human capital category because the ability to make decisions comes from the accumulation of professional experiences. Decisional capital can be applied to thinking about diversity and inclusion in STEM and academia. One clear example lies with university leadership. For example, a university president is charged with making decisions about the university, while other academic leaders (e.g. chairs or deans) are charged with making decisions about their own individual programs or units. While the accumulation of the skills and knowledge held by all of these leaders contribute to the university's overall human capital, each individual engages with decisional capital in order to make decisions about the university and its programs, thus maintaining a functional and productive university. Unfortunately, university leadership across the nation continues to be predominantly white and male (Espinosa et al., 2019), therefore the people in charge of making decisions within academic spaces are prone to promoting and reinforcing structures and systems that are not representative of the cultures of individuals from underrepresented groups. The same concept applies to the leaders of the scientific community; if the people in charge of making decisions about what science gets funded and published reinforce the values of white dominant culture, scientists from underrepresented groups will continue to be left behind (Hoppe et al., 2019; Prescod-Weinsten, 2019; Roberts et al., 2020).

Finally, the secondary capitals that were sorted into the "other" category were classified as being specific forms of intrinsic capital- a new primary capital category that emerged from inductive coding. Aspirational capital, identity capital, and psychological capital. These capitals referred to internal strengths and resources and self-awareness that enable individuals to either overcome obstacles (aspirational and psychological capitals) or advance in their professional aspirations (identity capitals). While aspirational and psychological capitals have been acknowledged as intrinsic strengths (Revelo & Baber, 2008; Perez & Taylor, 2015; Yosso, 2005), they have not been formalized as a primary capital in the literature. In our study, we created this new primary capital category to formally recognize and validate this intrinsic asset. Furthermore, we suggest that as a discipline, the STEM education community needs to acknowledge these intrinsic capitals as vital for people of color and other marginalized identities to persist in these spaces and recognize and validate those strengths to promote inclusivity and a sense of belonging in the sciences.

The traditional forms of primary capitals are too constraining as conceived; they are representative of Western culture and its norms and values. Yosso pointed out in her critique of interpretations of cultural capital (Yosso, 2005), that these primary forms of capital fail to recognize or acknowledge the strengths and values cultivated within communities of color and other marginalized or oppressed communities. Striving towards creating a more inclusive and diverse environment within the STEM community means recognizing and validating the lesser recognized capitals (e.g. cultural strengths and resources) exhibited by people of color and other marginalized identities in this system, creating spaces for them to be seen, heard, and validated, and taking action to support systematic change. We propose that the definitions of the primary five forms of capital (cultural, economic, human, social, and symbolic), which are often used as a framework for developing programs that seek to support and increase the participation of students of color and other marginalized identities (Callahan et al., 2015; Enriquez, 2014; Stolle-McAllister, 2011), should be redefined and expanded to include non-western strengths and values. For example, our inclusion of resistant capital within the cultural capital model suggests that cultural capitals' definition might need to be expanded to include "and work to change social norms". Yosso expanded our understanding of cultural capital through the introduction of CCW; all other primary forms of capital should be revisited to expand their definitions to be more inclusive of non-dominant social groups.

Limitations

We acknowledge that our search procedures and criteria may not have captured all relevant documents pertaining to capital and STEM education. Our search only incorporated documents that were about STEM, engineering or science. Limiting the search to only science or STEM or engineering excluded documents that were discipline-specific (geosciences, biosciences). Thus, our systematic review may not necessarily be representative of all of the secondary capitals that exist in the STEM education literature in relation to specific disciplines such as biosciences, geoscience, etc.

Conclusion

This systematic literature review identified twenty-seven forms of capital that are applied in STEM education literature. This work provides insight into how secondary capitals (e.g. physical capital, academic capital) emerge from primary forms of capital (e.g. economic capital, cultural capital). Our study provides an explanation of the relationships between secondary and primary capitals. This work also introduces the concept of a new primary capital type- intrinsic capital. Intrinsic capital includes secondary capitals that are recognized as individualistic strengths but not formally categorized in the literature. Overall, we demonstrate the need for STEM educators to expand their understanding and interpretation of traditional forms of capital to include those resources and strengths that are often not valued in academic or scientific settings, some of which are cultivated among Communities of Color and other marginalized groups. In this study, we provide a starting foundation for scholars to understand capital theory within STEM education and its implications in future work. A future study that we would like to do is to apply this Capital Framework Model to explore how scientists from underrepresented persist in STEM careers.

CHAPTER 2

EXPLORING THE ROLE OF THE CAPITAL FRAMEWORK MODEL ON THE CAREER PERSISTENCE OF SCIENTISTS FROM UNDERREPRESENTED GROUPS

Introduction

In the United States, broadening participation in science, technology, engineering, and mathematics (STEM) has long been a national priority (Leggon, 2018; Means et al., 2018; Saw, 2020). While efforts initially focused on recruiting individuals from underrepresented racial/ethnic groups, over time they have expanded to include women, and individuals from the disabled and queer communities (Leggon, 2018; National Science Foundation, 2019; Yoder & Matheis, 2016). Unfortunately, individuals from underrepresented groups continue to be underrepresented in STEM (Byars-Winston et al., 2010; Cech & Pham, 2017; National Science Foundation, 2019; Pew Research Center, 2018).

While many scholars advocate for increasing diversity in STEM due to the potential for scientific innovation and to contribute to the global competitiveness of the United States (Ferrini-Mundy, 2013; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011; Valantine & Collins, 2015), broadening the participation of individuals from underrepresented groups in the science also has larger environmental and social justice implications. Marginalized communities experience the most negative impacts of the effects of current global crises such as the COVID-19 pandemic, climate change, natural disasters, and other public health problems (CDC, 2020; Gilio-Whitaker, 2019; Whyte, 2018). Policymakers, who enact policies and allocate funding for combatting pressing environmental and public health crises, often rely on scientific evidence and recommendations to do this. Therefore, it is critical that the voices and perspectives of those communities be included and represented in scientific spaces where research and policy conversations take place.

Initiatives that seek to broaden participation in STEM have evolved from focusing on the quantitative dimension (increasing numbers), to also focusing on the qualitative dimension (i.e. quality of education, training, and research) (Leggon, 2018). Research used to inform efforts that seek to broaden participation in STEM, has historically focused on the qualities and characteristics that individuals from underrepresented groups lacked (Harper, 2010; Leggon, 2018; Stolle-McAllister, 2011). As such, individuals from underrepresented groups have been portrayed as having deficits that impede their participation in STEM (Leggon, 2018; Stolle-McAllister, 2011). Therefore, broadening participation in science initiatives have often focused on "fixing" those perceived deficits and providing individuals with the skills, tools, and knowledge believed to be necessary to experience success in STEM (Ackerman, 1991; O'Connell, 2011; Stolle-McAllister, 2011). These approaches are considered deficit-based models (Harper, 2010; Leggon, 2018). However, the lack of diversity in STEM continues to be a problem (Cech & Pham, 2017; National Science Foundation, 2019; Pew Research Center, 2018). As such, scholars have argued for the use of an asset-based model that explores the strengths and resources that individuals use in order to navigate scientific careers (Harper, 2010). Broadening participation in STEM requires an understanding of the different factors that support student persistence in STEM and figuring out what works for different groups of students. In this study, we shift away from the deficit-based model and use an asset-based approach to explore the factors that contribute to the persistence of individuals from underrepresented groups in STEM.

Literature Review

Deficit-Based Models

Here, we provide a brief background into the concepts that are often used in initiatives and science education programming that seek to broaden the participation of individuals from underrepresented groups in STEM (Archer et al., 2012; Ovink & Veazey, 2011; Saw, 2020). Those concepts are usually grounded in capital theories (Bourdieu, 1986; Stolle-McAllister, 2011; Turnbull et al., 2020). In this study, capital is defined as the financial and non-financial resources that individuals use to succeed in life (Jaimes et al., unpublished work, Ch.1). Within the context of STEM, social and cultural capitals are the primary capital concepts used to explore the persistence of individuals from underrepresented groups (Callahan et al., 2015; Cole & Espinoza, 2008; Martin et al, 2013; Ovink & Veazey, 2011; Stolle-McAllister, 2011). Social capital can be understood as "*the networks of people that lead to resources and opportunities to benefit individuals and networks*". Within the context of STEM, social capital is often acquired via mentoring relationships between students and mentors (Callahan et al., 2015; McCallum, 2018; Mondisa, 2020). Those mentoring relationships can be impactful because they can contribute to a students' desire to engage and pursue a scientific career (Barlow & Villarejo, 2004; Carter et al., 2009; Hathaway et al., 2002). As such, many initiatives that seek to broaden the participation of individuals from underrepresented groups in STEM, aim to provide students access to social capital by helping them establish mentoring relationships and cultural capital through enrichment programs and research opportunities (Barlow & Villarejo 2004; Carter et al. 2009; Hathaway et al. 2002; Tsui, 2007; Stolle-McAllister, 2011; Villarejo et al. 2008).

Generally speaking, cultural capital can be understood as having familiarity with the dominant culture of a society (Bourdieu, 1986; Bourdieu & Passeron, 1977). Within this study, cultural capital is defined as "*being knowledgeable about societal or cultural norms and values and having the ability to reproduce and replicate those values and norms in order to be an active, welcome, and successful member of that society or culture*" (Table 1). Within education, cultural capital has been used to explain how a society's elite or dominant group maintains their social status through the accumulation of knowledge and replication of a culture's specific social norms, behaviors, habits, and language (Bourdieu, 1973; Gonzales, 2012). Individuals utilize cultural capital to successfully navigate social, professional, and academic institutions, which tend to validate and promote those who exhibit the knowledge and behaviors that they themselves value (Bourdieu, 1973; Bourdieu, & Passeron, 1990; Claussen & Osborne, 2011; Gonzales, 2012). Cultural capital can be viewed as a gatekeeper for climbing up the social ladder. Individuals who do not possess or replicate the types of cultural capital valued by the dominant groups are at a social disadvantage (Claussen & Osborne, 2011). As such, cultural capital has been used to promote a deficit model where groups that are not a part of the dominant group are often depicted as being culturally-deficit and need to acculturate to the dominant group in order to experience academic success (Bourdieu, 1986; Gonzales, 2012; Yosso, 2005).

Unfortunately, many of the diversity increasing initiatives in STEM are grounded in this deficit-based perspective. Program initiatives that seek to broaden the participation of individuals from underrepresented groups often seek to provide students with the social and cultural capitals valued by the dominant groups (e.g. white, wealthy, middle-class) (Ovink & Veazey, 2011; Stolle-McAllister, 2011; Wilson, 2019). Cultural capital can be acquired through social capital networks (Bourdieu, 1986). Therefore, students from underrepresented groups are often connected with scientific mentors who help provide them with the necessary tools and knowledge that can help them assimilate and adapt to the dominant scientific community. For example, undergraduate research programs provide students with mentors and opportunities to learn about the norms and culture of the scientific community through engagement with the scientific process (Linn et al., 2015). Engaging in undergraduate research experiences, gaining those skills, and connecting with scientific networks (e.g. mentors) can help students obtain the credentials and qualifications that are recognizable and accepted by the admissions committees of STEM graduate programs (Gazley et al., 2014) and acquire the supports that are needed to navigate academic and scientific spaces.

While studies have shown that these initiatives have been useful to an extent (Graham et al., 2013; Linn et al., 2015; Villarjo et al., 2008), focusing only on these two forms of capital negates to appreciate and value other kinds of resources and strengths that are found among marginalized communities. Students from underrepresented communities bring with them many resources and assets that help them navigate academic and scientific spaces that go unrecognized in those spaces (Harper, 2010; Samuelson & Litzler, 2016; Yosso, 2005). Utilizing this deficit-based approach for improving diversity in the sciences also fails to recognize systematic barriers that lead to the departure of scientists from underrepresented groups. Examples of these systematic barriers include racism, sexism, etc. (Dutt, 2020; Pew Research Center, 2018). Dutt (2020) discusses the problem of racism in the geosciences, the least diverse of the STEM disciplines, and how its non-inclusive and homogenous culture leads to geoscientists from underrepresented groups departing from the discipline. To help fix this problem in the discipline, they call for systematic cultural change that is grounded in anti-racist and anti-deficit thinking (Dutt, 2020).

Please note that while the science education literature heavily emphasizes the roles of social and cultural capitals on scientific career success, some studies also discuss the roles of economic, human, and symbolic capital, though not as prevalent (Thompson et al., 2016; Turnbull et al,, 2020). For the purposes of this dissertation, please refer to Chapter 1 (Jaimes et al., unpublished work Ch.1) for a more detailed discussion of economic, human, and symbolic capitals.

Asset-Based Models

To combat the deficit-based perspectives in diversity increasing initiatives in STEM, scholars have called for using an anti-deficit or assets-based approach to understanding how individuals from various underrepresented groups navigate pursuing scientific degrees (Braun et al, 2017; Harper, 2010; Samuelson & Litzler, 2016; Yosso, 2005). An example of an asset-based model is Dr. Tara Yosso's (2005) Community Cultural Wealth (CCW) framework. Grounded in Critical Race Theory (Delgado & Stefanic, 2001), CCW is an extension of Bourdieu's cultural capital theory and describes how students of color utilize the many attributes of their culture and communities in order to successfully navigate spaces such as academic institutions. Yosso (2005) critiqued how Bourdieu's cultural capital work has been used in discussions of social and racial inequities by insinuating that communities of color do not have cultural capital. While Bourdieu (1986) focuses on the cultural capital of the dominant group in society, Yosso argues that the resources cultivated by communities of color and their families should also be recognized as cultural capital. CCW consists of six types of capital that are "*not mutually exclusive or static, but rather are dynamic processes that build on one another as part of community cultural wealth*" (Yosso, 2005, p.96). These capitals include aspirational capital, familial capital, linguistic capital, navigational capital, social capital, and resistant capital and can be found in Table 1.

Although CCW is grounded in the culture and values of communities of color, scholars have applied this model to other underrepresented groups in society (e.g. disabled or queer) in order to explore their own perseverance and success in life (Braun et al., 2017; Samuelson & Litzler, 2016; Pennell, 2015). STEM education scholars have used CCW to study the scientific pursuits of African Americans and disabled scientists (Braun et al., 2017; Burt & Johnson, 2018; Samuelson and Litzler, 2016). For example, Samuelson and Litzler (2016) explored the types of capital that students of color in engineering relied on while pursuing their degrees and how they contributed to their persistence. In this qualitative study, the authors found that navigational, aspirational, familial, and resistant capitals supported students in various ways. In their interviews, students discussed relying mostly on aspirational and navigational forms of capital during their engineering programs. Samuelson and Litzler (2016) concluded that using CCW is a useful anti-deficit construct to explore the persistence of Latinx and African American engineering students. Similarly, Braun et al. (2017) found that anti-deficit frameworks, such as CCW, can and should be utilized for understanding how to recruit, retain, and support scientists from underrepresented groups.

A Holistic Theoretical Framework: The Capital Framework Model

Building off the work of Yosso and other scholars (Bourdieu, 1986; Becker, 1964;1994; Coleman, 1988; Putnam, 1993;1995), Jaimes et al., (unpublished work, Ch.1) combined deficit-based and asset-based models and developed a holistic capital model framework model, incorporating both models. Jaimes et al., (unpublished work, Ch.1) conducted a systematic literature review in which they explored the forms of capital that exist in the science education literature in order to gain a better understanding of the factors that contribute to student success in STEM. They found that most of the capitals in the science education literature could be identified as secondary forms of capital that stem from five primary capital categories: cultural capital, economic capital, human capital, social capital, and symbolic capital (Bourdieu, 1986; Becker, 1964, 1994; Coleman, 1988; Putnam, 1993, 1995). Their work also introduced the concept of a new primary capital type- intrinsic capital, which included secondary capitals that were recognized as individualistic, self-authored strengths, but had not been formally categorized in the science education literature (Figure 2) (Jaimes et al., unpublished work Ch.1). They developed a new Capital Framework Model (Figure 2) that could be used as a holistic asset-based model to explore the academic and scientific persistence of individuals from underrepresented groups.

This Study

This work is an exploratory study that evaluates the work of Jaimes et al., (unpublished work, Ch.1), Yosso (2005), and Harper (2010), in using an asset-based research approach to understand the types of capital scientists from underrepresented groups used to persist in their academic and scientific endeavors. Using the Capital Framework Model (CFM) created by Jaimes et al., (unpublished work, Ch.1) we seek to explore the following research questions:

Research Question 1: In what ways can the Capital Framework Model be used to explore the educational and career persistence of scientists from underrepresented groups?

Research Question 2: Which capitals are most useful to scientists from underrepresented groups for educational and career persistence?

Methods

Data Collection

The Michigan State University Institutional Review Board approved all research procedures in this study. Participants were recruited via survey responses from a national study focusing on the role that mentoring has on diversity in STEM; all participants had indicated their willingness to participate in a follow-up interview. Fifteen semi-structured interviews were conducted virtually via videoconference, each lasting for about 50 minutes. Upon completion of the interview, all participants were provided with an electronic $20 gift card as compensation for their time.

All participants in this study identified as a member of one or more of the underrepresented groups discussed above. That is, they identified as an ethnic minority, as queer, and/or as disabled. All participants held scientific positions within academia, non-profit educational organizations, or national laboratories. Their education levels ranged from pursuing a bachelor’s degree to completion of a Ph.D. Overall, a range of ethnicities, scientific disciplines, and academic and professional positions were represented in this study (Table 3). Although we did not specifically ask about household income, some participants discussed how coming from a lower-socio-economic household shaped their educational and career goals.

Semi-Structured Interview Protocol

The semi-structured interview protocol was developed in collaboration with researchers at Michigan State University and Eastern Michigan University. The questions were developed with the intention of exploring how an individual entered and navigated their scientific careers. Specifically, we wanted to learn more about the resources that scientists relied on and utilized during their career pursuits. Interview questions were written to explore the internal and external resources that participants accessed and utilized while pursuing a higher education degree and a scientific career.

The beginning of the protocol was designed to understand what led a participant to pursue a scientific major and learn about the experiences they had while in college, graduate school, and professional careers. We explicitly probed for any resources that helped participants during their schooling or professional pursuits. Additional information about the intrinsic strengths that participants exhibited during these pursuits emerged during conversations of future goals, reasons for those goals, and discussions of barriers and challenges.

Data Analysis

Coding of the data occurred in two stages. In the first stage of coding, a deductive thematic analysis was performed on the data (Braun & Clark, 2006; Crabtree & Miller, 1999; Fereday & Muir-Cochrane, 2006), meaning that we coded each transcript using a predetermined codebook. The codebook that was used for this study was the Capital Framework Model (Figure 2) created by Jaimes et al., (unpublished work, Ch.1) which consisted of the primary capital categories of cultural capital (Bourdieu, 1986), economic capital (Bourdieu, 1986), human capital (Becker, 1964; 1994), social capital (Coleman, 1988; Putnam, 1993; 1995), symbolic capital (Bourdieu, 1986), and intrinsic capital (Jaimes et al., unpublished, Ch.1), and the secondary capitals that exist within each of those categories.

Several steps were taken to ensure trustworthiness during the coding process. First, the codebook used was created by the three authors. This codebook was discussed before the coding of data began to ensure that all authors were in agreement in understanding how to code the data. Second, each author independently read and coded the interview transcript. Third, all three authors subsequently discussed and reviewed each other’s coding. While most codes were in strong agreement, discrepancies were easily resolved through discussion. Discrepancies were discussed until consensus was reached.

Once deductive coding was completed, interview transcripts were analyzed inductively (Fereday & Muir-Cochrane, 2006; Nowell et al., 2017; Roberts et al., 2019) to determine if there were any additional strengths or resources that participants described accessing during their educational and scientific pursuits. The three authors conducted this inductive analysis together and reached agreement about the addition of new secondary capital to the Capital Framework Model, in the primary intrinsic capital category of Jaimes et al.'s (unpublished, Ch.1) (see Figure 3).

Results

Findings indicate that participants relied on access to social, cultural, economic, and intrinsic capitals in order to persist in their scientific endeavors. Within the context of social capital, we found that participants described having access to the five types of secondary capitals from the social capital model determined by Jaimes et al., (unpublished work, Ch.1) (Figure 2). We also found that from the cultural capital model determined by Jaimes et al., (unpublished work, Ch.1) (Figure 2), participants described accessing five of the secondary forms of cultural capital. These five types were: academic capital, discipline capital, technical capital, navigational capital, and resistant capital. Resistant was discussed only by participants of color and emerged when they described challenging racial stereotypes and being able to push past those racial biases.

Although all participants had access to financial resources, those resources differed from participant to participant. Having access to economic capital was how participants funded their academic and scientific pursuits. Finally, we found that participants described two types of intrinsic capitals- aspirational and identity. However, during the inductive coding process, we noticed a third strength emerge from the data of participants of color. We found that participants of color demonstrated an awareness of the social inequities that faced communities of color and aspired to use their scientific and academic privileges to help those communities. This was a strength and resource that was not found in the systematic literature review in Jaimes et al., (unpublished work, Ch.1). Since this strength was prevalent in the data of participants of color, we made the decision to create a fourth type of intrinsic capital (Jaimes et al., unpublished work, Ch.1) which we identified as critical consciousness capital.

Social Capital

In this study, participants described having access to five forms of social capital. This section is divided into describing these five types: college social capital, familial social capital, parental social capital, peer-related social capital, and STEM social capital.

College Social Capital

When asked about their educational aspirations, some participants described having participated in college preparatory programs that made them knowledgeable about the college-going application process and inspired them to pursue a higher education degree. Arturo is an example of someone who participated in such a program.

> *"I was in a program called AVID… They always talk to us, like we were going to go to college. Like, Some of you-- all of you are going to college, so you need to decide what you want to study by junior and senior year of high school… Really, I think it's just an accumulation of all the little experiences."*

AVID (Advancement Via Individual Determination) is a program that helps high school students from underrepresented groups prepare for college by providing them with resources and information about higher education and how to navigate the college-going process. Arturo credited AVID for contributing to the development of his educational aspirations.

Familial & Parental Social Capitals

Here, we describe familial and parental social capitals together, because participants often described familial and parental support within the same context. For most participants, familial support for education came in the form of educational encouragement and sometimes financial assistance. Overall, we found that most participants credited their families for playing an influential role in shaping their educational goals.

Virginia gave us examples of specific actions that her family took in order to demonstrate to her that her education was highly valued. In addition to receiving messages about the educational expectations desired of Virginia, her parents were involved in her academics by asking what she was learning in school. Additionally, her grandparents had set up a college savings bond at a young age, implying that she would be going to college.

> "*I think it included – they [parents] wanted to know about what I was doing in school. They encouraged me in school and put a high value on my education from the time I was a small child. And I think there was just this expectation. My grandparents would give me a savings bond for college when I was six years old. Those kinds of very specific things that were expected that was a choice that I was going to make*."

Sarah also had parents that laid out clear expectations of what her career aspirations should be. It was expected that she would pursue a higher education degree that would lead to a high-paying job. For her parents, education was deemed valuable only for the purpose of social and economic upward mobility.

> "*So, definitely, like that was sort of already established that higher education is a valuable thing. But I think kind of where maybe if differs from some of my peers is*

it's seen as a valuable thing sort of only for the purpose of getting a better job or kind of, you know, moving up in classes—that kind of thing—rather than, you know, inherently valuable? And that's become kind of clear depending on—you know, sort of—but I would go home to my parents and say, "Oh, I'm interested in—a purely academic thing- and they would kind of respond of, Oh, like—is that going to give you a higher-paying job?"

Some participants had families that exposed them to science and nature by taking them on hiking trips, on field trips to museums, or encouraging them to participate in scientific or educational programming. For example, Martha described how her mother helped nurture her interest in science by finding educational programs that supported that interest.

"*My mom helped a lot. She was really good at finding programs—after-school programs. There was this program I did in high school that was a week-long, women-only—or, girls-only, go out and help scientists do research. That was definitely a really good experience to show me what it would be like*."

Though the support that participants' families provided differed between each family, it was clear from our data that families played an important role in the early development of their educational goals.

Peer-Related Social Capital

When discussing the individuals who supported them during their scientific journey, participants also described relying on their peers and colleagues. Here we present the various ways in which participants described their peers supporting them.

Some participants relied on peer support for academic purposes. For example, participants Sam and Rosa both described having a supportive group of peers with who they were able to study. Sam shared that her study groups consisted of peers within her discipline, which were separate from her group of friends.

> "*I mean there were people who supported me, I mean friends and stuff. But within my field, like study groups were really good. I had peers who were really supportive*."

While Rosa did not describe a formal study group, she shared that she was able to study with her group of friends whom she felt were really supportive of her.

> "*I had two friends, we used to be a group of three, two guys and me. One guy was brilliant, he was really brilliant. The other one was really smart. We were funny, we were hanging out, they were really supportive. The times that I said, okay, I'm going to ask for help, they would actually study with me and help me with stuff*."

While many participants described their peers as providing academic support, we also noticed that many participants of color expressed finding a sense of community among other peers of color. Many of the Black and Latinx participants shared feeling shocked to find that there were very few people of color in the sciences. They found that being able to connect with other scientists of color was meaningful to them. For example, Lydia, a Latinx female, shared with us that she found a community with a group of other Latinx scientists that she connected with via a leadership institute hosted by several scientific organizations.

> "*One of the wonderful things about it is that it created such a strong sense of community with all of us that participated… we're a super-tightknit group. Like we all are connected on social media… If we end up in a city close to a different person, we connect. We connected at the SACNAS conference... And I don't know that it was the first time, but it was definitely the time that stands out the most*

where I felt that the skill set that I have was valued by people that I admired. You know, we were all at different stages of our careers… And I think it was perhaps one of the first times that I acknowledged the skill set that I have and the things that I can bring to the table…"

By having this sense of community, and interacting with her peers and colleagues, this participant was able to acknowledge and recognize her own skills and realized that she could make an impact within science. The relationships created during this leadership institute lasted beyond the program. Lydia described the various ways in which they all kept in touch, despite being in different stages of their careers.

Sarah, a Black woman shared with us that during her summer internships, she found it very helpful to connect with other students who had also experienced marginalization with academia.

"*What really was helpful for me was meeting other undergrads who were under-represented in similar ways to me. Or not even similar ways but who were—who've experienced marginalization, who've experienced kind of, you know, being the only representative of X, Y, Z group in, you know, like a meeting or a classroom… I think meeting people like that and having the ability to—meeting them through summer internships, to clarify- and sort of like having the ability to talk to them and sort of get their insight and advice… I think, was helpful, and that sort of what I think has been the thing that I've leaned on a lot… I think that's been really helpful for me—sort of validated a lot of what I was feeling*."

Sarah described both her in-person and virtual interactions with peers as very important and helpful for her. While was the only participant who spoke about those virtual connections, this provided some valuable insight into how peer-networks could be established.

Another woman of color, Magali, also described the importance of developing a sense of community with other students of color. These peers were at her institution and she was able to connect with them more than the students in her own cohort/program.

> "*I have developed my community, which are all graduate students of color just because we really understand each other and so, within that, that really strong tight-knit group, is where I continue to pursue trying some activism with and they're more like my cohort than my actual incoming cohort class*."

Ultimately, we found that access to a network of peers was an important source of support for our participants. While many participants mostly described the academic benefits of having a supportive peer network, some participants of color also articulated finding a sense of community among other peers of color. While those peers of color may not necessarily have been in the same institution or workplace as our participants, those connections were so helpful for participants of color. Many of them described themselves as being one of the very few people of color in their programs, which could be mentally challenging, so being able to connect with other peers who understood what they were going through was beneficial because it validated their feelings and experiences.

STEM Social Capital

All participants described having access to STEM social capital- the networks, resources, and opportunities to acquire knowledge and skills to navigate a scientific career trajectory. For most participants, access to this capital emerged in the form of their scientific mentors and advisors. For example, Jo shared some fond memories of his graduate school mentor and how he approached the scientific training of his graduate students.

"*He was simultaneously a good mentor. He did a lot to encourage keeping up with the current literature, and networking. And he did, we did a lot of group editing of each other's stuff so that we could improve our writing, things like that. And whenever there was a big grant that he knew of, he would always be like hey, you should apply for this*."

Jo's mentor helped his students (including Jo) network, keep up with current literature relevant to their work, helped them improve their scientific writing, and shared grant opportunities with them. This mentor sharing information on scientific knowledge and resources is a form of STEM social capital.

However, STEM social capital was not just limited to advisors and program mentors. Some participants gained STEM social capital by attending conferences or participating in scientific bridge programs. For example, Lydia recalled that when she transferred from a community college to a four-year institution, she was surprised to learn that compared to her peers, there were many aspects of scientific research that she was unaware of. When asked about how she navigated those surprises, she responded with "gaining access to a network of scientists".

"I ended up going to the SACNAS conference. And this was back in 2002. And one of the things that I did while I was at SACNAS is I made as many friends as I could. And it was mostly with like program directors. So, I got really lucky in being able to go to SACNAS. And I started asking like people a ton of questions… I was like, "Do you know any other professors that are like Mexican American?"

And they'd be like, "Oh, yeah. I know so-and-so. Like let me introduce you". Or like, "Oh, do you know anybody else that like is a gay scientist?" And they'd be like, "Oh, yeah. I do. Let me introduce you". So that helped way more than I would've ever anticipated."

This experience helped Lydia in more ways than she anticipated. These networks of scientists answered questions she had about research and even connected her to queer and Latinx scientists- two identities that she identified with.

In addition to helping participants gain scientific knowledge and learn more about how to navigate a STEM career (e.g. going to graduate school), mentors also connected participants with scientific opportunities that would help with career advancement. Martha described how her mentors helped her in this way.

"*I had a couple of mentors in college, in the geology department, who also talked to me about opportunities and told me how grad school is a possibility. I have continued to talk with at least one of those mentors on career advice and things like that…They said, 'Do you want to help me with my research?' and 'Here, I can pay you this much for this amount of work'. And so, I got to do actual science and learn techniques and get experience and all that to see if I liked it. You know, I got to go on some trips and do some field work, so it was really good for my resume as well as it was really fun*."

Through those mentors, Martha learned about the possibility of graduate school. At least one of her mentors continues to give her career advice and even took her on to do scientific research. She described this experience as being beneficial for her career since she could add that knowledge and experience to her resume.

The above narratives illustrate the various ways in which having access to scientific networks benefitted participant's academic and scientific careers. Those networks provided participants with scientific knowledge, connected them with scientific opportunities, and exposed them to new career information (such as the possibility of graduate school).

Cultural Capital

In this section we describe the different types of cultural capital that participants described in their interviews. The four types of cultural capital that emerged in this dataset are academic capital, discipline capital, technical capital, navigational capital, and resistant capital.

Academic, Discipline, and Technical Capitals

Academic capital refers to being knowledgeable about academic norms, practices, and resources. Disciplinary capital refers to knowledge about discipline-specific paradigms related to doing scientific research. Technical capital refers to knowledge, skills, and abilities. Here, we simultaneously present our findings on academic capital, discipline, and technical capitals due to the fact that participants often described these capitals within the same context. Many participants described gaining academic, disciplinary, and technical capitals, from participating in scientific programs, or through their networks- usually mentors or advisors, but sometimes also peers. For example, in the quote below, Rosa described how she struggled with understanding the implicit norms of the physics discipline as well as some of the physics concepts.

> "*Once I started my advanced physics courses, I started noticing there were a lot of implied understandings that I didn't have, something as simple as the Greek Alphabets. I didn't recognize lower case from the upper case. I started having a lot of difficulties trying to differentiate which ones were variables and which ones*

were constants. That's when that gap between me and them, the physicists, started showing... I had another friend that I met. He was really nice, and he would notice l notice this and he would help me. He knew the alphabet, he knew those implicit norms in physics that I wasn't aware."

Although once she entered her advanced coursework, she initially struggled with understanding some physics concepts, Rosa was able to gain a better understanding of the physics norms and concepts after her friend helped her.

Magali described participating in several internships as a student. The knowledge and skills that she gained through those internships and her coursework made her a better researcher and helped her learn how to think like a scientist. She described thinking through ideas with her advisor. Being able to ask research questions and figure out how to answer those questions are important skills for scientists to have and gaining those skills (i.e. discipline capital and technical capital) finally made her feel like she belonged in the scientific community.

"*I guess it was when the more internships I pursued, the more I realized that I really love research. Within that, I started having some of my own research ideas within that. It just would spark like, Oh, wait. What if it's not answering this question, but maybe it can answer this question? And so, as I progressed with my education, as I progressed with my reading, it was actually I think this year that I really, really felt that I'm heading towards the scientist-thinker I want to become. I've been working really hard with my advisor trying to articulate my thoughts and clearly lay out what I'm trying, what's in my head. And so, I guess it was really this year that I really feel that I progressed and that I really do belong in this scientific world*."

Arturo described how an El Salvadorian mentor taught him and other students of color necessary study skills to be able to navigate their scientific classes; skills that were not explicitly taught in school but were necessary to study effectively. An example of one of these skills is reading a math book.

> "*There was an El Salvadorian mentor… he liked helping out some of the students of color in STEM. You could ask him for a small question, and he'd give you like an hour worth of derivations and he would teach you how to work with vectors and this and that. He taught us how to do study groups efficiently and effectively. He drilled us, he taught us what it was like to read a book. No one ever taught you how to read a math book. And he called us out, like get up on the board and do this problem, while all your peers are watching you. I think this instilled that spirit in us and he drilled us for classes beyond those physics classes. We didn't have to put our hands up; we knew how to fight after that*."

Acquiring this knowledge from his mentor empowered this participant and his peers to feel like they could do well in their science courses and continue pursuing their scientific goals. Gaining disciplinary and technical knowledge was necessary for participants to do well in their educational and scientific endeavors. By accessing those capitals, they became knowledgeable about scientific concepts and norms and gained scientific skills, such as the ability to do research. Overall, we found that participants described accessing scientific disciplinary and technical capitals through their various networks, further illustrating the benefits derived from those connections.

Navigational Capital

Navigational capital referred to the ability to successfully navigate unfamiliar institutions or organizations. While most participants met their mentors, advisors, and faculty – the individuals who helped them learn to navigate the scientific and academic communities- by chance through their classes or by participating in scientific programs, one participant proactively sought out this type of help prior to entering college. Max described not having parental guidance when it came to figuring out how to navigate the college-going process. When asked how he gained the knowledge to navigate the academic journey he shared that he took a proactive approach.

> "*Since I lived in the inner-city, even though the precedent of going to college was set, the means to get there in terms of finances and sort of that specific knowledge of how you go about it really wasn't present…. Really [I gained that knowledge] by having to be proactive and learn myself. Because of the financial situation, I visited the community college and talked to the faculty there. I was, again, very concerned about transferring; what requirements do you have to get to do that? The faculty there said, 'Well, with your academic background and record you could just go straight on to a school like Cornell'. I said, "Well, yeah. It's not an academic question, it's a financial question*."

Despite having the academic credentials to be able to pursue a degree at a prestigious 4-year college, Sam knew that they did not have the financial means to go that route and recognized the need to start their college career by pursuing a more affordable community college option. Looking ahead and prior to beginning his college journey, he was proactive about asking the faculty at a community college what he needed to do to navigate the transfer process when it was time to transfer to a four-year institution. Despite not having the parental guidance to give him this knowledge, he knew what he needed to do to gain it, therefore demonstrating having navigational capital.

Resistant Capital

Resistant capital emerged when participants of color described challenging stereotypes and being able to push past the racial biases that others had of them. For example, participants of color shared the negative experiences they had in STEM due to their racial identities. For example, some participants who identified as Black, described their qualifications and merits being questioned within scientific spaces. For example, Cynthia mentioned several times in her interview that as a Black woman scientist, she was often questioned about whether she had truly "earned" her place and the awards that she had received. This resulted in a strong work ethic that challenged other's perceptions of her to demonstrate to them that she had earned her way.

> "*Yeah. Definitely. Or, like there's been assumptions that I didn't work as hard to get to where I am. No, like, I bust my butt to do things. I used to be the type of person that I wanted to make sure no one had, without a doubt, that I deserved to be where I am. But now I know that I deserve it. So I took my ACT twice, because I thought a 24 wasn't good enough to get into school. So I didn't want there to be any doubt. So I retook it to get a 28. So even now, people are like, I do all this stuff and I do it because I enjoy it."*

While she tried to challenge those negative stereotypical perceptions that others had of her by pushing herself to work hard and challenging her own self, she eventually realized that she did not need to do that. She realized that deserved to be where she was at and no longer pushed herself to work hard to prove herself to others, but rather because she enjoys doing what she does.

Janet described a similar experience in being perceived negatively as a Black woman in STEM. In her interview, she recalled that while she had not been directly told that she could not do science due to her being a Black woman, she did experience many microaggressions throughout her career. She shared a few examples of some of those microaggressions.

> "*There have been things like looks or asking me if I'm lost or immediately shutting me out of the conversation in group work. Things like that. Those I consider microaggressions or just immediately deeming me as incompetent. I would say that dealing with microaggressions is something I reigned in on myself as something I will deal with the entirety of my life unless things make radical changes. As I'm sure all of us know, change comes slow or not at all. I definitely think about it a lot but it's definitely something I don't put any stock in besides the occasional bouts of imposter syndrome and stuff like that that I have to deal with. But my identity as a Black woman is static. It stays the same and will stay the same until time goes on. So, it's not something I've ever let stop me in any of my interests or pursuits regardless of what anybody had to say about it*."

Janet recognized that her identity as a Black woman was static and she would continue to encounter those negative experiences as time goes on. Janet decided that she would not let that negativity deter her from pursuing her goals and interests. Like Cynthia, Janet was able to push past those stereotypes and not let them get in the way of her future pursuits.

Other participants who had shared their negative STEM experiences due to their racial identities, also developed a similar attitude and resiliency to Cynthia's and Janet's and continued aspiring toward their scientific goals. While this resiliency was a strength that emboldened participants to continue with their career pursuits, these experiences illustrate the racism that continues to exist within academic and scientific spaces.

Economic Capital

All participants described having access to financial resources (i.e. economic capital) that funded their education. In this study, we asked participants how they financed their educational pursuits. Participants described having access to different forms of financial support. Within the context of this study, economic capital emerged in the forms of 1) familial contributions, 2) financial aid packages 3) scholarships or fellowships, 4) graduate assistantships, 5) paid research experiences or internships, 6) off-campus jobs, and 7) loans.

For example, Martha shared that the way she financed her education was through familial support, loans, and her graduate school funding package (e.g. assistantship).

> "*So, I got a fairly large scholarship to go to college, but I also took out some loans, and every year me and my parents, we each had our own contributions we had to make as well. So, that's how undergrad was paid for. And then, yeah, grad school is all included in these awards that the professors give out—TA-ships and things like that*."

Lydia had a slightly different experience than Martha during her undergraduate years. Lydia had to work and save money in order to be able to pay for her college education. She worked a regular job during the school year and worked (paid) internships during the summers. While her undergraduate experience was different than Martha's, her graduate school experience was similar in that she also received a graduate school funding package.

> "*So for undergrad, I worked like all the time. And then I would do internships over the summer, and I would save all of the money… like all of the stipends. I would save like as much as I could. Like I would only spend money on food, and I would save the rest of it to pay tuition for the next semester. So for the summer, I would save all that money and pay the fall semester. And then I would work all of the fall semester and use that money to pay for the spring semester. And in the spring, I would work and save all that money to supplement whatever I had left over. And then for my PhD, being in the biomedical sciences, I received a full stipend and full tuition*."

Cam had similar experiences to both Martha and Lydia. Cam described having parental support, working, and also having graduate school funding.

> "*Like as an undergrad – my parents did pay part of my tuition. I still have a lot of student loans from when I was an undergrad. And I worked work/study jobs to, you know, have spending money then? But then once I went to grad school, I was on tuition waiver and a graduate stipend."*

The above are examples of some of the ways in which participants described accessing economic capital. Although each participant had different experiences with the types of financial resources they had access to, they all found a way to finance their education making it possible for them to pursue a higher education degree and a scientific career path.

Intrinsic Capital

Intrinsic capitals were internal strengths demonstrated by participants. These strengths were tied to their identities and culture. In this study, we found participants describing aspirational and identity capitals. However, we also found an additional strength not found in

Jaimes et al., (unpublished work, Ch.1). This strength was found among participants of color and was grounded in a commitment to helping communities of color through a social justice lens using their scientific and academic privileges. We created a new type of intrinsic capital and identified this strength as critical consciousness capital.

Aspirational Capital

Aspirational capital refers to a participant maintaining their hopes and dreams of a STEM career, despite facing barriers and challenges. For some participants, the ability to maintain aspirational capital tied back to their communities and families and the work they put into supporting and encouraging their educational journey. For example, at the start of his interview, Arturo shared with us the work and sacrifice that his single, immigrant mother put into his education. When asked if he had experienced any challenges in pursuing a scientific career he responded:

> "*… I feel like-- inspired just because of the whole minority thing. I know I should represent. Oftentimes, I feel like, Damn. If I'm trying to get acceptance in all these spaces, and some of these spaces, I don't really-- I don't know if they respect a lot of those identities or a lot of the things that I identify with. I'm like down, trying to get approval from people that don't really respect my folks. At the end of the day, I'm not really even trying to get approval-- I guess I have to, to apply to stuff, the people that deem me worthy to enter their institution, or whatever. I feel like the representation is important. In a way, I constantly go back and forth between being inspired and also, being hesitant to continue pursuing. I think, for the most part, at the end of the day, I know that what I'm pursuing is what I want to do…. Just by being a minority, or just by coming from the hood, I know I'll get to where*

I want to be, even if I can't-- Because my mom, she put in all that work…. so I could put in the work and end up where I want to end up. I just think about her whenever it gets tough."

Arturo expressed an internal conflict between continuing to pursue a scientific career or leaving it behind. He knew that by continuing to pursue this career path, he would need to gain the acceptance of individuals that were not accepting or respectful of his identity or his community. He also acknowledged the work that his mom put into his education so that he could pursue any career path he wanted. However, he recognized that despite the challenges and conflicts he experienced, he would continue to pursue a scientific career path. He understood the significance of him being in scientific spaces because 1) the representation of people of color in STEM was important and 2) he owed it to his mother.

Other participants who also experienced challenges or barriers in pursuing their scientific ambitions were able to rely on their networks of peers or mentors for support to keep striving towards those goals. Magali tearfully recalled an experience she had when she tried to apply to a summer research internship.

"*There is many times where I wanted to give up. I was actually discouraged from my undergraduate biology advisor for the whole biology department. Initially, in my first two years, I wasn't doing well in those weeder-out courses. And when I found a research opportunity, a research internship for the summer, I brought it out to the departmental, the department biology undergraduate advisor and I said, I'm interested in applying to this, and that advisor said that maybe you should change majors and leave these opportunities for students that are actually doing well. Yeah, so then I actually switched into a more, I guess prestigious* *aspect of the college, within the university… which was more prestigious in the sense where it's research-based and you actually do have to apply to get in on that portion. But the reason why I got in is because my actual advisor, my mentor now, he's awesome and helped me navigate the system that way.*"

Like Arturo, Magali also shared that there were times that she wanted to give up her scientific career goals. She was being discouraged from pursuing career advancement opportunities (i.e. research internships) by her scientific advisor. However, this experience did not deter her from switching to a more research-focused college within her university, a college that she described as more prestigious. Despite encountering discouragement from some science advisors, she was able to connect with more supportive mentors who helped her get into the competitive program.

Overall, we found that participants of color often expressed challenges and barriers in their scientific journey due to racial biases. Those challenges sometimes made them question whether or not to continue pursuing their scientific career goals, but ultimately, with the support and encouragement of families or mentors, they continued persisting.

Identity Capital

Some participants described how their marginalized identities impacted the way they navigated their professional careers. For example, Janet recalled how her queer identity influenced her career trajectory.

"*In some jobs if that came out before me really wanting that to come out it could be uncomfortable…. It can be a struggle. It's part of the reason why I shirk towards more academia because I didn't find it wasn't an issue as much in academia where everyone is more focused towards a specific topic and answering* *a specific question. Whereas when I had regular, normal people jobs that was a topic of conversation. I just didn't want to talk about it... If I showed pride it was viewed as being over the top, so I erred toward academia where it was a non-issue more so."*

When she worked in non-academic jobs, which she described as "normal people jobs", she would feel uncomfortable if her queer identity came out before she felt ready to come out. She felt judged in those spaces and she described that those feelings are what pushed her to pursue an academic career path, where everyone is mostly focused on their own research (i.e., answering a specific question).

Participants of color also understood that because of their racial identities, they were judged differently than their white peers. This influenced the way they presented themselves in their work environment. Cynthia describes what it means to be a Black woman in her lab.

"*As a Black woman, I have curves. Every day I have to like be conscious of what I wear… So even the shirts I wear, I have to make sure they're not too low cut. My hair is natural, so sometimes I wear my hair in an Afro, or my hairstyles change and I get comments about that. Which is kind of annoying, very annoying… I can't just put my hair back in a ponytail and think I can just come to work. Or I don't get the same benefit of the doubt as far as professionalism... I have to make sure my clothes are cleaned and they're ironed, and pay attention to what I'm wearing. But I can't dress up too much, because then the thought process is that I care too much about my appearance and not enough about my research… there are people with purple hair and pink hair, and they still get more respect as scientists than I do*."

She shared that this experience was unique to her as the only Black woman in her lab. Her white female lab mates would come into work with colorful hair and were still treated with more respect as a scientist than Cynthia was. She recognized that as a Black woman, this was an experience that would continue to follow her in her career. Cynthia continued to share that she understood that on the totem pole within STEM, males were always on top, then white women, and she (a Black woman) was at the "*complete bottom*".

Unlike skin color, there are some marginalized identities that participants were able to "hide". For example- their disability status. One participant, Sam, shared how they hid their disability status from an internship employer in an effort to keep their job once the internship ended. They did not want to be deemed as incapable of being able to do their work in order to not be replaced once the internship period ended.

> "*A lot of the disability stuff, because the job was – like an internship was four months, and I really wanted to get hired after the internship. So basically, I was doing a lot of obscuring of any [health] impacts that that was having on me during the internship portion. Because I also knew it was a government-funded internship and they could keep applying to have different people come in on that internship. They didn't need to keep any of us on afterwards. So I really wanted to I guess show my best face, which is a non-disabled, best capitalist worker kind of face through that period because I needed to get hired*."

Sam tried to hide the health impacts that the job had on them in order to give off the image of being a healthy, able-bodied worker. They were well-aware of the capitalist workforce values that dominate society and felt that they needed to portray themselves as an able-bodied individual in order to increase their chances of getting hired once their internship ended.

Overall, we found that most participants described the various ways in which their marginalized identities affected the way they navigated their workspace. Some participants shared hiding their queer identity or disability status in the workplace in order to avoid discomfort or stigma. Women of color participants described how they modified their appearance in order to appear professional. Some participants also shared that their identities influenced the career trajectories they pursued because they believed that certain career paths were more tolerable and accepting of their identities than others. Overall, participants engaged with identity capital by recognizing how their marginalized identities were perceived by their colleagues and working to adapt or conform their appearance and behaviors to the standards and expectations of the dominant work culture in order to fit in.

The Development of Critical Consciousness Capital

The most insightful finding of this study was that all participants of color expressed having an understanding and awareness of social and environmental injustices that primarily impacted communities of color. Most Black and Latinx participants expressed a desire to help those communities using their scientific and academic knowledge. Some participants wanted to pursue STEM careers because they wanted to help bring more minority students into STEM careers. They wanted to help mentor and guide those students. Other participants described participating in diversity, equity, and inclusion work within STEM programs at their universities. Many participants expressed having an understanding of the concepts, theories, and histories that explained how social and environmental injustices happened and recognized that most people in STEM did not have that same appreciation or understanding for social justice work, making it challenging for them to engage in intersectional work.

For example, Marisol shared with us that she belonged to an environmental justice collective where she, along with other scientists, collaborated with Indigenous communities on environmental justice issues that affect them. Engaging in that collective made her think about the importance of integrating social and scientific disciplines in order to truly understand the emerging issues in environmental research.

> "*Like even as much as ecologists, as much as we want to separate the natural from the social, in our [environmental justice] collective, and in a lot of indigenous communities, there is no separation… So, the [environmental justice] collective is really where – in that interdisciplinary field, having those conversations – that's where I really felt that I belonged. And so that gave me the confidence and the strength to really bring that [environmental justice] into the coral reef ecology lab. And I've butted heads with the coral reef ecologists a couple times but I refuse to back down.*"

Despite encountering resistance from other ecologists, she refuses to back down from the work that she does with the environmental justice collective she belongs to. She recognizes the importance of taking into consideration the intersection of issues, such as imperialism or colonialism and scientific research when doing environmental work.

When asked about the impact she would like to make, Sarah expressed a desire to change the structures of STEM to be more inclusive and welcoming to people of color. She had encountered many issues due to her identity as a Black woman and wanted to change that for future students of color pursuing STEM careers. Like Marisol, she also experienced resistance with her vision of science which led her to sometimes question that career path she wanted to take.

"*I would say I've had a big shift in my thoughts on that topic [career]. Because I initially—so, I kind of mentioned earlier I wanted to be a professor for a little bit. I think that also was influenced by like, I want to be the professor that I never had and maybe that'll change things. maybe have like a little bit of power to change this small thing—or to, you know, be the professor for a handful of students? And I think now I'm sort of considering, how can I still pursue? You know, I do enjoy research. I really do. But sort of like how can I pursue that and still be able to like impact larger structural change*?"

Sarah questioned how she could continue to pursue a scientific research career path as a professor, while still impacting systematic and structural change within academic and scientific spaces. She went on to express frustration at diversity and inclusion initiatives. She stated that she was a very well-read person, and she understood the cultural and social history that led to the underrepresentation of people of color within spaces like STEM.

"*… if you don't acknowledge why we have the problems that we have—right? Like racism, sexism… I think because we [scientists] don't use those terms, because we don't call them what—call the source of these problems what they are… I think you have people that are like confused about the purpose of diversity inclusion efforts, you know, who are sort of still not understanding like why we need to even be doing this*."

Like Marisol, she had an understanding of how social problems such as sexism and racism bled into STEM, creating a "lack of diversity" problem. She recognized that other scientists did not understand why diversity and inclusion work was necessary in STEM. While she is unsure if she wants to continue an academic career path as a science professor, she still wants to find a way to carry out her research interests and crate "structural change" within STEM.

Critical consciousness can be understood as "*marginalized individuals' ability to analyze and take action to address social oppression* (Cadenas et al., 2020, p. 163)". Based on findings from this study, we created a new intrinsic capital category of critical consciousness capital. While critical consciousness is already a recognized concept in education (Cadena et al., 2020; Freire, 1973), it is not formally recognized as a strength or capital. In this study, we identified it as a capital, because we considered it an internal strength and resource that participants of color demonstrated having, which helped them with their scientific careers. This capital helped shape their career aspirations and for many participants and this desire to help impact underrepresented communities in a positive way helped them push past the challenges and barriers they faced (i.e. *representation is important- Arturo*). The above quotes illustrate two clear examples of participants' knowledge of the intersection of social justice issues and STEM, a knowledge demonstrated by most participants of color.

This finding was not seen among our white participants. When white participants were asked about their reasons for going into their field of work and about the impact they hoped to make with their career, their responses were different than the Black and Latinx participants. Some participants expressed enjoying their jobs and field of work. Some expressed a desire to get their work "*out there*" through publications. Some participants expressed a desire to mentor future generations of scientists that would help solve current scientific problems. Several scientists also described the impact their work would have on major issues such as climate change. Many of them recognized the importance of their work and the contributions it would make to the larger scientific community. However, when discussing motivations for working in their discipline and the impact they hoped their work would have, they did not express the same social justice commitment that Black and Latinx participants articulated in their interviews.

Discussion

In this exploratory study, we used an asset-based research approach to understand the resources that scientists from underrepresented groups used to persist in their scientific endeavors. Using the Capital Framework Model created by Jaimes et al., (unpublished work, Ch.1) we explored the following research questions: 1) In what ways can the Capital Framework Model be used to explore the educational and career persistence of scientists from underrepresented groups? and 2) which capitals are most useful to scientists from underrepresented groups for educational and career persistence?

Within this study, we found that participants found social capital, cultural capital, economic capital, and intrinsic capital as most useful for their educational and career persistence. Participants accessed all five forms of social capital (college, familial and parental, peer-related, and STEM social capitals). These social capitals provided multiple forms of support for participants. Participants also accessed five types of cultural capital (academic capital, disciplinary capital, technical capital, navigational capital, and resistant capital). To finance their education, all participants found access to economic capital, often in the form of familial support, financial aid, loans, assistantships, or employment. We found two forms of intrinsic capital: aspirational capital and identity capital. However, we also identified an additional intrinsic capital which we named critical consciousness capital, which emerged only in the interviews of participants of color.

Social capital emerged in the discussions of the various networks that participants had access to throughout their lives. When discussing social capital within the context of STEM, the science education literature heavily emphasizes the importance of mentoring relationships as critical for student success in STEM (McCallum et al., 2018; Mondisa, 2020; Wilson et al., 2012). In this study, mentoring relationships emerged as an example of STEM social capital. Having STEM social capital, meant that participants accessed networks of mentors that provided them with information on how to navigate a scientific career path and opportunities for career advancement with STEM. Those opportunities enabled participants to make progress in their scientific careers. Similarly, having access to college-social capital prepared some participants to be able to navigate pursuing a higher education degree. While these findings reiterate the importance of mentoring relationships for student success (McCallum et al., 2018; Mondisa, 2020), we must recognize that college social capital and STEM social capital are not the only types of social capital that helped participants with their academic and scientific endeavors; familial, parental, and peer-related social capitals were influential as well.

When referring to familial and parental social capitals, participants mostly relied on families for support and encouragement related to their education. Most families helped shape participants' early career aspirations, however, some participants also shared that their families provided financial support. Within the context of social capital, the most insightful findings were participants' discussions of peer-related social capital. Most participants articulated that they often relied on their peers for academic support, sometimes in the form of study groups or tutoring. However, for many participants of color, the support derived from peer-related social capital extended beyond traditional academic support. For participants of color, peer-social capital emerged in the form of establishing friendships and connections with other scientists of color that led to a sense of community and belonging with STEM. Many participants described themselves as being one of the very few people of color in their programs, which was sometimes mentally challenging due to the racism and microaggressions they often encountered in those spaces. Being able to connect with other peers of color who understood what they were going through was helpful to participants because it validated their feelings and experiences of racism within the academy and science. For many participants, having that supportive group of scientists of color helped them establish a feeling of belonging within STEM. Studies show that while establishing a sense of belonging in the STEM community can help improve retention, establishing this feeling can be challenging for individuals from underrepresented groups (McCallum et al., 2018; Rainey et al., 2018). While the literature does not heavily emphasize the benefits of peer-to-peer interactions as it does of mentoring relationships, perhaps science educators should consider how to embed peer support and community building initiatives to create welcoming and inclusive environments for students of colors in STEM in order to encourage student retention (Revelo, 2015; Revelo & Baber, 2018).

Regarding cultural capital, we identified two primary findings. The first is that academic and scientific knowledge, as represented by academic, disciplinary, and technical capitals, was necessary for participants to experience success in their scientific coursework and research endeavors. Many participants acknowledged that they had to acquire that specific knowledge and skills in order to successfully navigate (i.e. gain navigational capital) the academic and scientific spaces they were in. Those four types of cultural capital almost always stemmed from social capital further illustrating the career benefits of social networks.

However, as stated earlier in this paper only validating the cultural capital recognized and valued by the scientific community- grounded in white middle-class values (Wilson et al., 2019) - is problematic as it negates other capitals that individuals from underrepresented groups bring with them to scientific spaces. This brings us to our second cultural capital finding, regarding resistant capital. Resistant capital emerged from the interviews of participants of color when they spoke about the resiliency they developed in response to the racism and microaggressions they experienced in academic and scientific spaces. That resiliency gave them the strength to push back against those barriers and continue persisting in their scientific career. Yosso (2005) described resistant capital as emerging from "*the legacy of resistance to subordination exhibited by communities of color*" (Yosso, 2005, p. 80). Within this study, participants of color articulated various ways in which they resisted the oppression and marginalization of their racialized identities within academia and STEM. Despite questioning their belonging in STEM, they chose to remain in their fields. That action of embracing their identity (i.e. *my identity as a Black woman is static*) and choosing to stay in STEM is an act of resistance.

We also found that participants of color engagement with resistance capital overlapped with aspirational and critical consciousness capital- two forms of intrinsic capital. For example, when discussing their career aspirations, some participants of color shared examples of explicitly being told that they did not belong in STEM by authoritative figures, such as advisors or professors. However, through developing resiliency, participants maintained their career goals alive and continued pushing through with their educational and professional endeavors. Through their lived experiences, participants of color became knowledgeable about social justice issues- specifically environmental injustice and racism and recognized how those issues intersected with STEM. Many participants of color expressed a desire to use their scientific positions to strive for and enact structural change within academia and STEM; some participants acknowledged that their representation in STEM was important for their communities and for future scholars of color. Other participants explained that, despite encountering resistance, they tried to convey the importance of environmental justice in conversations with other scientists and in the work that they do.

Finally, identity capital – another form of intrinsic capital- was something that emerged among the all marginalized groups- queer, ethnic/racial minority, and disabled. Most participants explained how their marginalized identities affected the way they navigated their work environments. Often, participants explained having to hide or modify components of their identities to fit within the dominant culture and be accepted as scientists. While those strengths and resources (i.e. resistant, aspirational, identity, and critical consciousness capitals) are certainly admirable and enable scientists from underrepresented communities to persist in scientific careers, unfortunately, those experiences are clear examples of the racism, ableism, sexism, and heteronormativity that dominates academia and STEM (Brown & Leigh, 2018; Cech & Pham, 2018; Clark & Hurd, 2020; Dutt, 2020) that make it challenging for individuals from underrepresented groups to remain in those spaces.

Overall, we found that most participants experienced challenges in STEM due to their marginalized identities and used social, cultural, economic, and intrinsic capitals to persist in STEM careers. Despite all participants identifying as belonging to one or more underrepresented groups, participants of color interacted with some of these capitals differently than white participants. A new type of intrinsic capital (i.e. critical consciousness capital), emerged from the racialized lived experiences of participants of color. Their experiences made them aware of social inequities and they were able to bridge the connection between STEM and social justice work. While we did not identify every single capital found in Jaimes et al.'s Capital Framework Model (unpublished work, Ch.1) within this exploratory study, we were able to find many of them. Therefore, we argue that the Capital Framework Model, developed by Jaimes et al.

(unpublished work, Ch.1) is appropriate for studying the career persistence of scientists from underrepresented groups. Some of the CFM capitals that we were unable to identify within this study included forms of capital that tied back to the cultural experiences of communities of color (e.g. hidden capital) (Eglash & Bennett, 2009). A future study, applying the Capital Framework Model, with the inclusion of critical consciousness capital, to explore the cultural resources that scientists of color utilize during their scientific careers, might be warranted to further test the application of this model.

Conclusion

In this study, we evaluated the application of the Capital Framework Model (Jaimes et al., unpublished work, Ch.1) to explore the educational and career persistence of scientists from underrepresented groups. Our findings suggest the CFM is an appropriate framework to explore career persistence among underrepresented groups. Participants accessed all five forms of social capital (Figure 2), five forms of cultural capital, economic capital, and two types of intrinsic capital. We also identified an additional secondary capital that was added to the intrinsic capital category (Figure 3). While our findings align with previous studies that demonstrate the benefits of traditional interpretations of social, cultural, and economic capitals for the persistence of individuals from underrepresented groups in STEM (Luedke et al., 2019; Stolle-McAllister, 2011), our findings also illustrate the importance of lesser-recognized forms of capital (e.g., resistant capital, critical consciousness capital) that are grounded in the cultural and lived experiences of underrepresented communities. Some of those lesser recognized strengths and resources (e.g., capitals) are essential for the educational and career persistence of scientists from underrepresented groups, allowing them to overcome systemic barriers they encounter on their professional journeys.

The findings from this study could have larger implications for the academic and scientific communities as it relates to broadening the participation of individuals from underrepresented groups in STEM. For example, as graduate schools are seeking to be more inclusive with their admission requirements (Wilson et al., 2019), less emphasis is being placed on subjective criteria such as GRE and GPA scores. Letter of recommendation and personal statements will weigh more heavily during the application reviewing process; those are areas where those capitals could be discussed in detail. We urge STEM programs to recognize and validate those forms of capital that emerge from the cultural and lived experiences of individuals from underrepresented groups and utilize them to create a more holistic approach for admitting students. As STEM programs move towards removing subjective admissions criteria, often rooted in the values of the dominant culture, which is primarily middle-class, male, and white (Wilson et al., 2019), there exists an opportunity to reimagine the admissions process to be more inclusive for individuals from underrepresented groups in order to increase their participation in STEM.

CHAPTER 4

BEING LATINX IN STEM: EXPLORING THE CAPITALS THAT CONTRIBUTE TO LATINX PERSISTENCE IN SCIENTIFIC CAREERS

Introduction

Over the last decade, the Latinx community has made considerable gains in college degree attainment (Excelencia in Education, 2020). Unfortunately, despite these gains and the continuous efforts to broaden the participation of individuals from underrepresented groups in science, technology, engineering, and math (STEM), Latinx students continue to be underrepresented in the sciences (National Science Board, 2020; National Science Foundation, 2019; PNPI, 2020).

Despite the educational gains of Latinx students they are often perceived through a deficit-based educational lens and are portrayed as being culturally deficit, underprepared, and at risk for failure (Becera, 2012; Yosso, 2005; 2006). Initiatives that seek to broaden the participation of individuals from underrepresented groups in STEM are often grounded in this deficit-based thinking and seek to “fix” students and provide them with tools and knowledge that is needed to assimilate and succeed in scientific spaces (Ackerman, 1991; Castro, 2014; O’Connell, 2011; Stolle-McAllister, 2011). Using this deficit-based model for initiatives that seek to broaden participation in STEM is problematic because it fails to recognize and appreciate the strengths and resources that are found among marginalized communities and ignores the systematic barriers they face when entering academic and scientific spaces. Examples of these systematic barriers include racism, sexism, or ableism (Brown & Leigh, 2018; Cech & Pham, 2018; Clark & Hurd, 2020; Dutt, 2020).

Scholars have begun to shift away from this deficit-based model, towards an asset-based model when exploring the educational and scientific persistence of students from underrepresented groups (Braun et al., 2017; Harper, 2010; Samuelson & Litzler, 2016; Yosso, 2005). Harper (2010) suggested a more appropriate and effective way to understand underrepresentation in STEM would be for researchers to utilize anti-deficit frameworks that "deliberately attempt to discover how some students of color have managed to succeed in STEM" (p. 7). That is, researchers should explore the resources that enabled scientists from underrepresented groups to be successful instead of focusing on the deficits. In order to address the issue of underrepresentation in the sciences, a growing body of literature is examining the social and cultural factors that contribute to the persistence of students from underrepresented groups in STEM fields (Braun et al., 2017; Denton et al., 2020; Peralta et al., 2013; Revelo & Baber, 2018; Samuelson & Litzler, 2016).

Literature Review

Cultural Assets of Latinx Students

Research on Latinx students in science education scholarship reveals a myriad of factors that contribute to student persistence in STEM careers (Cole & Espinoza, 2008; Revelo & Baber, 2018; Rincon et al., 2020; Samuelson & Litzler, 2016). Scholars are recognizing the cultural strengths, assets, and knowledge that Latinx students bring with them into STEM careers which enable them to persist and experience success (Samuelson & Litzler, 2016; Revelo & Baber, 2018; Rincon et al., 2020). These cultural strengths derive from their familial and cultural knowledge, as well as their lived experiences (Burt & Johnson, 2018; Revelo & Baber, 2018; Yosso, 2005; 2006). For example, families play an important role in the development of the educational aspirations and academic success of Latinx students; students report wanting to pursue a scientific degree to obtain a job to help improve their family's socioeconomic situation (Aguirre et al., 2020; Ceja, 2004; Mien, 2020; Peralta, et al., 2013; Rincon et al., 2020).

Unfortunately, pursuing a STEM career can be isolating and challenging for students from underrepresented groups. Scholars have found that Latinx scientists are able to navigate those feelings of isolation by engaging with ethnic-based student organizations that embrace both cultural and scientific values (Revelo, 2015). This allows them to establish a sense of community and belonging among other Latinx peers, thus helping them embrace their scientific identities (Revelo, 2015; Revelo & Baber, 2018). To combat the challenges of pursuing a scientific degree, Latinx students also actively engage in various forms of resistance (a cultural strength) within STEM while during their educational journey, enabling them to succeed in their engineering programs (Revelo & Baber 2018).

Theoretical Framework

As is typically done in science education research that explores the problem of underrepresentation in STEM, the aforementioned studies on Latinx scientists employ a capital theory lens. In this study, "capital" is defined as the financial and non-financial resources that enable individuals to succeed in life (Jaimes et al., unpublished work, Ch.1; Ch.2). While previous scholarship has examined the factors that contribute to the success of Latinx scientists, those studies typically focus on one or two capital concepts, including social capital (Coleman, 1988; Putnam, 1993), cultural capital (Bourdieu, 1986), or Community Cultural Wealth (Yosso, 2005).

Traditional interpretations of social and cultural capital theories in science education usually utilize the definitions of Bourdieu (1986), Coleman (1988), or Putnam (1996). They emphasize how the norms and values, including communication style, cultural references, and social networking abilities, of the dominant group, are rewarded in academic and scientific spaces. These dominant values and norms are grounded in white, western, and wealthy culture (Wilson et al., 2019). An individual can obtain social and cultural capital through family connections or through formal schooling (Bourdieu, 1986). However, the educational system produces a system that is grounded in the cultural and social values of the dominant, more privileged groups in society (Bourdieu, 1986). Therefore, experiencing academic success often requires familiarity with the dominant culture which is typically gained through family upbringing or through cultural assimilation (Bourdieu, 1986; Cole & Espinoza, 2008). When they enter academic and scientific spaces, students of color are expected to assimilate to the dominant (white) culture in order to succeed, reinforcing the notion that communities of color are culturally deficit (e.g. deficit-based model) (Yosso, 2005; 2006; Gonzales, 2012).

Community Cultural Wealth (CCW) was conceptualized by Yosso (2005) to demonstrate how communities of color groups cultivate and hold valuable forms of capital, pushing back against the notion that communities of color are culturally deficient. CCW comprises six forms of capital; aspirational, familial, linguistic, navigational, social, and resistant (Yosso, 2005; 2006); definitions for these capitals can be found in Table 1. These capitals emerge from the cultural knowledge and lived experiences of communities of color. Yosso argues that while the capitals that comprise CCW may not be recognized or valued in academic spaces, they are essential to the survival and educational persistence of communities of color.

Building off the work of Yosso and other capital theory scholars (Bourdieu, 1986; Becker, 1964;1994; Coleman, 1988; Putnam, 1993;1995), Jaimes et al., (unpublished work, Ch.1) combined deficit-based and asset-based models and developed a holistic Capital Model Framework model. Jaimes et al., (unpublished work, Ch.1) conducted a systematic literature review in which they explored the forms of capital that exist in the science education literature in order to gain a better understanding of the factors that contribute to student success in STEM. They found that most of the capitals in the science education literature could be identified as secondary forms of capital that stem from five primary capital categories: cultural capital, economic capital, human capital, social capital, and symbolic capital (Bourdieu, 1986; Becker, 1964, 1994; Coleman, 1988; Putnam, 1993, 1995). Their work also introduced the concept of a new primary capital type- intrinsic capital, which included secondary capitals that were recognized as individualistic, self-authored strengths, but had not been formally categorized in the science education literature. This study resulted in the development of a Capital Framework Model (CFM) that could be used as a holistic asset-based framework to explore the persistence of individuals from underrepresented groups in STEM.

In an exploratory study by Jaimes et al. (unpublished work, Ch.2), they evaluated how the CFM could be used to explore the educational and career persistence of scientists from underrepresented groups. While they found that participants from various underrepresented groups (e.g. disabled, ethnic/racial minorities, queer) all accessed social capital, cultural capital, economic capital, and intrinsic capital to persist in STEM careers, scientists of color engaged with capitals differently than white scientists. They also identified a new capital- critical consciousness capital- only found in scientists of color. Critical consciousness capital developed from scientists of color their career aspirations related to the intersection of STEM and social justice issues.

This Study

This study builds off the work of Jaimes et al., (unpublished work, Ch.1; Ch.2) to further explore how the CFM developed by Jaimes et al., (2020, Ch.1), explain the persistence of Latinx scientists, incorporating the addition of critical consciousness capital into the model (Jaimes et al., Ch.2). The research questions (RQ) in this study are RQ1) How does the CFM (with the addition of critical consciousness capital) help explain the career trajectory of Latinx scientists? RQ2: How are the different forms of capital manifested in the career aspirations of Latinx scientists?

Methods

Data Collection

Participants were recruited from an interdisciplinary scientific national conference in the United States. Ten semi-structured interviews were conducted virtually via videoconference. Upon completion of the interview, all participants were compensated with an electronic $20 gift card. All participants in this study identified as Latinx. All participants held scientific positions within academia, industry, or national laboratories. Their education levels ranged from a bachelor's degree to completion of a Ph.D. Seven participants identified as male and three as female. Participant demographic information can be found in Table 4.

Semi-Structured Interview Protocol

The semi-structured interview protocol was developed to explore how an individual entered and navigated their scientific careers. Specifically, we wanted to learn more about the resources that scientists relied on and utilized during their career pursuits. Interview questions were written to explore the internal and external resources that participants accessed and utilized while pursuing a higher education degree and a scientific career.

Data Analysis

Data was coded via a deductive thematic analysis (Braun & Clark, 2006; Crabtree & Miller, 1999; Fereday & Muir-Cochrane, 2006), meaning that each transcript was coded using a predetermined codebook. The codebook that was used for this study was the Capital Framework Model (Figure 2) created by Jaimes et al., (unpublished work, Ch.1, Ch.2) which consisted of the primary capital categories of cultural capital (Bourdieu, 1986), economic capital (Bourdieu, 1986), human capital (Becker, 1964; 1994), social capital (Coleman, 1988; Putnam, 1993; 1995), symbolic capital (Bourdieu, 1986), and intrinsic capital (Jaimes et al., unpublished, Ch.1), the secondary capitals that exist within each of those categories, and included the addition of critical consciousness capital.

Several steps were taken to ensure trustworthiness during the coding process. First, Jaimes was one of the three authors who developed the CFM. Second, coding was performed by three researchers. The codebook was discussed by the three researchers before coding began to ensure that they all understood how to code the data. The researchers coded each transcript independently. Third, the authors subsequently discussed and reviewed each other's coding. Any coding discrepancies were easily resolved through discussion. Discrepancies were discussed until consensus was reached.

Results

Findings reveal that participants described having access to economic, social, cultural, symbolic, and intrinsic capitals during their educational and professional journeys (Jaimes et al., unpublished work, Ch.1; Ch.2). The cultural and lived experiences of these Latinx participants greatly influenced how they viewed their positions within the STEM community, thus activating lesser-known capitals (e.g. hidden capital, critical consciousness capital) that are not typically valued within the dominant academic or scientific communities. All participants emphasized wanting to use their scientific privileges to give back, positively impact, and empower individuals from underrepresented communities and increase the participation of those communities in STEM.

This section begins through the summarization of the economic capital that participants had access to while pursuing a higher education degree. Then social capital findings are described. The social capital section is divided into two sections. The first section discusses parental and familial social capital. The second social capital section is incorporated into the cultural capital section and describes the interconnectedness of other forms of social capital and some types of cultural capital. Specifically, findings regarding the relationship between 1) college social capital and academic capital and 2) peer-related social capital and discipline and technical capitals, and 3) STEM social capital and discipline, technical, and navigational capitals.

Other forms of cultural capital found in these interviews are then described. These are credential capital, experimental capital, hidden capital, and resistant capital. This is followed by a symbolic capital section. The results section concludes with findings regarding intrinsic capital types which include aspirational, identity, psychological, and critical consciousness capital.

Economic Capital

All participants described having access to various forms of financial resources during their educational journeys. These often came in the form of federal financial aid, fellowships, loans, or parents helping finance tuition costs. For example, Maria relied on her parents and on scholarships and graduate fellowships to finance her degrees:

> "*For undergrad, I had a scholarship, so my parents pretty much just paid for the housing. And then, for my doctoral degree, I had a fellowship that also gave me a stipend, so I didn't really – I mean, I didn't need money because I had it, and I lived with my parents at that time. So financially, I was fortunate for that aspect*."

Oscar described having various sources of funding for his undergraduate geology degree:

> "*It was through scholarships, financial aid, grants. That's how pretty much my undergrad was paid for*."

Gerardo, a first-generation college student, had made a deal with his parents that if he went to college after high school, they would help him finance the costs.

> "*Yeah, I paid a little bit out of my pocket, but mostly it was my parents that helped me through the whole college process of paying*."

Most participants had access to similar forms of financial support. Although some participants had little support from parents, most primarily funded their education by relying on federal financial aid and scholarships during their undergraduate career and obtaining fellowships or graduate assistantships during their graduate years. Participants recognized that this financial support made it possible for them to pursue their educational goals.

Social Capital

Parental and Familial Social Capitals

Participants described the multiple ways in which their families helped them and supported them during their educational endeavors. This support included emotional and sometimes financial support. Many of these Latinx scientists had families that were invested in their educational success and most of them discussed how their educational aspirations had been shaped and molded by their parents and their upbringing. Although the interview protocol did not probe for socio-economic status, most participants described themselves as coming from low-income households. They saw getting an education as the path to a more prosperous future. For example, Jose explained:

"*As I mentioned I was the only one – the only U.S. citizen in my family. The rest of my siblings were born in Mexico. My mother was a single mother. She didn't even finish high school. She didn't even get into high school. So she had a junior high education, as did my father. And so education has been viewed as important, but they haven't really had a thorough understanding of how that works, or how to navigate that, right, or how to support that as best as they could. So school was important for those multiple reasons. And it was believed that education would have been important for – because it opens up other opportunities*."

Additionally, many participants identified as the first in their families to go to college and explained that although their families prioritized and encouraged them to get an education, most parents were unable to provide specific guidance on how to navigate the college-going process, having never gone to college themselves. For example, Roberto explained that nobody in his family went past a middle school education but received many messages from his family about the importance of getting an education, despite them not being able to guide him through that journey. He stated:

"*So there wasn't a lot of, you know, going to college. My parents knew they wanted me to go to college. They didn't know how I could there. They always told me that, you know, 'you need to continue your education because when you're done with it, you're going to be in a better place than we are now'. So that was about it. I mean, they pushed me, and they really helped me kind of foster that curiosity that I had about science, but they didn't know anything about higher education or what to tell me about it*."

Oscar shared with us that his mother did not complete high school and did not know how the university or higher education worked. When he spent time at the university doing lab work, she became upset because she thought that he was engaging in non-academic activities. He stated:

> "*When I was doing my undergrad, when I was spending a lot of time in the lab, she thought I was actually out, like doing some other stuff like partying or something, and she would get upset. And for them, it's a very important thing to do for us because my brother and I are the first ones in the whole [family] – in all the generations to actually go to a higher education*."

Other participants also shared with us that their families were adamant about them pursuing an education. The narratives above illustrate some of the messages and encouragement these scientists received from their families and how that influenced their own educational pathway.

Cultural Capital

The manifestations of cultural capital were noted in two ways. First, in association with social capital. Participants received several types of cultural capital from some of their social capital networks. Second, participants also described some lesser-known cultural capital types that stemmed from their own lived experiences as Latinx scientists.

Cultural Capital Associated with Social Capital

Although most participants described their families as being supportive and influential in forming their educational goals, despite not being able to guide them with their academic or scientific careers, all participants had access to advising and mentorship from academic and scientific professionals, who were able to help them navigate and gain academic and scientific skills. Therefore, college, peer-related, or STEM social capital cannot be described without also describing the cultural capital that was gained from having those relationships. The four forms of cultural capital that stemmed from these connections were academic capital, discipline capital, technical capital, and navigational capital. These connections were useful in helping participants gain the academic and scientific skills that are needed to pursue a college degree and a scientific career.

College Social Capital and Academic Capital

Prior to attending college, some participants recalled participating in college preparatory programs and connecting with college advisors that helped them learn about the college-going process. For example, Erik said:

> "*I was in a program called AVID, which is Advancement Via Indifferent Determination and it was just a class that when I got into high school. Once I started AVID I realized or I learned that this was to get minority students to go to college, so obviously, that did everything for me. Had it not been for that, I don't know what I would've done, but you know. So, they prepped us for the GRE or the SAT. They prepped us for these college entrance exams, applications, prepared you how to go to college, took us to campuses so that you could see like what it's like to be at college, all that kind of stuff.*"

Participating in these programs provided participants with knowledge about the college-application process, helped them prepare for college entrance exams, and prepared them for attending college. These programs were beneficial for participants to be able to enter and learn how to navigate college.

Peer-related Social Capital and Discipline and Technical Capitals

Participants mostly relied on their peers for assistance with better understanding of academic coursework or scientific concepts and psychosocial support while in school. For example, Roberto described how the more advanced graduate students in his lab helped him with learning how to write a scientific abstract and how to communicate "like a scientist". He says:

> "*I remember in the lab that I was in as a Master's student I had, there were multiple PhD students. So I would sit down with them, and I would ask them, 'what are the different components of an abstract?' And they would tell me. And I would go off and try to write it myself and send it to them. And basically, just go back and forth through multiple revisions of it until I finally understood what the components of the abstract are, and how you should talk or how you should write like a scientist.*"

Other participants shared similar experiences regarding learning from their peers. They studied together and also relied on each other to deal with the challenges of school. Alicia shared:

> "*We kind of lean on each other to kind of come up with ideas on how do you – well, if this exam is – or this prelim is this hard, let's just work on it… having a support system with other students as well.*"

Some participants also shared that they found community among their peers. Beto described:

> "*You know, in my department, there are a handful of people of color, and those tend to be the people, you know, I've befriended the most, largely because, you know, we naturally gravitate towards each other. We have similar experiences.*

You know, they may have not come from the same community, but they understand, as a person of color in STEM, it's difficult. And we've learned to be, you know, a cohort, in some sense, of supporting each other".

Overall, participants described their peers as providing several channels of support which ranged from helping participants gain academic and scientific skills, to being a source of community.

STEM Social Capital and Discipline, Technical, and Navigational Capitals

Many participants described how their mentors taught them some of the skills that are needed to produce scientific writing- an important component of being a scientist. They were provided with disciplinary knowledge about the norms of the scientific community and the steps that they needed to take to advance in their careers. Most participants described learning how to produce scientific writing through their interactions with their advisors or professors. Some stated that they were being trained to pursue scientific careers, which meant having to refine their writing abilities (i.e. technical capital).

For example, participant Alicia described how her mentor taught her and her peers how to write a scientific manuscript which is an experience that has been great for her career.

"*My old mentor from grad school would be one of those very important people that have definitely shaped the way that I think about science… We would actually bring up our manuscripts [to the lab]… so we would critique it as a group. Coming as a brand new grad student, you really don't know how to frame a question, 'How do you structure a manuscript?' So seeing the senior graduate students going through that, and the post-docs actually going through that, then you can start to see… then I know more or less the structure of a manuscript."*

This participant indicated that being provided with this writing knowledge helped boost her own confidence in her abilities. She went on to share that currently, she sees other scientists in the same position as her, struggling with scientific writing and she expressed gratitude for her mentor for teaching her those writing skills. Erik also described the writing mentorship that he received from his advisor which helped him pursue a career at a Research 1 institution (R1). He recalled:

> "*He was very critical in terms of my writing, but he didn't do it in the same kind of demeaning way. You know what I mean? I was being trained to go to an R1 institution, right? So, he wanted – he was like you know, 'It's going to go very fast. You're going to have to publish a lot. You're going to have to work your butt off.' So a lot of what he did in terms of critical …. was more in a motivational way. So, he like explained, 'This is why I marked that paper so much not to make you feel stupid, but if you want to publish in this journal, your writing has to get better'.*"

In addition to learning about some of the writing skills associated with being a scientist from their mentors, these Latinx participants also described how their professors, advisors, mentors, or PI's helped them navigate their academic journey by explicitly telling them what to do or by exposing them or connecting them to resources or opportunities that would lead to career advancement. For example, participant Roman described how when he switched to a physics major, the professors that he connected with shared a wealth of resources that would help him eventually pursue a graduate education. He said:

> "*They saw what I had, and they're like, 'apply to this fellowship'. And I was like, all right, [I'll] apply to it. I got it. And then they're like, 'Apply to this REU'. And*

I applied to it, I got it. And then [they're] like, 'All right, you got to get into grad school'. You know, it's like, well, I didn't have any money, I didn't take my GREs, so I had missed all those deadlines. And they're like, '… there's still an opportunity… apply to this Bridge program. They'll take a look at your college application. Even though all the deadlines are already past, they'll look at you'. So I applied to it, and I got into grad school through this Bridge program."

These educational programs were essential for many participants; they provided them with information, knowledge, and access to resources that would help advance in their scientific careers. Beto also described his experiences with science education outreach programming. He had participated in a scientific mentorship program funded through a federal organization where he learned how to navigate a scientific career. He describes:

"*I got involved in this mentorship program… It was a program, at the time, that was funded by the National Science Foundation... that program basically equipped me with the right tools to navigate the journey in STEM... they introduced me to this concept of STEM disciplines and what I could do with it, such as having mentorship sessions and workshops and seminars from professionals who work in industry and government and in academia… And I found it most beneficial pursuing a degree in STEM*."

These participants described how access to scientific training programs and mentors helped them make progress toward pursuing a scientific career. Not only did both participants gain scientific skills and knowledge, but both described how these experiences instilled confidence in their own scientific potential and helped them navigate their career paths. Other participants also described similar experiences with their mentors and the scientific programs they participated in; those mentors and programs were important sources of the cultural capital- disciplinary, technical, and navigational - that was necessary to be able to successfully navigate these scientific spaces.

Cultural Capital Stemmed from Lived Experiences

In the previous section, the interconnectedness of some social capital and cultural capital types were described. This section will describe some of the other forms of cultural capital that emerged in this data, which were rooted in the participant's culture and lived experiences. The other cultural capital types that appeared in these interviews were credential, experimental, hidden, and resistant. With the exception of resistant capital, which was described by many participants, only two participants described credential, experimental, and hidden capitals. Although only two participants discussed these capitals in their interviews, these are examples of forms of cultural capital that are not often represented in the academic literature, yet are manifested from the lived experiences of individuals from underrepresented groups. Thus, it was important to highlight them in this paper.

Credential Capital and Experimental Capital

Jose identified himself as a non-traditional student and in his interview shared that he had been incarcerated and gotten into some trouble in his youth, which has influenced how he approaches STEM diversification initiatives. His lived experiences give him credibility and help him connect with communities of color because he can relate to them. He is not "an outsider" coming in to work with the community, he is someone who has lived some of their same experiences. This connection can help bridge the divide between the scientific community and the communities they are trying to reach. He explains:

"*… my position to increase diversity in STEM it really is definitely helpful because I'm able to develop ideas and write programs and grants to be able to support those ideas. And really bring together resources that have already existed, but weren't necessarily connected in the right way, or we didn't have the right formula of it… And I think also I would be remiss if I didn't mention the ability to code-switch and the street credibility of things because I think that's a huge part, especially when you're talking about brown and black communities that have been disenfranchised and oppressed for too long, trust is a big piece of that. So being able to go into a community as what would be considered a non-traditional student, having had struggled with a lot of the issues that inner-city kids deal with, really helps me to connect with communities and really helps to illicit hope. And then they're able to prepare themselves to receive whatever it is that we're putting in front of them*."

He also described his desire to redefine how individuals from underrepresented communities relate to STEM by creating content that explained how they interact with scientific concepts on a daily basis. He recognized the value of the skills and knowledge that workforce laborers possess (as it relates to STEM). Jose was also thinking about how to empower those individuals to capitalize on their talent and enter the scientific workforce, where the "good-paying jobs" will be.

"*I hope to redefine the image that young men and women from underrepresented communities see when they think of STEM. I want to challenge them to see more brown and black faces... And I also am working on redefining how they perceive science, and really normalize science for them. So that could be creating lessons* *that capture certain principles or science components in things that they interact with daily… an example of that would be I did a course with somebody… who was an auto tech instructor, and we were talking about the science of cars… the physics, the combustion, the chemistry, the engineering, what happens when you just turn that car, right? But … we're [so] used to having cars that we don't even think twice about that… a mechanic would think a mechanic is just a mechanic, but really folks that are mechanics have great abilities to become better engineers… one of the things I look at, too, is it's how do we help folks – because all of the jobs in the next few decades are going to be STEM, the good paying jobs are going to be in STEM – how do we provide opportunities for folks that are good with their hands that are good laborers with certain things, like mechanics for example, and get them to optimize that ability and skill set in a STEM-based job, if that makes any sense*?"

This participant aspired to diversify STEM through establishing the connections between the everyday lives of individuals from underrepresented communities and the scientific concepts that surround them. Both his credentials and his recognition of the importance of incorporating scientific lessons into everyday activities put him in a place in which he could help redefine science and how it is taught to underrepresented communities. He hoped that this would help encourage individuals from underrepresented groups to pursue STEM careers, thus increasing their representation within the scientific community.

Hidden Capital

Roman shared with us that despite not getting a formal education or obtaining a degree, his father utilized engineering skills to fix cars and other things around the house. He learned to recognize the value of the informal knowledge that his father shared with him and through this experience discovered that there are many forms of obtaining scientific knowledge:

> "*… my dad, uh, he dropped out of high school in Mexico, so he didn't… that wasn't his way. But he always was very handy, um, he was always very, uh, able to fix anything that came his way, whether it was a house, a car, anything that came his way… he taught me a lot of my education when it comes to engineering. Um, but was informal, right? So, I mean, formal — it wasn't in an institution, I didn't get a degree, the certificate. But it was very formal because I was with my dad every single day when he was teaching me these things. Um, so I learned how to how to be an engineer, um, basically outside of an institution, which made me realize the value of… of education not from an institution, not formal education, right. So there's plenty (of) avenues to knowledge*."

This narrative echoes what Jose described earlier, about individuals from underrepresented groups utilizing scientific concepts in their everyday lives, despite not formally recognizing it as science. This informal knowledge was just as important to the formal education this participant was receiving. This experience with his father made Roman appreciate non-traditional educational experiences.

Resistant Capital

When participants exhibited resistant capital, they spoke about their experiences with other people's negative perceptions of them during college and within STEM. They described some of those negative interactions and recognized that they were rooted in those individuals' perceived stereotypes and the racial and social biases they held against them. Though challenging, participants were able to push back against those stereotypes and approached their work and educational journey with resilience and determination. Racism was something that was very prevalent throughout Roberto's life. He shared with us several racist incidents that he experienced in school.

> "*You know, basic racism… I think any time I find myself in a situation where I feel like the reason why that is happening is because of my ethnicity. I just – it's sort of just, basically giving up. I want to work harder and prove that person wrong. So I think a lot of the reason why I work so hard and like, I try to go above and beyond, is because I want to prove to people that I'm there – not because I'm just a minority, but because I deserve it and I've earned it*."

Although he felt discouraged when he encountered individuals that questioned his place within STEM due to his identity, these perceptions motivated him to work hard to prove those folks wrong. He demonstrates oppositional behavior by pushing back against and defying those stereotypes about him. His need to prove others wrong fueled his strong work ethic.

Beto also shared racial incidents that he experienced and the lack of feeling of belongingness within academia and STEM. He shared a classroom experience where many of his (white) peers were shocked by his inquisitiveness and his intelligence in the classroom and felt intimidated by him. He credited this shock to him "sticking out like a sore thumb" in his class due to being a Brown student, sitting in the back of the classroom, dressed in sweatpants, a big sweater, and a hat that said "dope era". He clarified that he did not think of himself as having "superior intelligence", but he was bothered by his white classmates' reactions to him because he knew that they were shocked because of his appearance. His white peers could not believe that someone like him (a Brown man) could be that intelligent. He wondered if those same responses to his academic successes would continue to follow him throughout his life as he advanced in his career and achieved important milestones such as getting papers published and grants funded. These thoughts made him question his place in STEM. However, as he moved through his classes, those feelings of doubt changed into self-acceptance.

> "*When I was able, you know, to make that work, I realized I don't need to sacrifice anything, and I don't need to wear a different mask. If they can't accept me for who I am, that's their problem, not my problem. You know, they're the ones that are going to miss out on having, you know, a potential lifelong friendship with me...You know, if you want to be my friend, you don't have to make any effort. You just have to accept me for who I am. And I would say, again, that because of that, it was difficult because a lot of people didn't like me. They didn't like that I wasn't willing to conform to their identity of what a STEM major is. And it's not my problem.*"

With the affirmations of other students of color and his professors and mentors, this participant eventually realized that he did belong in STEM. He realized that he did not need to conform to others' perceptions of what a scientist should look like and he did not need the acceptance of people who did not accept him. Other participants shared similar doubts about their ability to pursue scientific careers due to their identities and others (negative) perceptions of them. However, most participants who shared these negative experiences with us, also shared how they were able to overcome those feelings of doubt and gain confidence in their scientific potential to pursue leadership positions within STEM.

Symbolic Capital

Scientific Capital

Roman and Jose were the only participants who discussed being given scientific capital- a type of symbolic capital (honor and prestige) within the sciences. Both participants described the positions and platforms they had been given as a result of their educational successes. These participants wished to use those platforms to make a positive impact and provide resources for underrepresented communities. For example, Roman shared that he had participated in a Bridge program that helped him get into graduate school. He was asked to share his story with Congress, the group that allocates funding for these types of programs, to convince them to continue supporting the program:

> "*I have the credentials, the platform, the people behind me and all that to create an impact. Um, and it's being recognized… Like just a couple weeks ago I got a phone call from the Bridge program, and I was telling them about my accomplishments and how I've been involved and all that. And they're like, 'You know what, it's like we're trying to convince Congress to keep money for this Bridge program, and want to take your story up there… it's going to be a lot more impactful if you go yourself and talk to Congress yourself'… they're going to fly me out to D.C. to talk to Congress and tell them about the things that we're able to do*".

Jose shared that he was leading STEM diversity initiatives for his institution, something he described as being great. He had previously been doing outreach in underrepresented communities, establishing relationships with those folks, and getting them excited about higher education and STEM. Due to his experiences and credentials, he was now in a position to leverage university resources to connect the communities he had been working with.

> "*Now, I'm in a position to be able to leverage a lot of the resources from the institution with my intimate knowledge of the community, and really help to bridge that and get folks in K-14 excited about being engaged in the sciences and seeing people like them*."

Both participants recognized that they could use their knowledge, expertise, and credentials to create a positive impact on marginalized communities by advocating for the allocation of resources for those communities. The above narratives illustrate a few examples in which they were provided with the platform and resources to make those impacts.

Intrinsic Capital

Aspirational Capital

The educational aspirations of these Latinx participants were mostly shaped by their own lived experiences and cultural upbringing. As described earlier, most participants described themselves as coming from low-income backgrounds and saw education as a way to improve their socioeconomic situation. Many participants were the first in their families to attend college and acknowledged what getting an education signified to their families and communities. Being Latinx, they recognized the underrepresentation of their communities within science and some expressed a desire to change the face of STEM. They were determined to honor and help their families and communities by completing their degrees and obtaining positions of leadership within STEM.

Maria recognized the struggles her parents experienced when they immigrated to the United States from Mexico, having to learn English and work different jobs so that she can go to college.

> "*So, I think for me, just seeing them go through that and the struggles also highlighted the fact of, okay, there's really no choice for me but to go to college and finish because they're working their asses off so that I could do that*."

To her, going to college and getting her degree means making the hard work and sacrifice of her parents worth it; not finishing college was not an option for her. Other participants also explained how their aspirations were tied to the well-being of their communities and how they continued pursuing those goals despite the challenges they faced because their success would ultimately benefit their communities. For example, Beto described some of the goals that he had set for himself. When he shared those goals with others, people doubted his abilities to accomplish them, yet he persisted.

> "*I'm going to get that National Science Foundation fellowship, I'm going to become a professor at my former community college, and I'm going to be a research head. And, you know, back then, you know, people were like, Dude, you're crazy. But, you know, I had an internship and then they're like, 'Okay, well, you got an internship. That doesn't mean much'… But I'm still here. I'm going on six years now working at the National Lab. And a lot of that is due from me making that definitive statement to myself why I wanted to pursue education. And that was not for personal gain. It was because I realized I have an opportunity to help other people and to help my community be empowered, not*

just through education but through policy, through community action and so forth."

Despite people casting doubt on his ability to be successful in the goals he had set for himself, this participant has been successful in his endeavors, essentially proving those folks wrong. He did not view his accomplishments as beneficial for only him, rather he considered them opportunities to help and empower his community. Other participants expressed similar sentiments regarding community empowerment and helping to increase the representation of underrepresented communities within the sciences, which will be discussed in the critical consciousness section of this paper.

Identity Capital

Most participants were very cognizant of their identities as Latinx folks within the sciences. When discussing their identities, some participants mentioned becoming increasingly aware of the racial or social stigmas that surrounded them throughout their lives due to their identities. Some shared that as they went through college, they gained a better understanding of social constructs and racial issues. This allowed them to reflect on some of their own negative interactions in academia and in STEM through a racial or social justice lens. Maria stated:

> *"I think the more I am versed in how my identity impacts, the more conscious I become of every single interaction that I've had. So it's almost like a blessing and a curse, because when I was in undergrad or even in high school, I didn't really understand the theories stuffed behind stuff. So you just took every transaction or how it was. You didn't necessarily link it back to being a Latina as to like, 'Woah, did they treat me like that because of this or that?' And I feel like it's more heightened now*."

Other participants shared that they learned to embrace their identities over time. Erik, a queer Latinx man shared that he grew up in a conservative home and that he had to hide his queer identity during his childhood. Once he entered college, he did not want to hide who he was and was very open about his queer identity.

> "*I remember there were – those were the years, like I said, when I was unapologetically gay that I would dress very flamboyant and I would behave very flamboyant and I would walk down in the stadium seating, you know, in those big lectures hall, you know, very obviously gay. And essentially, it was my way of saying like gay guys can do this, too, you know, do this math and physics stuff.*"

Almost all participants recognized that communities of color, communities they identified with, were extremely underrepresented within science. Being cognizant and accepting of their marginalized identities influenced how participants viewed their roles within STEM. Many participants viewed it as their responsibility to use their positions to create avenues for other marginalized communities to be able to pursue a higher education degree and STEM career.

Psychological Capital

Psychological capital was defined as developing dispositions such as resilience, risk tolerance, adaptability, and mindsets around flexibility and career malleability. Within this dataset, participants demonstrated mindset adaptability around their increased understanding of social inequities and racial stereotypes. Some participants spoke about recognizing negative norms or behaviors that they were conditioned to believe when they were younger and described how they were shifting away from reinforcing those beliefs. For example, Beto described how his worldview and understanding of social constructs had expanded since he entered college. He shared how he broke away from the mindset he grew up with and is now more accepting of individuals from diverse backgrounds and experiences.

> "*And when I say, "treating people", you know, that ties back in, again, to how I was raised and the environment I was in; the way we were conditioned that it's not okay for a male to show emotion or to have feelings or to accept that maybe people from different backgrounds, creeds or religions are better than us. And when I was unable to, you know, kind of just let that go and realize, you know, we're human, we're all human and it doesn't matter, you know, what race someone is, it doesn't matter what gender someone is, it doesn't matter, you know, what background someone is. You know, hell, it doesn't even matter, you know, what sexual preference someone has. You know, at the end of the day, if you're human and you accept people for who they are, you belong in the same circle as me. And that was a difficult thing for me to break away from because I was conditioned to think very differently. And a lot of that, I broke away from that mindset*."

This participant then explains how he shares this experience with his students and teaches them about the importance of being accepting of diverse backgrounds and of being aware of the world, outside of their own bubble. He does not want his students to grow up with the beliefs that he had been conditioned to believe in when he was younger and teaches them the value of diversity.

Several participants also described feeling doubtful and sometimes questioning their own ability to succeed in STEM due to their background or messages they received from other folks.

However, they demonstrated resilience through learning to embrace themselves and seeing themselves as valuable and worthy of belonging to the STEM community. Jose shared:

> "*As I started going to school, I was reminded of how smart I was, how capable I was to do things. And there was also a place there to integrate all this – these skills sets that I had acquired on the street, right, and kind of these survival skills, the hustle I call it. And so when I learned that I had all these skills sets at a place in academics, and I learned how to kind of fold that in. And I learned to accept that I was worth more than I gave myself credit for. And I started learning about the capabilities that I have and the influence of my voice, things really changed because I started to see myself in a new light*."

He was able to recognize the non-traditional skillsets he developed through his lived experiences. This perspective allowed him to "fold-in" and complement his academic training with those "survival" skills and empowered him to see his worth in these academic and scientific spaces. Other participants who expressed similar doubts in themselves also described developing increased confidence in themselves, their abilities, and their contributions to the scientific workforce.

Critical Consciousness Capital

Perhaps the most insightful results were participants' commitments to serving and empowering underrepresented communities and increasing their representation within STEM. For most participants, their educational aspirations were influenced by their lived experiences. Many participants grew up in immigrant, low-income, and underserved communities. They witnessed the struggles their families and their communities experienced daily. Many stated that as they went through college, they became aware of the racial, social, and even public health issues that affected their communities. They were able to see the many ways in which their scientific knowledge could be applied to help their communities. Almost all participants expressed a desire to use their positions to help or make an impact on their communities.

Participant Alicia, a post-doc, recalled being told by others that there were not many Hispanics with doctorate degrees, something that was greatly needed because diversity in the sciences influenced the type of research being done. She realized that her research could have an impact on her community, and this motivated her to pursue a PhD.

> "*I knew that there was really not a lot – well, for one thing, there is really very few PhD who are from the Hispanic background – with Hispanic background. So, going through these fellowships it was told to us there's really not a lot of you guys, and we need to increase that because it eventually affects the type of research that we end up doing… So that kind of gave me a little more incentive. There are so few of us, and if I could do it I do want to make a positive impact on my people*".

Oscar, who grew up on the U.S.-Mexico border, recognized that financial barriers were one of the reasons why Latinx folks in his community did not pursue higher education degrees. People from his community could not afford to pay for high school much less college due to their low socio-economic status. He believed that this was a contributing factor to the lack of Latinx representation in the sciences. His goal was to one day be able to set up scholarship funds to help students from his community pursue a higher education degree.

> "*I do hope to make an impact. One of the things is, I – going back to kind of my roots in Mexico, there's been many – well, many, many people don't get an education because of money issues. And the impact that I would like to make is*

give the opportunity for those people who cannot afford high school or … college education because of their economic status… If I ever get the chance, or I do things the right way, I can provide scholarships offers or any funding offers for these students in order for them to not be limited – [due to the] financial part of the education. So they can actually have the chance – have a shot of actually getting an advanced education".

Roman described himself as a revolutionary. He shared that he wakes up each morning and asks himself "*what actions will I take today that can actually change the world and make it better*?" He shared that his icons were Malcolm X and Tupac, individuals who tried to change the world and improve it for their people, but were often discredited, deemed "violent" or classified as "thugs" by society. He said that since both these individuals were murdered, they were unable to do the revolutionary work they had set out to do.

"*So now here I am, um, learning from them, and I'm in a position where I'm a graduate student, I have a graduate research fellowship from the government, whatever, a physics Ph.D. You know, it's just like, "Whoa!" It's like… But I'm from the hood. But I'm still a revolutionary. And these things allow me to be a revolutionary, right. So I have to be a revolutionary because… I mean, I want to, and I have the clean slate and the platform to do the effects that the people before me didn't get the chance to*."

He recognized that as a scientist with the proper "credentials", he had a platform to influence and revolutionize through his scientific work in a way that his icons and others before him were unable to. Participants Beto and Maria also recognized the impact that their work could have on their communities. Beto describes:

"*I realized that civil engineering is one of the few majors in STEM that incorporated explicitly concepts of science and social issues because when it comes to building new developments or trying to implement, you know, new housing or bridges and so forth, anything that has to do with civil infrastructure, we have to get it passed through the society that it's going to impact. And I just thought, you know, 'Wow', you know, I could finally do something to make a difference with a degree that would directly impact the community I'm living in*."

Maria had a similar realization within her field which focused on the intersection of public health and microbiology:

"*It's really because like I want my community to be healthier. I grew up – I mean, seeing my own family members affected by a lot of different, you know diseases and conditions. And like now, understanding that, you know, even individuals – it's not that they have the choice to be unhealthy, but there's a lot of decisions that are made in our society that are not made by one person, you know? … for me, it's just of course I want to make a difference! And of course I hope that my work could be used, right? To sort of be that driving force to address injustices. It's just that also through my time being here, you know, you get a little jaded of like, there's a lot of work that people just do for the show, and you know, it's just a matter of, I don't want to do that type of work. I want to do work that's actually going to improve lives*."

Although described in a myriad of ways, most participants had the theme of "*positively impacting my community*" in common. They were aware of the social and racial injustices that existed within their communities and how those were tied to structural and institutional barriers that had been imposed on by society. They recognized that they could utilize their scientific knowledge and credentials to go back into those communities and positively impact them. They saw specific ways in which they could apply their knowledge to help their communities. This desire to positively impact was a driving force for many participants to continue pursuing scientific careers.

Discussion

This study builds off the work of Jaimes et al., (unpublished work, Ch.1; Ch.2) to further explore how the CFM developed by Jaimes et al., (2020, Ch.1), explain the persistence of Latinx scientists, incorporating the addition of critical consciousness capital into the model (Jaimes et al., Ch.2). Findings from this study demonstrate that the Latinx scientists described economic, social, cultural, symbolic, and intrinsic capitals as factors that helped them persist in their STEM careers.

How does the Capital Framework Model help explain the career trajectory of Latinx scientists?

Similar to findings from Jaimes et al. (unpublished work, Ch.2) this study found that participants described having access to economic capital in a myriad of ways which included fellowships, scholarships, financial aid, loans, and parental support. Most participants came from low socioeconomic households and findings indicate that having access to those forms of economic capital allowed participants to finance their education, making it possible for them to pursue higher education degrees.

All five forms of social capital in the CFM emerged in these interviews: familial capital and parental social capital, college social capital, peer-related social capital, and STEM social capital. Familial and parental capitals emerged in the form of support and encouragement from families for participants to pursue a higher education degree. Findings align with previous scholarship (Mien, 2020; Saenz et al., 2018; Saenz et al., 2020)and indicate that families and parents instilled strong educational values in the lives of participants, which were the foundation and starting points of their academic and scientific goals. Although families and parents could not always guide participants in helping them navigate academic or scientific spaces, most participants indicated that their families played an influential role in helping shape their educational aspirations.

While those familial and parental capitals were important sources of support for participants and were important in the shaping of their educational aspirations, their academic, peer, and scientific connections were also quite beneficial. Through those non-familial networks, participants obtained knowledge about academic and scientific norms. That knowledge gave them the tools they needed to be successful in college courses and scientific endeavors. Having access to college, peer-related, and STEM social capitals led to participants gaining three types of cultural capital which were discipline capital, technical capital, and navigational capital, which were important in helping them develop academic and scientific skills and knowledge needed for educational and career advancement.

Having access to those social and cultural capitals led some participants to achieve scientific capital, a type of symbolic capital found within STEM. Their accomplishments and successes were “validated” and recognized by people in positions of power who were able to provide participants with privileges and opportunities. For example, some participants were given platforms and were put in positions where they could leverage and advocate for resources for marginalized communities. Those recognitions and opportunities made them aware of the potential positive impact they could have on their communities, which inspired them to continue pursuing their scientific career goals despite the challenges they encountered along the way.

The cultural and lived experiences of these Latinx participants led to participants recognizing and appreciating lesser-known forms of cultural capital which were credential capital, experimental capital, and hidden capital. Participants described the non-traditional ways they learned to think about scientific concepts and science education. Recognizing those non-traditional forms of knowledge helped participants think about innovative approaches to science education strategies. They viewed their understanding of non-traditional forms of scientific knowledge as an asset they could use to engage with and bring science education to underrepresented communities to get them involved in scientific careers.

While their cultural and lived experiences provided participants with these unique strengths and assets, they also experienced many challenges due to their Latinx identities. Many participants described experiencing racist incidents while in college which sometimes led to them feeling a sense of doubt about their belonging in STEM. However, over time, they were able to overcome the challenges associated with those events and were determined to continue pushing through in pursuing their scientific endeavors. This resiliency and determination was identified as resistant capital and was a strength that participants used to continue to persist in a scientific career trajectory.

Intrinsic forms of capital were mostly rooted in the identities and culture of participants and stemmed from their lived experiences. All four capitals - aspirational, identity, psychological, and critical consciousness- are interconnected and emphasize how those experiences, identities, and culture all played influential roles in shaping our participant's educational and career aspirations. For example, when participants described the different milestones they were aspiring towards (aspirational capital), we saw that those aspirations were grounded in a need to honor their families or help their communities of color. When talking about their identities (identity capital), all participants were very cognizant about what it meant to be a Latinx in STEM; many described feeling like they did not belong in the predominantly white scientific spaces they were in. However, several participants stated that when they entered college, they better understood the concept of racism and other social inequities that existed in society, which they recognized as some of the systematic barriers that oppress their communities. They were able to connect some of their own negative experiences to those concepts and structures and quickly realized how underrepresented their communities were in academic and scientific spaces. This increased understanding of systems of oppression combined with their academic and scientific knowledge, allowed participants to see the connection between science and social justice. Therefore, despite the challenges they encountered while pursuing their educational and professional goals, participants learned to embrace their identities, recognize their own worth, and envision the positive impact they could have on their communities as scientists and as college-educated individuals (psychological capital).

Although many participants described being victims of racism or other forms of oppression, some also became aware of their own biases once they entered college and strived to be more inclusive and welcoming in their behaviors and even with their teaching (also psychological capital). This increased awareness of systematic barriers, being cognizant of their struggles as Latinx scientists in relation to those barriers and learning to embrace the knowledge and experiences they brought into academic and scientific spaces, led to the cultivation of critical consciousness capital (Jaimes et al., unpublished work, Ch.2) among participants. Those experiences empowered and motivated participants to seek to use their positions as scientists to support their communities. This was a theme among most participants and was the primary driving force behind their motivation to pursue a scientific career. While participants acknowledged enjoying being scientists, ultimately, they wanted their work to have a positive impact on their communities. They stated wanting to use their scientific expertise to help combat social inequities, improve the lives of the people in their communities, and increase the representation of underrepresented scientists in STEM.

How are the different forms of capital manifested in the career aspirations of Latinx scientists?

When thinking about the capitals that we found in this study, they are primarily categorized into two types. The first type is the more traditionally recognized types of capitals that are widely discussed in science education literature (Bourdieu, 1986; Coleman, 1988; Putnam, 1993;1995, Yosso, 2005). This includes typical examples of social capital (i.e. mentors, bridge programs), cultural capital (knowledge about academic and scientific norms), economic capital (financial resources), and even symbolic capital (recognition and prestige). The second types are lesser recognized types of social capital (parental and familial), cultural (understanding of non-traditional scientific knowledge), and all the intrinsic forms of capital.

This section begins by discussing the more traditionally recognized forms of capital widely discussed in the science education literature (Bourdieu, 1986; Coleman, 1988; Putnam, 1993;1995, Yosso, 2005). As described by (Bourdieu, 1986) many of these capitals do not exist as a single entity, rather they're all interconnected. Having access to one form of capital helps participants access other forms of capital (Bourdieu 1986). These findings echo other studies that discuss the benefits of social capital on the persistence of scientists from underrepresented groups. Through these networks, they were provided with tools and opportunities to advance their education and careers and exposed them to graduate school and potential scientific careers (). Being in programs that provided participants access to mentors (social capital) and knowledge about academia and STEM (cultural capital) led to participants being able to access financial aid, fellowships, scholarships, and other financial resources (economic capital) that helped them fund their education and careers. Most participants in this study described themselves as coming from low socioeconomic status households and it was through those social and cultural capital channels that they learned about educational funding opportunities that made it possible for them to pursue higher education degrees. It was because of access to those capitals that participants were able to obtain the skills needed to experience some academic and scientific achievements such as winning prestigious funding opportunities and publishing manuscripts, which are necessary milestones to advancing in a scientific career.

We recognize the importance of the educational and scientific programs as well as the funding initiatives that have been established to recruit individuals from underrepresented groups into STEM majors. These initiatives often provide individuals from traditionally underrepresented groups access to economic capital that makes it possible for them to fund their education, as well as access to more recognized forms of social and cultural capital that help them enter and navigate academic and scientific spaces (Stolle-McAllister, 2011; Turnbull et al., 2020). While it has been widely established that those initiatives are very beneficial to helping students pursue a higher education/scientific degree (Eagan et al., 2013; Hernadez et al., 2018; Nagda et al., 1998; Schultz et al., 2011), this study is unique in that it highlights the significance of lesser-recognized forms of capital on shaping the career trajectories of Latinx scientists. We found that the lived experiences of our participants resulted in the emergence of other forms of capital, including those from Yosso's CCW model (Yosso, 2005) as well as others such as hidden, credential, experimental, etc. (Drazan et al., 2015; Eglash & Bennett, 2009). Those lesser recognized capitals provided participants with strengths and assets that complemented their academic and scientific training and allowed them to reimagine science education initiatives and the positive impact that science could have on their communities. Some of the lesser recognized capitals (e.g. identity, psychological, resistant) also provided participants with the ability to overcome challenges such as the racism that some of them experienced and be inspired and motivated to continue persisting in their professional endeavors.

Now let's take a moment to discuss resistant and psychological capitals; two capitals that seem to go hand in hand. While resistant capital is understood as an action or behavior against oppressive systems (Yosso, 2005; Revelo & Baber, 2018), psychological capital is the development of that resilient disposition (Paull et al., 2019) which allows those anti-oppressive actions to take place. In this study, the development of psychological capital led to the emergence of resistant capital. For example, participants expressed sometimes having doubts about their own scientific capabilities. Some participants also recognized that many of their white colleagues questioned their belonging in STEM and whether they had "earned" their place or if it had been given to them due to their Latinx identity. However, participants described that as they advanced in their educational careers, they gained a better understanding of racism and social injustices and realized that they had been victims of those systems of oppression. Participants were able to develop resiliency (i.e. psychological capital) and were able to challenge those perceptions (i.e. resistant capital) to demonstrate to those folks that a) they did belong in STEM and b) that they did not need to conform to other's ideas of what a scientist should look like. This mindset of non-conformity was a common theme among many participants and was a strength that drove them to want to achieve scientific success.

The accumulation of all the above capitals - social, cultural, economic, symbolic, and intrinsic - led to the cultivation of critical consciousness capital. This capital refers to marginalized individuals' ability to analyze and take action to address social oppression (Cadenas et al., 2020, p. 163). Before entering college, participants described having been victims of racism and prejudices and were already aware of the struggles and challenges their communities faced, such as poverty, low-educational attainment, health disparities, environmental injustices, etc. However, as they navigated college, participants described gaining a better understanding of those social injustices and systematic barriers (i.e. racism) by being exposed to theories and concepts that explained those injustices and barriers. Furthermore, being in STEM allowed them to see the impact that science and science policy has on society, specifically on their communities. By merging their academic and scientific training with their own lived experiences and cultural knowledge, participants were able to recognize the intersection of science and social justice and were inspired to use their positions in STEM to serve, give back, and empower their communities. Some of the ways they envisioned doing this are through 1) reimagining science education initiatives to establish meaningful connections between science concepts and the everyday activities of their communities in order to get involved in science careers, 2) using their platforms to help increase the participation of individuals from their communities within STEM, and 3) applying their work and their knowledge to create positive change within their communities, such as through public health initiatives, policy or providing input on the building of infrastructures in areas where marginalized communities live. This commitment to community was a driving force among most participants; when asked about the impact they wanted their work to have, the majority of participants connected their aspirations back to some form of community empowerment.

This commitment to one's community is a theme that is common among communities of color and is supported by previous scholarship that suggests that for minorities, working toward social change is more important for their career aspirations than those of their non-minority counterparts (Garibay, 2015; McCallum, 2017; McGee et al., 2016). For example, McCallum (2017) found that the concept of "giving back to community" was an influencing factor in Black students' decisions to enroll in PhD programs. Similarly, McGee et al. (2016) found that students of color are drawn to social justice causes such as giving back to one's community; a motivating factor for Black students choosing to enroll in STEM doctoral programs. While other scholars have examined the community-oriented motivational and influential factors behind the career aspirations of students of color (Garibay, 2015; Means, 2019; McCallum, 2017; McGee et al., 2016), this study differs in that it looks at these factors through the lens of capital in STEM with a focus on lesser recognized forms of capital within science education scholarship. Those intrinsic strengths and cultural knowledge are assets (i.e. capitals) that Latinx scientists hold which have propelled them to complete a scientific degree to use that degree to give back to their communities and reimagine the face of STEM.

How should we reimagine STEM?

This study has implications for national efforts to broaden the participation of underrepresented groups in STEM. Findings illustrate that while traditional programming and funding initiatives that seek to recruit underrepresented scientists are effective, the cultural and intrinsic strengths that empower and enable Latinx scientists to persist in scientific careers are just as important. Most importantly, findings reinforce the notion that scientists of color are drawn to the social justice implications of a scientific career and strive towards helping their communities combat the oppressive systems that hold them back (Jaimes et al., unpublished work, Ch.2). Universities, programs, and organizations that seek to diversify their membership would benefit greatly from embedding the cultural and intrinsic strengths found among Latinx communities into their programming with a focus on applying scientific principles into social justice work. By doing this, diversity increasing initiatives may foster better connections with Latinx scientists not only with recruitment efforts but also retention.

As described by participants, it is necessary to recognize and validate "non-traditional" forms of scientific knowledge when working with communities of color. This ties back to Yosso's (2005) CCW model where she argued that communities of color possessed cultural strengths that helped them navigate life and educational spaces. Developing scientific programming that incorporates non-traditional forms of scientific knowledge and connects scientific concepts to the everyday activities that communities of color engage in is another way to establish positive connections with those communities and get them into STEM careers.

Conclusion

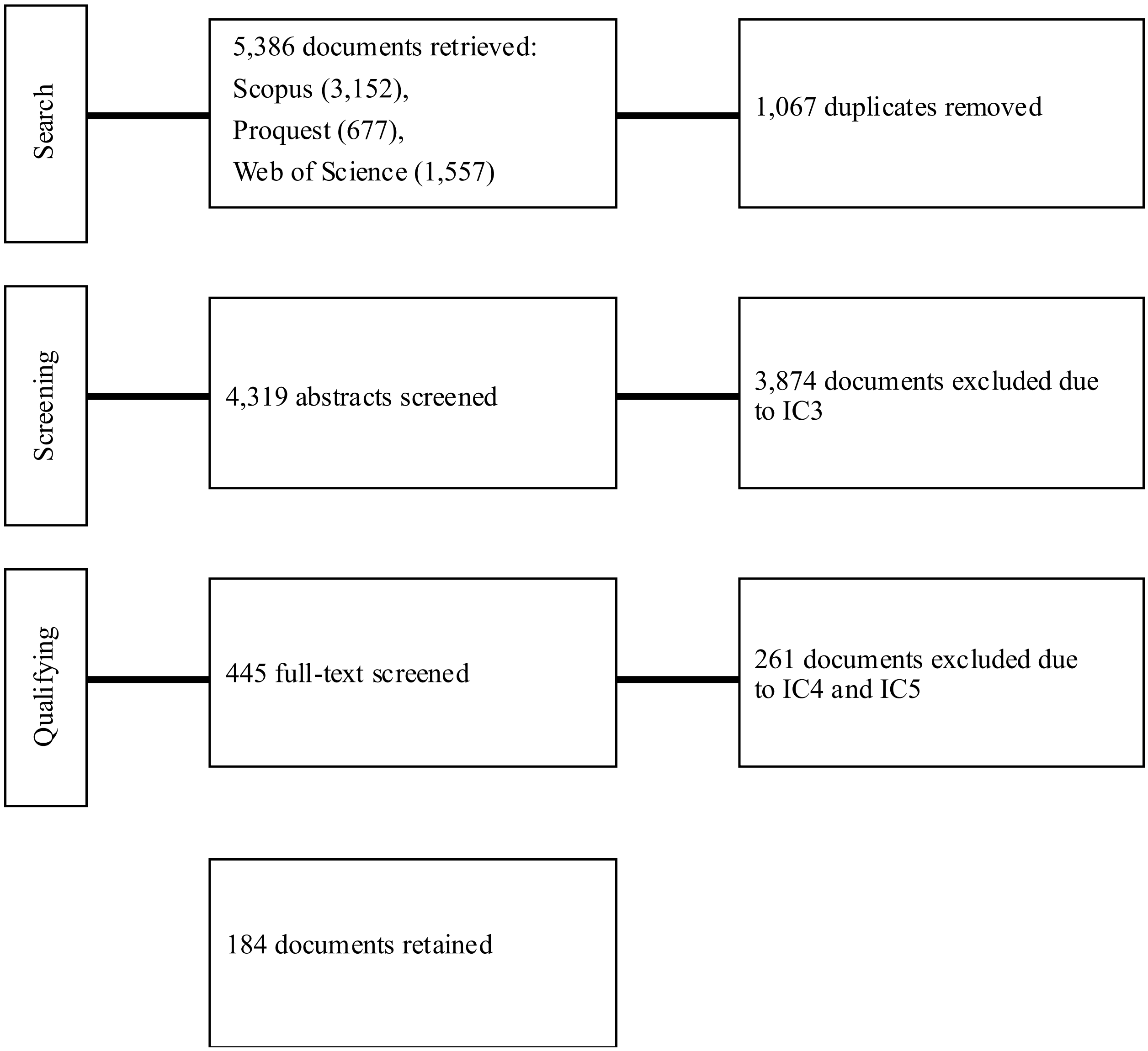
This study utilized an asset-based approach to explore the factors that influence the career trajectories of Latinx scientists. Building off of previous work (Jaimes et al., unpublished work, Ch.1; Ch.2; Yosso, 2005) this work was conducted through a capital theory lens. This study revealed how Latinx students use the cultural knowledge and resources derived from their communities, as well as self-authored intrinsic strengths, to navigate academia and persist in STEM careers. These strengths and resources are identified as different forms of capital (Figure 2). Findings demonstrate that Latinx students are drawn to social justice issues that affect their communities and seek to integrate social justice into their scientific work to help and empower their communities.

APPENDICES

APPENDIX A

SYSTEMATIC LITERATURE REVIEW SCREENING PROCESS

Figure 1 Search Results. The systematic literature review screening and selection process.



APPENDIX B

CAPITAL DEFINITIONS

Table 1 Capital definitions. This table contains all synthesized definitions for all primary and secondary forms of capital. Italicized capitals and definitions are primary forms of capital. Non-italicized capitals and definitions are secondary forms of capital.

Capitals	**Definitions**
Academic Capital	The accumulation of an individual's educational and academic experiences that makes them knowledgeable about academic norms, practices, and resources and allow them to be academically successful.
Aspirational Capital	The ability to maintain hopes and dreams for the future alive despite real and perceived barriers and challenges.
Career Capital	Knowing how to acquire relevant work knowledge and work skills and knowing with whom to build interpersonal relationships, organizational partnerships, and social alliance to be able to access information and forge channels for self-promotion in the workplace.
Community Capital	The support of the community, the benefits of language and culture, and the mores and cultural life script of the community.
College Social Capital	Having access to and utilizing academic support staff and resources such as counselors or college prep programs.
Credential Capital	"Mutual membership or in-group identity; a sense of ownership over an interest that is mutually shared between students and teacher–in which both have "credentialing capital". (Drazan, 2015)
Cultural Capital	*Being knowledgeable about societal or cultural norms and values and having the ability to reproduce and replicate those values and norms in order to be an active, welcome, and successful member of that society or culture.*
Decisional Capital	The capacity to make sound decisions in situations where there are no fixed rules or evidence to rely on for guidance; can only be developed through years of experience.
Discipline Capital	The set of discipline-specific paradigms, including facts, beliefs, and values, related to conducting research.
Economic Capital	*Having money, financial resources, or material assets that benefit an individual.*
Educational Capital	The resources that make up educational capital are economic, cultural, infrastructural, social, and didactic capitals (Stoeger et al., 2017).
Engineering Transfer Capital	Claims that transfer students have opportunities at the sending institution to accumulate specific forms of capital that enable their success in engineering programs at the receiving institution. (Builds off of transfer capital- see below)
Experience Capital	An individual's developed and accumulated capital from his/her professional work and life experiences, which exists at the partial union of social, human, cultural, economic, and symbolic capital.

Table 1 cont.

Experimental Capital	A resource that can be utilized to intrinsically motivate students to engage with material; dependent on cultural ownership over a domain of knowledge that is not yet known.
Familial Capital	The familial or community networks that provide an individual with cultural knowledge and support and allow those individuals to form, maintain, and navigate kinship bonds.
Financial Capital	Economic and financial resources.
Hidden Capital	Having an intrinsic understanding of scientific and mathematical concepts that goes unrecognized by the educational system is termed.
Human Capital	*The accumulated skills and knowledge an individual has which is of value to an employer. (e.g., an organizations human capital is their employees)*
Identity Capital	Having the ability to build pre-professional identity and 'demonstrate alignment between emergent identities and future performance within a specific working context.
Intellectual Capital	The sum of an organization's knowledge, institutions, infrastructure, and resources.
Linguistic Capital	The intellectual and social skills learned through communication experiences in more than one language and/or style; having the ability to communicate between communities or environments (e.g., "code switching").
Navigational Capital	Having the skills (or being taught the skills) and knowledge to successfully navigate and maneuver unfamiliar institutions, organizations, or communities.
Parental Social Capital	Parental involvement in children's educational journey.
Peer Related Social Capital	The networks of people and resources that provide instrumental and emotional support to navigate through institutions- specifically related to peers.
Physical Capital	Money and other material assets.
Psychological Capital	Developing dispositions such as resilience, risk tolerance, adaptability and 'mindsets around flexibility and career malleability'.
Resistant Capital	Promoting knowledge and skills through behaviors that challenge inequality.
Science Capital	The sum of an individual's science-related qualifications, knowledge, attitudes, experiences and resources.
Science Related Social Capital	Knowing someone who works in science-related jobs.
Scientific Capital	A symbolic capital based on knowledge and recognition within STEM that allow an individual to obtain more grants, bigger labs, etc.
Social Capital	*Social capital is the networks of people that lead to resources and opportunities to benefit individuals and networks.*

Table 1 cont.

STEM Social Capital	Access to resources or networks that allow an individual to acquire the associated knowledge and skills to successfully navigate the STEM community.
Symbolic Capital	*An individual's accumulated honor and prestige and the recognition that derives from them.*
Technical Capital	Knowledge, skills, abilities, know-how.
Transfer Student Capital	The accumulation of knowledge about higher education and the transfer process between sending institutions (i.e., the place(s) where students begin their degree paths) and receiving institutions (i.e., the final degree-granting institution).

APPENDIX C

CODING OF CAPITAL DEFINITIONS

Table 2 The coding of secondary capitals in relation to primary capitals. Each secondary form of capital as aligning with one or more of the primary forms of capital. Italicized secondary capitals were coded as aligning with multiple primary capitals and were removed from final framework model

Secondary Capitals	Primary Capitals					
	Cultural Capital	Economic Capital	Human Capital	Social Capital	Symbolic Capital	Other
Academic Capital	X					
Aspirational Capital						X
Career Capital	*X*			*X*		
Community Capital	X					
College Social Capital				X		
Credential Capital	X					
Decisional Capital			X			
Discipline Capital	X					
Educational Capital	*X*	*X*		*X*		
Engineering Transfer Capital	X					
Experience Capital	*X*	*X*	*X*	*X*	*X*	
Experimental Capital	X					
Familial Capital				X		

Table 2 cont.

Financial Capital		X				
Hidden Capital	X					
Identity Capital						X
Intellectual Capital	*X*	*X*	*X*	*X*	*X*	
Linguistic Capital	X					
Navigational Capital	X					
Parental Social Capital				X		
Peer Related Social Capital				X		
Physical Capital		X				
Psychological Capital						X
Resistant Capital	X					
Science Capital	*X*				*X*	
Science Related Social Capital				X		
Scientific Capital					X	
STEM Social Capital				X		
Technical Capital	X					

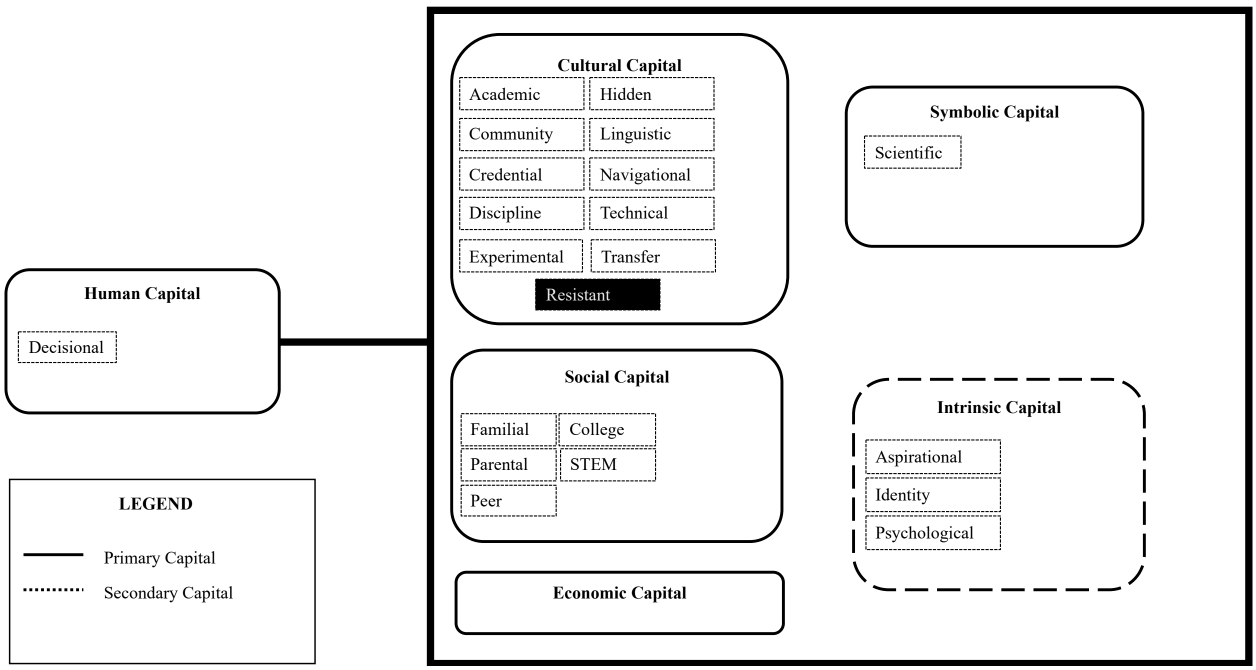
Table 2 cont.

Transfer Student Capital	X					

APPENDIX D

CAPITAL FRAMEWORK MODEL

Figure 2 Capital Framework Model (CFM) from Chapter 1. Secondary capitals were grouped into the primary capital categories. Intrinsic capital category was created by authors. Secondary capitals that had been grouped into the "other" category (refer to Table 2), were grouped into the intrinsic capital category after completion of inductive coding.



APPENDIX E

PARTICIPANT DEMOGRAPHICS

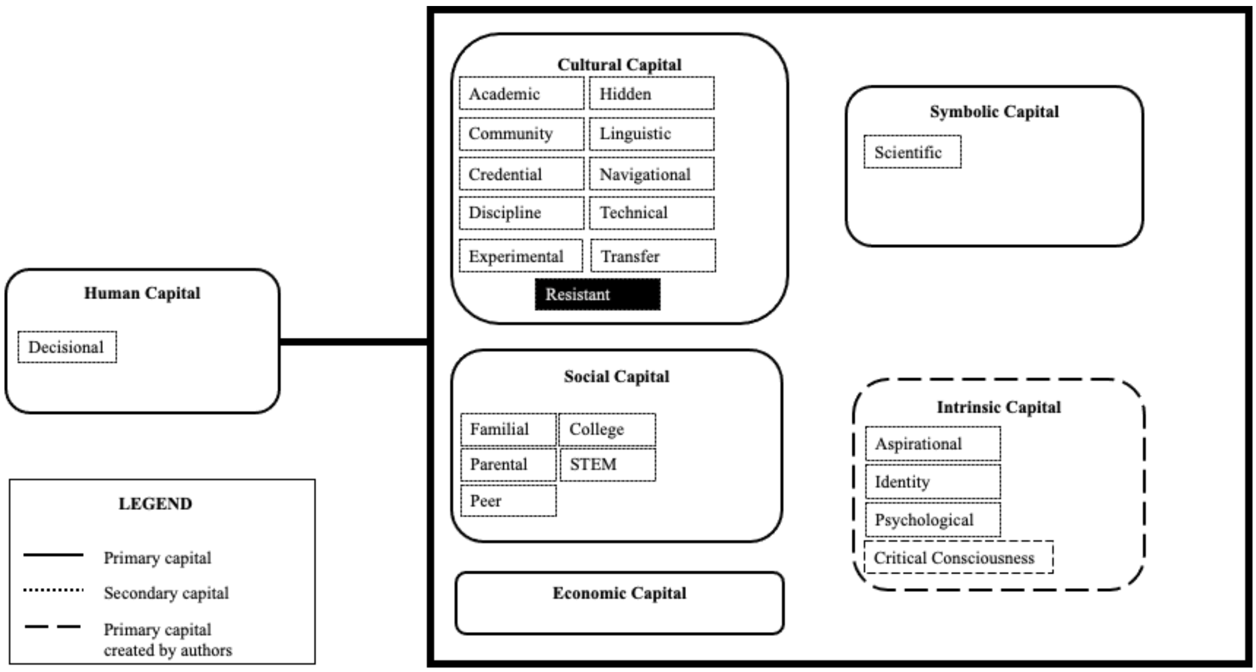
Table 3 Participant demographic information for Chapter 3.

Disability		N= 4
Discipline	Biosciences	N = 5
	Engineering	N = 2
	Geosciences	N = 7
	Physics	N = 1
Ethnicity	Bi-racial (Asian-American / White)	N = 1
	Black	N = 4
	Latinx	N = 5
	White	N = 5
Gender Identity	Male	N = 2
	Female	N = 10
	Other	N = 3

APPENDIX F

UPDATED CAPITAL FRAMEWORK MODEL

Figure 3 Updated Capital Framework Model (CFM) from Chapter 2. This figure is derived from the capital framework model developed in Chapter 1. After data analysis was completed, critical consciousness capital was added to the model in the intrinsic capital category.



APPENDIX G

PARTICIPANT DEMOGRAPHICS (2)

Table 4 Participant demographic information for Chapter 4.

Discipline	Biosciences	N = 4
	Engineering	N = 1
	Earth and Environmental Sciences	N = 4
	Physics	N = 1
Gender Identity	Male	N = 7
	Female	N = 3
Status	Graduate students	5
	Non-students	5

REFERENCES

REFERENCES

Ackermann, S. P. (1991). The benefits of summer bridge programs for underrepresented and low-income transfer students. *Community Junior College Research Quarterly of Research and Practice*, *15*(2), 211–224. https://doi.org/10.1080/0361697910150209

Adamuti-Trache, M., & Andres, L. (2008). Embarking on and persisting in scientific fields of study: Cultural capital, gender, and curriculum along the science pipeline. *International Journal of Science Education*, *30*(12), 1557–1584. https://doi.org/10.1080/09500690701324208

Aguirre, H. C. C., Gonzales, E., & Banda, R. M. (2020). Latina college students' experiences in STEM at Hispanic-Serving Institutions: Framed within Latino critical race theory. *International Journal of Qualitative Studies in Education*. https://doi.org/10.1080/09518398.2020.1751894

Archer, L., Dawson, E., DeWitt, J., Seakins, A. and Wong, B. (2015), "Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *J Res Sci Teach*, 52: 922-948. https://doi-org.proxy1.cl.msu.edu/10.1002/tea.21227

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881–908. https://doi.org/10.3102/0002831211433290

Barlow, A. E. L., & Villarejo, M. (2004). Making a difference for minorities: Evaluation of an educational enrichment program. *Journal of Research in Science Teaching*, *41*(9), 861–881. https://doi.org/https://doi.org/10.1002/tea.20029

Becerra, D. (2012). Perceptions of educational barriers affecting the academic achievement of Latino K-12 students. *Children and Schools*, *34*(3), 167-177. https://doi.org/10.1093/cs/cds001

Becker G. (1964) *Human Capital*. Columbia University Press, New York; 2nd ed., 1975 and 3rd ed., 1994.

Blanden, J., and Gregg, P. (2004). Family income and educational attainment: A eeview Of approaches and evidence for Britain. *Oxford Rev. Econ. Policy* 20, 245–263. doi: 10.1093/oxrep/grh014

Blake, R.A. Liou-Mark, J. & Chukuigwe, C. (2013) An effective model for enhancing underrepresented minority participation and success in geoscience undergraduate research, *Journal of Geoscience Education*, 61:4, 405-414, doi: 10.5408/12-417.1

Borrego, M., Foster, M. J., & Froyd, J. E. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education*, *103*(1), 45–76. https://doi.org/10.1002/jee.20038

Bourdieu, P. (1986*).* The forms of capital. In J. Richardson (Ed.), *Handbook of Theory and Research for the Sociology of Education* (pp. 241–258). Westport, CT: Greenwood.

Bourdieu, P. (1989). Social space and symbolic Power. *Sociological Theory, 7*(1), 14-25. doi:10.2307/202060

Bourdieu, P. (1990). *The logic of practice*, Cambridge: Polity Press.

Bourdieu, P. & Passeron, J. (1977) *Reproduction in education, society and culture*. London, Sage).

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development.* Sage Publications, Inc.

Brandt, C.B. (2008). Discursive geographies in science: Space, identity, and scientific discourse among Indigenous women in higher education. *Cultural Studies in Science. Education*. 3, 703–730.

Braun, D. C., Gormally, C., & Clark, M. D. (2017). The Deaf mentoring Survey: A community cultural wealth framework for measuring mentoring effectiveness with underrepresented students. *CBE Life Sciences Education*, *16*(1), ar10. https://doi.org/10.1187/cbe.15-07-0155

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, 77–101.

Brosnan, C. (2011). The significance of scientific capital in UK medical education. *Minerva*, *49*(3), 317–332. https://doi.org/10.1007/s11024-011-9177-z

Brown, N., & Leigh, J. (2018). *Ableism in academia: where are the disabled and ill academics?* https://doi.org/10.1080/09687599.2018.1455627

Burt, B. A., & Johnson, J. T. (2018). Origins of early STEM interest for Black male graduate students in engineering: A community cultural wealth perspective. *School Science and Mathematics*, *118*(6), 257–270. https://doi.org/10.1111/ssm.12294

Byars-Winston, A., Estrada, Y., Howard, C., Davis, D., & Zalapa, J. (2010). Influence of social cognitive and ethnic variables on academic goals of underrepresented students in science and engineering: A multiple-groups analysis. *Journal of Counseling Psychology*, 57(2), 205–218. https://doi.org/10.1037/a0018608

Cadenas, G. A., Angé Lica Cantú, E., Spence, T., & Ruth, A. (2020). Integrating critical consciousness and technology in entrepreneurship career development with diverse community college students. *Journal of Career Development*, *47*(2), 162–176. https://doi.org/10.1177/0894845318793968

Castro, E. L. (2014). "underprepared" and "at-risk": Disrupting deficit discourses in undergraduate STEM Recruitment and retention programming. *Journal of Student Affairs Research and Practice*, *51*(4), 407–419. https://doi.org/10.1515/jsarp-2014-0041

Callahan, C. N., Libarkin, J. C., Mccallum, C. M., & Atchison, C. L. (2015). Using the lens of social capital to understand diversity in the earth system sciences workforce. *Journal of Geoscience Education*, *63*(2), 98–104. https://doi.org/10.5408/15-083.1

Carter, F. D., Mandell, M., & Maton, K. I. (2009). The influence of on-campus, academic year undergraduate research on STEM Ph.D. outcomes: Evidence from the Meyerhoff scholarship program. *Educational Evaluation and Policy Analysis*, *31*(4), 441–462. https://doi.org/10.3102/0162373709348584

Cech, E., & Pham, M. (2017). Queer in STEM organizations: Workplace disadvantages for LGBT employees in STEM related federal agencies. *Social Sciences*, *6*(1), 12. https://doi.org/10.3390/socsci6010012

Ceja, M. (2004). Chicana college aspirations and the role of parents: Developing Educational Resiliency. *Journal of Hispanic Higher Education*, 3, 338-362.

Center for Disease Control (CDC). 2020. *Health equity considerations and racial and ethnic minority groups*. https://www.cdc.gov/coronavirus/2019-ncov/community/health-equity/race-ethnicity.html

Clark, U.S., Hurd, Y.L. (2020) Addressing racism and disparities in the biomedical sciences. *Nat Hum Behav* 4, 774–777. https://doi.org/10.1038/s41562-020-0917-7

Clarke, V., & Braun, V. (2014). Thematic analysis. In A. C. Michalos (Ed.), *Encyclopedia of quality of life and well-being research* (pp. 6626–6628). Dordrecht, The Netherlands: Springer

Claussen, S., & Osborne, J. (2013). Bourdieu's notion of cultural capital and its implications for the science curriculum. *Science Education*, *97*(1), 58–79. https://doi.org/10.1002/sce.21040

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. https://doi.org/10.1353/csd.0.0018

Coleman, James S. (1988). Social capital in the creation of human capital. *The American Journal of Sociology.* 94, S95-S120.

Crabtree, Benjamin, Miller, W. (1999). A template approach to text analysis: Developing and using codebooks. In *Doing Qualitative Research* (pp. 93–109).

Delgado, R., Stefancic, J. (2001). *Critical race theory: An introduction, first edition*. New York; London: NYU Press. Retrieved November 19, 2020, from http://www.jstor.org/stable/j.ctt9qg9h2

Denton, M., Borrego, M., & Boklage, A. (2020). Community cultural wealth in science, technology, engineering, and mathematics education: A systematic review. *Journal of Engineering Education*, *109*(3), 556–580. https://doi.org/10.1002/jee.20322

Dika, S. L., & Martin, J. P. (2018). Bridge to persistence: Interactions with educators as social capital for Latina/o engineering majors. *Journal of Hispanic Higher Education*, *17*(3), 202–215. https://doi.org/10.1177/1538192717720264

Drazan, J. F., D'Amato, A. R., Winkelman, M. A., Littlejohn, A. J., Johnson, C., Ledet, E. H., & Eglash, R. (2015). Experimental and credentialing capital: An adaptable framework for facilitating science outreach for underrepresented youth. *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, 3691–3694. https://doi.org/10.1109/EMBC.2015.7319194

Dutt, K. (2020). Race and racism in the geosciences. *Nature*, *13*, 2–3. https://doi.org/10.1038/s41561-019-0519-z

Eagan, M. K., Hurtado, S., Chang, M. J., Garcia, G. A., Herrera, F. A., & Garibay, J. C. (2013). Making a difference in science education: The impact of undergraduate research programs. *American Educational Research Journal*, *50*(4), 683–713. https://doi.org/10.3102/0002831213482038

Eglash, R. & Bennett, A. (2009). Teaching with hidden capital: Agency in children's computational explorations of cornrow hairstyles. *Children, Youth and Environments, 19*(1), 58-73. Retrieved November 18, 2020, from http://www.jstor.org/stable/10.7721/chilyoutenvi.19.1.0058

Enriquez, A. G. (2014). Enhancing the success of minority STEM students by providing financial, academic, social, and cultural capital. *121st ASEE Annual Conference & Exposition*.

Espino, M. M. (2014). Exploring the role of community cultural wealth in graduate school access and persistence for Mexican American PhDs. *American Journal of Education*, *120*(4), 545–574. https://doi.org/10.1086/676911

Espinosa, Lorelle L., Jonathan M. Turk, Morgan Taylor, and Hollie M. Chessman. (2019). Race and ethnicity in higher education: A status report. Washington, DC: American Council on Education.

Excelencia in Education. 2020. Latino college completion rates: United States [factsheet]. https://www.edexcelencia.org/sites/default/files/LCCStateStats/Exc-2020-50StateFS-USA-05.pdf

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods*, 80–92. https://doi.org/10.1177/160940690600500107

Ferrini-Mundy J. (2013). Science education. Driven by diversity. *Science (New York, N.Y.)*, *340*(6130), 278. https://doi.org/10.1126/science.1235521

Field, J. (2003). Social capital. London, Routledge.

Freire, P. 1973. Education for critical consciousness. New York, NY: Seabury.

Garibay, J. C. (2015). STEM students' social agency and views on working for social change: Are STEM disciplines developing socially and civically responsible students? *Journal of Research in Science Teaching*, *52*(5), 610–632. https://doi.org/10.1002/tea.21203

Gazley, J. L., Remich, R., Naffziger-Hirsch, M. E., Keller, J., Campbell, P. B., & McGee, R. (2014). Beyond preparation: Identity, cultural capital, and readiness for graduate school in the biomedical sciences. *Journal of Research in Science Teaching*, *51*(8), 1021–1048. https://doi.org/10.1002/tea.21164

Gilio-Whitaker, D. (2019). *As long as grass grows: The indigenous fight for environmental justice, from colonization to Standing Rock.*

Goldenberg, B. M. (2014). *White teachers in urban classrooms: Embracing non-white students' cultural capital for better teaching and learning*. *49*(1), 111–144. https://doi.org/10.1177/0042085912472510

Gonzales, L. D. (2012). Stories of success: Latinas redefining cultural capital. *Journal of Latinos and Education*, *11*(2), 124–138. https://doi.org/10.1080/15348431.2012.659566

Graham M , Frederick J, Byars-Winston A, Hunter A, Handelsman J. 2013. Science education: Increasing persistence of college students in STEM. *Science*, 341, 1455–1456.

Hadinger M. A. (2017). Underrepresented minorities in medical school admissions: A qualitative study. *Teaching and learning in medicine*, *29*(1), 31–41. https://doi.org/10.1080/10401334.2016.1220861

Harper, S. R. (2010). An anti-deficit achievement framework for research on students of color in STEM. *New Directions for Institutional Research*, 148,63–74. https://doi.org/10.1002/ir.362

Hathaway, R., Nagda, B., and Gregerman, S. (2002). The relationship of undergraduate research participation to graduate and professional educational pursuit: An empirical study. *Journal of College Student Development*, 43(5), 614–631.

Hernandez, P. R., Woodcock, A., Estrada, M., & Schultz, P. W. (2018). Undergraduate research experiences broaden diversity in the scientific workforce. *BioScience*, *68*(3), 204–211. https://doi.org/10.1093/biosci/bix163

Hoppe, T. A., Litovitz, A., Willis, K. A., Meseroll, R. A., Perkins, M. J., Hutchins, B. I., Davis, A. F., Lauer, M. S., Valantine, H. A., Anderson, J. M., & Santangelo, G. M. (2019). Topic choice contributes to the lower rate of NIH awards to African-American/black scientists. *Science Advances*, *5*(10), eaaw7238. https://doi.org/10.1126/sciadv.aaw7238

Jaimes, P., Libarkin, J.L., McCallum, C.M. (Chapter 1, unpublished work) Rethinking initiatives to increase diversity in STEM: A new capital framework model.

James, S. M., & Singer, S. R. (2016). From the NSF: The National Science Foundation's investments in broadening participation in science, technology, engineering, and mathematics education through research and capacity building. *CBE - Life Sciences Education*, *15*(3), 1–8. https://doi.org/http://dx.doi.org/10.1187/cbe.16-01-0059

Lee, J.-S., & Bowen, N. K. (2006). Parent involvement, cultural capital, and the achievement gap among elementary school. In *Source: American Educational Research Journal* (Vol. 43, Issue 2).

Leese, M. (2010). Bridging the gap: supporting student transitions into higher education. *Journal of Further and Higher Education*, *34*(2), 239–251. https://doi.org/10.1080/03098771003695494

Leggon, C. B. (2018). Reflections on broadening participation in STEM: What do we know? What do we need to know? Where do we go from here? *American Behavioral Scientist*, *62*(5), 719–726. https://doi.org/10.1177/0002764218768866

Linn M , Palmer E, Baranger A, Gerard E, Stone E. (2015). Undergraduate research experiences: impacts and opportunities. *Science*, 347 art. 1261757

Luedke, C. L., McCoy, D. L., Winkle-Wagner , R., & Lee-Johnson, J. (2019). Students perspectives on holistic mentoring practices in STEM fields. *JCSCORE*, *5*(1), 33-59. https://doi.org/10.15763/issn.2642-2387.2019.5.1.33-59

Martin, J. P., Simmons, D. R., & Yu, S. L. (2013). The role of social capital in the experiences of Hispanic women engineering majors. *Journal of Engineering Education*, *102*(2), 227–243. https://doi.org/10.1002/jee.20010

McCallum, C., Libarkin, J., Callahan, C., & Atchison, C. (2018). Mentoring, social capital, and diversity in earth system science. *Journal of Women and Minorities in Science and Engineering*, 24(1), 17-41.

McCallum, C. (2012) *Understanding the relationships and experiences that contribute to African Americans' decision to enroll in doctoral education*. [Doctoral Dissertation, Michigan State University]. ProQuest.

McGee, E. O., White, D. T., Jenkins, A. T., Houston, S., Bentley, L. C., Smith, W. J., & Robinson, W. H. (2016). Black engineering students' motivation for PhD attainment: passion plus purpose PhD attainment. *Journal for Multicultural Education*, *10*(2), 167–193. https://doi.org/10.1108/JME-01-2016-0007

Means, B., Wang, H., Wei, X., Iwatani, E., & Peters, V. (2018). Broadening participation in STEM college majors: Effects of attending a STEM-focused high school. *AERA Open*, *4*(4), 233285841880630. https://doi.org/10.1177/2332858418806305

Mein, E., Esquinca, A., Monarrez, A., & Saldaña, C. (2020). Building a pathway to engineering: The influence of family and teachers among Mexican-origin undergraduate engineering students. *Journal of Hispanic Higher Education*, 19(1), 37–51.

Mobley, C., & Brawner, C. E. (2019). "Life prepared me well for succeeding": The enactment of community cultural wealth, experiential capital, and transfer student capital by first-generation engineering transfer students. *Community College Journal of Research and Practice*, *43*(5), 353–369. https://doi.org/http://dx.doi.org/10.1080/10668926.2018.1484823

Mondisa, J. L. (2020). The role of social capital in African American STEM mentoring relationships. *Journal of Women and Minorities in Science and Engineering*, *26*(2), 125–153. https://doi.org/10.1615/JWomenMinorScienEng.2020022267

Nagda, B. A., Gregerman, S. R., Jonides, J., Von Hippel, W., & Lerner, J. S. (1998). Undergraduate student-faculty research partnerships affect student retention. *The Review of Higher Education*, *22*(1), 55–72.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine (2011). Expanding minority representation, America's science and technology talent at the crossroads, Washington, DC: National Academies Press.

National Science Foundation, National Center for Science and Engineering Statistics. (2019). *Women, minorities, and persons with disabilities in science and engineering: 2019.* Special Report NSF 19-304. Alexandria, VA. Available at https://www.nsf.gov/statistics/wmpd.

Newman, M., & Gough, D. (2020). Systematic reviews in educational research: Methodology, perspectives and application. In O. Zawacki-Richter, M. Kerres, S. Bedenlier, M. Bond, & K. Buntins (Eds.), *Systematic Reviews in Educational Research* (pp. 3–22). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-27602-7_1

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, *16*, 1–13. https://doi.org/10.1177/1609406917733847

O'Connell, S., & Holmes, M. A. (2011). Obstacles to the recruitment of minorities into the geosciences: A call to action. *GSA Today*, *21*(6), 52–54. https://doi.org/10.1130/G105GW.1

Olsson, C., Kalén, S., & Ponzer, S. (2019). Sociological analysis of the medical field: using Bourdieu to understand the processes preceding medical doctors' specialty choice and the influence of perceived status and other forms of symbolic capital on their choices. *Advances in health sciences education : theory and practice*, *24*(3), 443–457. https://doi.org/10.1007/s10459-018-09872-3

Ovink, S. M., & Veazey, B. D. (2011). More than "Getting us through:" A case study in cultural capital enrichment of underrepresented minority undergraduates. *Research in Higher Education*, *52*(4), 370–394. https://doi.org/10.1007/s11162-010-9198-8

Paull, M., Lloyd, N., Male, S.A., & Clerke, T. (2019) Engineering work integrated learning placements: The influence of capitals on students' access, *Journal of Higher Education Policy and Managemen*t, 41:5, 534-549, doi: 10.1080/1360080X.2019.1646382

Peralta, C., Caspary, M., & Boothe, D. (2013). Success factors impacting Latina/o persistence in higher education leading to STEM opportunities. *Cultural Studies of Science Education*, *8*(4), 905–918. https://doi.org/http://dx.doi.org/10.1007/s11422-013-9520-9

Pérez, D., & Taylor, K. B. (2015). Cultivando logradores: Nurturing and sustaining Latino male success in higher education. *Journal of Diversity in Higher Education*, *9*(1), 1–19. https://doi.org/10.1037/a0039145

Petticrew, M., & Roberts, H. (2006). Systematic reviews in the social sciences: A practical guide. Malden, MA: Blackwell.

Pew Research Center. (2018, January 9). Women and men in STEM often at odds over workplace equity. Washington, DC: Pew Research Center. Retrieved from https://www.pewsocialtrends.org/wpcontent/uploads/sites/3/2018/01/PS_2018.01.09_STEM_FINAL.pdf

Postsecondary National Policy Institute (PNPI). (2020). Factsheets Latino students [factsheet]. https://pnpi.org/latino-students/

Prescod-Weinstein, C. (2019). Making Black women scientists under white empiricism: The racialization of epistemology in physics. *Signs: Journal of Women in Culture and Society*, *45*(2), 421–447. https://doi.org/10.1086/704991

Putnam, Robert D. 1993. "The prosperous community." *The American Prospect* 4(13):35–42.

Putnam, R. D. (1995). Bowling alone: America's declining social capital. *Journal of Democracy,* (1), 65-78.

Reay, D. 1998. *Class work: Mothers' involvement in their children's primary schooling*, London: UCL Press.

Revelo, R. A. (2015). Engineering familia: The role of a professional organization in the development of engineering identities of Latina/o undergraduates (Doctoral Dissertation). Retrieved from ProQuest.

Revelo, R. A., & Baber, L. D. (2018). Engineering resistors: Engineering Latina/o students and emerging resistant capital. *Journal of Hispanic Higher Education*, *17*(3), 249–269. https://doi.org/10.1177/1538192717719132

Rincón, B. E., Fernández, É., & Dueñas, M. C. (2020). Anchoring comunidad: how first- and continuing-generation Latinx students in STEM engage community cultural wealth. *International Journal of Qualitative Studies in Education*, *33*(8), 840–854. https://doi.org/10.1080/09518398.2020.1735567

Rincón, B. E., & Rodriguez, S. (2020). Latinx students charting their own STEM pathways: How community cultural wealth informs their STEM identities. *Journal of Hispanic Higher Education*. https://doi.org/10.1177/1538192720968276

Rincón, B., Fernández, E. F., & Hinojosa, J. J. (2020). "I want to follow in her footsteps": Activating, nurturing, and extending community cultural wealth for students of color entering STEM pathways. *Teachers College Record*, 122(9).

Roberts, K., Dowell, A. & Nie, JB. Attempting rigour and replicability in thematic analysis of qualitative research data; a case study of codebook development. *BMC Med Res Methodol* **19,** 66 (2019). https://doi.org/10.1186/s12874-019-0707-y

Roberts, S. O., Bareket-Shavit, C., Dollins, F. A., Goldie, P. D., & Mortenson, E. (2020). Racial inequality in psychological research: Trends of the past and recommendations for the future. *Perspectives on Psychological Science*, *15*(6), 1295–1309. https://doi.org/10.1177/1745691620927709

Russel, S.H., Hancock, M.P., McCullough, J. (2007). Benefits of undergraduate research experiences. *Education Forum, Science*, 316, 548-549.

Sáenz, V. B., García-Louis, C., Peterson Drake, A., & Guida, T. (2018). Leveraging their family capital: How Latino males successfully navigate the community college. *Community College Review*, *46*(1), 40–61. https://doi.org/10.1177/0091552117743567

Sáenz, V. B., García-Louis, C., De Las Mercédez, C., & Rodriguez, S. L. (2020). Mujeres Supporting: How Female Family Members Influence the Educational Success of Latino

Males in Postsecondary Education. *Journal of Hispanic Higher Education*, *19*(2), 169–194. https://doi.org/10.1177/1538192718787291

Samuelson, C. C., & Litzler, E. (2016). Community Cultural Wealth: An assets-based approach to persistence of engineering students of color. *Journal of Engineering Education*, *105*(1), 93–117. https://doi.org/10.1002/jee.20110

Saw, G. K. (2020). Leveraging social capital to broaden participation in STEM. *Policy Insights from the Behavioral and Brain Sciences*, *7*(1), 35–43. https://doi.org/10.1177/2372732219895997

Schultz, W.P., Hernandez, P. R., Woodcock, A., Estrada, M., Chance, R. C., Aguilar, M., & Serpe, R. T. (2011). Patching the pipeline: Reducing educational disparities in the sciences through minority training programs. *Educational Evaluation and Policy Analysis*, *33*(1), 95–114. https://doi.org/http://dx.doi.org/10.3102/0162373710392371

Shapiro, T., Meschede, T., and Osoro, S. (2013). The widening racial wealth gap, in the assets perspective, eds R. Cramer and T. Shanks (New York, NY: Palgrave Macmillan), 1–8.

Snively, G., Corsiglia, J., & Cobern, W. W. (2001). Discovering Indigenous science: Implications for science education. *Science Education*, *85*(1), 6–34. https://doi.org/10.1002/1098-237X(200101)85:1<6::AID-SCE3>3.0.CO;2-R

Stolle-McAllister, K. (2011). The case for summer bridge: Building social and cultural capital for talented Black STEM students. *Science Educator*, *20*(2), 12–22. https://files.eric.ed.gov/fulltext/EJ960632.pdf

Thompson, J. J., Conaway, E., Dolan, E. L., Thompson, J. J., Conaway, E., & Dolan, E. L. (2016). Undergraduate students' development of social, cultural, and human capital in a networked research experience. *Cult Stud of Sci Educ*, *11*, 959–990. https://doi.org/10.1007/s11422-014-9628-6

Tsui, L. (2007). Effective strategies to increase diversity in STEM fields: A review of the research literature. In *Source: The Journal of Negro Education* (Vol. 76, Issue 4). https://www.jstor.org/stable/40037228?seq=1&cid=pdf-

Turnbull, S. M., Meissel, K., Locke, K., & O'Neale, D. R. J. (2020). The impact of science capital on self-concept in science: A study of university students in New Zealand. *Frontiers in Education*, *5*, 27. https://doi.org/10.3389/feduc.2020.00027

United States (U.S.) Census Bureau. (2011). *Quick Facts*. Retrieved from https://www.census.gov/quickfacts/geo/chart/US/RHI225219

Valantine, H. A., Collins, F. S., & Verma, I. M. (2015). National Institutes of Health addresses the science of diversity. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(40), 12240–12242. https://doi.org/10.1073/pnas.1515612112

Villarejo, M., Barlow, A. E., Kogan, D., Veazey, B. D., & Sweeney, J. K. (2008). Encouraging minority undergraduates to choose science careers: career paths survey results. *CBE life sciences education*, *7*(4), 394–409. https://doi.org/10.1187/cbe.08-04-0018

Vryonides, M. (2007). Social and cultural capital in educational research: Issues of operationalisation and measurement, *British Educational Research Journal*, 33:6, 867-885, doi:10.1080/01411920701657009

Watts, R.J., Diemer, M.A. and Voight, A.M. (2011), Critical consciousness: Current status and future directions. *New Directions for Child and Adolescent Development*, 143, 43-57.

Whyte, K. (2018). Settler Colonialism, Ecology, and Environmental Injustice. *Environment and Society*, *9*(1), 125+. https://link.gale.com/apps/doc/A557313054/AONE?u=msu_main&sid=AONE&xid=9f546c4f

Wilson, M. A., Odem, M. A., Walters, T., DePass, A. L., & Bean, A. J. (2019). A model for holistic review in graduate admissions That decouples the GRE from race, ethnicity, and gender. *CBE—Life Sciences Education*, *18*(1), ar7. https://doi.org/10.1187/cbe.18-06-0103

Wilson, Z.S., Holmes, L., deGravelles, K. *et al.* (2012). Hierarchical mentoring: A transformative strategy for improving diversity and retention in undergraduate STEM disciplines. *J Sci Educ Technol* 21**,** 148–156. https://doi.org/10.1007/s10956-011-9292-5

Wood, S et al. A scientist like me: demographic analysis of biology textbooks reveals both progress and long-term lags. *Proceedings of the Royal Society B.* Published online June 24, 2020. doi: doi.org/10.1098/rspb.2020.0877

Yoder, J. B., & Mattheis, A. (2016). Queer in STEM: Workplace experiences reported in a national survey of LGBTQA individuals in science. *Technology, Engineering, and Mathematics Careers*, *63*(1), 1–27. https://doi.org/10.1080/00918369.2015.1078632

Yosso *, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, *8*(1), 69–91. https://doi.org/10.1080/1361332052000341006

Yosso, T. J. (2006). *Critical race counterstories along the Chicana/Chicano educational pipeline*. New York: Routledge.