APPLICATION AND IMPLICATIONS OF ASSET BUNDLE THEORY ON THE DEVELOPMENT OF SUCCESSFUL UNDERREPRESENTED SCIENTISTS

by

JAPERA JOHNSON

(Under the direction of Hal G. Rainey)

ABSTRACT

The objective of this dissertation is to explore the development strategies of successful underrepresented scientists in biomedical and health disciplines, with a specific focus on their acquisition and use of social capital and science capital. Exploring the experiences of successful scientists, as evidenced by their receipt of one of the most prestigious research awards, the Ruth L. Kirschstein National Research Service Award (NRSA) pre-doctoral fellowship, this dissertation provides a useful platform to unearth how these scientists developed and progressed through the scientific academic pipeline. Three manuscripts motivated by asset bundle theory were developed to pursue this objective. The asset bundle theory argues that scientific capital, social capital and economic capital are all necessary requisites for the fluid movement of a scientist through the academic pipeline. Using survey data collected from 505 recipients NRSA, the first manuscript examines social capital transfers to successful underrepresented scientists; it argues that social capital theory applications in the literature has undervalued the cultural and social resources important to the development of underrepresented scientists. The second manuscript explores the experiences of underrepresented scientists and suggests a focus on the ways in which cultural experiences and identities of underrepresented groups are relevant to their success. The final manuscript demonstrates that asset bundle theory, when applied to the use and development of science capital, underscores the need to better explore the institutional conditions in which scientists develop. The paper empirically explores the correlation between endowments of science assets and the potential for economic outcomes, finding little correlation between the two for underrepresented scientists.

INDEX WORDS: Underrepresented scientist, Minority scientist, Underrepresented minority, Economically disadvantaged scientist, Asset Bundle Theory, Social Capital Theory, Habitus, Science Pipeline, Biomedical and Health Scientist, Science, Technology, Engineering and Mathematics (STEM) pipeline, Development of Doctoral Scientists

FINANCIAL STATEMENT: Financial support for this work was provided by the National Institutes of Health grant #R01 GM088731 to Monica Gaughan, Principal Investigator.

APPLICATION AND IMPLICATIONS OF ASSET BUNDLE THEORY ON THE DEVELOPMENT OF SUCCESSFUL UNDERREPRESENTED SCIENTISTS

by

JAPERA JOHNSON

B.S. Spelman College, 2009

M.A. Lehigh University, 2010

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial

Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2014

APPLICATION AND IMPLICATIONS OF ASSET BUNDLE THEORY ON THE DEVELOPMENT OF SUCCESSFUL UNDERREPRESENTED SCIENTISTS

by

JAPERA JOHNSON

Major Professor: Hal G. Rainey

Committee: Barry Bozeman
Vicky M. Wilkins
Brian N. Williams

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
May 2014

DEDICATION

This work is dedicated to my beloved parents, the late Mr. Lawrance and Mrs. Sharon M. Johnson. Thank you for teaching me to question everything and to believe that obstacles are only disguised opportunities. I love you and miss you both. I hope I am making you proud.

ACKNOWLEDGEMENTS

This dissertation work is a reflection of the village that supports me. Each of you have been invaluable to my success and for that I am eternally grateful.

TABLE OF CONTENTS

LIST OF TABLES

Page

CHAPTER 1 – INTRODUCTION AND LITERATURE REVIEW

Introduction

The cultivation of scientific talent to address the nation's most pressing concerns has been an issue of significant importance for quite some time, as there is a link between national economic prosperity and the capacity to conduct research (Laredo and Mustar, 2001). Thus, an underutilization of scientific talent is inconsistent with a prosperous country. The common recognition in academic literature and in mainstream policy is that there is an underrepresentation of certain racial and ethnic groups in science (see e.g. NSF 2013). Thus, the purpose of this work is to explore factors that affect the development of underrepresented minority and economically disadvantaged scientists in the biomedical and behavioral sciences. Three manuscripts motivated by asset bundle theory were developed to pursue this objective.

The asset bundle theory, as will be described in more detail in the literature review, develops five bundles of capital to explore opportunities to support and advance underrepresented groups through the scientific pipeline. The leaky scientific pipeline is a common metaphor used to demonstrate that along the academic trajectory to develop scientists, there are opportunities for women, underrepresented minorities, and economically disadvantaged to attrite out of the pipeline (Metcalf, 2010). The causes of the leaky pipeline are numerous; scholarly work focused on this issue spans at least two decades and there is no shortage of literature and policy developed to correct leaks in the pipeline. While there has been progress, for example, in some science disciplines and for certain underrepresented groups (e.g. women in biological sciences), the leaky pipeline continues to be a significant and continuing problem that requires attention. The asset bundle theory is designed to assess the use of varying forms of capital within the social context of academic institutions. It was developed to patch the cracks at which underrepresented groups leak from the pipeline. The theory argues that scientific capital, social capital and economic capital are all necessary requisites for the fluid movement of a scientist through the academic pipeline. However, the theory also takes into account the cracks in the pipeline or institutional flaws that might force some groups out. The published form of this theory has only been available in the literature since 2012 and to date has yet to be empirically used to understand the progression of successful underrepresented scientists through the leaky academic pipeline. This work focuses on the development and use of science capital and social capital in successful scientists and provides implications for future research.

The first manuscript offers a critique of social capital theory application in science education literature, demonstrating that a key concept from Bourdieusian social capital theory, habitus, is well suited and in line with asset bundle theory and can inform the application of this theory to science. However, it is argued that improper operationalization of this theory muddles the potential application for this theory to members of underrepresented groups. The author concludes by performing empirical analyses to demonstrate that the misapplied theory produces spurious outcomes and requires improvement. The second manuscript expounds upon the social capital aspect of the asset bundle and demonstrates the necessity of reexamining the way that research institutions communicate problems regarding the leaky pipeline. It argues that *deficit* *thinking* about underrepresented groups a perspective advanced by Harper (2010), is a great obstacle to developing solutions to repair the institutional flaws. Lastly, the final manuscript demonstrates that the asset bundle theory, when applied to the use and development of science capital, underscores the need to better explore the institutional conditions in which underrepresented scientists develop. By exploring the use of science capital by successful underrepresented scientists this work can offer meaningful policy implications. In sum, this dissertation is an attempt to offer useful insight for the future of repairing the scientific pipeline.

Literature Review

Minority Representation in the Science Pipeline

America is currently facing rapid and transformative shifts in public health, education, and the economy, among many other aspects of American society. As such, scholars, think tanks and governmental agencies, among others, are intently concerned with identifying the human capital that the nation can bring to bear on its most pressing issues. PhDs are an invaluable resource to the knowledge capacity and scientific capital of the US and thus are an essential tool for addressing the nation's concerns. Notably, some argue that PhDs are not representative of the broader American constituency; specifically, many cite that there is an underrepresentation of African American, Hispanic American and Native American scholars in the science, technology, engineering and mathematics (STEM) disciplines. Given the severity and diversity of the issues facing the country and its continuously changing demographic, it is now more than ever unsustainable to underutilize any demographic of the academic talent pool.

Underutilization of minority talent in the STEM disciplines is evident by assessing the number of earned doctorates in these disciplines compared to the minority composition of the United States. As recently as 2007, minority groups accounted for 28.5% of the US population but only slightly over 9% of college-educated Americans in science and engineering occupations. When data is disaggregated by specific discipline, the numbers are even more telling: minority participation in the natural sciences and engineering is extremely low, biology participation is at 6%, physical sciences is below 5% and computer science is under 2%. Moreover, in 2007, minorities represented only 5.4% of science and engineering doctorates. Furthermore, of those minority doctoral degree holders, very few are awarded federal research grants (COSEPUP 2007). The high rate of doctoral attrition, compounded by the underproduction and progressive loss of minorities at every level of the scientific academic pipeline (COSEPUP 2007), suggests that minority participation in doctoral programs continues to present a problem for the scientific and technical human capital that can be brought to bear on the nation's most pressing science-intensive social and health problems. The demographic composition of the US is projected to dramatically change in the next decade (US Census 2008); efforts to assess the potential for recruiting and retaining minority participation are therefore more pressing than ever.

The pool for doctoral participation is most directly linked to the pool of academically eligible students who have completed undergraduate STEM education. Relative to non-STEM undergraduate completion, all students are less likely to finish STEM bachelor degrees. Research indicates that, of the students who enter college with STEM career aspirations, about half switch to non-STEM fields or leave college altogether (Chen and Weko, 2009). Furthermore, empirical evidence suggests that the general composition of students entering into STEM fields was predominately male, younger and dependent students, Asian/Pacific Islander students, foreign students, and students with more privileged family backgrounds and strong academic preparation (Chen and Weko, 2009). The implications of these statistics are clear: the pool of potential STEM candidates to pursue doctoral degrees is narrow. Moreover, given that minorities face representation inequities and achievement gaps in undergraduate education (American Council on Education, 2006; Hill and Green, 2007; National Action Council on Minorities in Engineering, 2008; National Science Foundation, 2007), it is obvious that the pool is further limited for minority candidates. Thus, a great deal of research and effort to increase diversity in STEM has focused on the high school and undergraduate level (Alvarez and colleagues, 2010; for a review of relevant literature see Tsui, 2007).

Scholars and education policy advocates generally propose the following actions to achieve increased diversity in STEM disciplines: eliminating structural barriers to academic access and success; sparking and sustaining interest in science of minority students before and during college through science socialization; exposure to scientists with whom minorities can racially or ethnically identify; preparation for high scores on Graduate Record Examinations and other professional examinations (e.g. The Medical College Admissions test); support of student attendance at conferences; assistance in the search for assistantships and fellowships for doctoral study for graduates; accessibility to financial support other than loans; and institutional and faculty commitments to diversity. It is argued that all of these approaches can help mitigate the barriers to undergraduate

STEM persistence through to doctoral programs (Hurtado et al., 2008; Brazziel and Brazziel, 1995). However, these policy prescriptions may not fully correct the problem of recruiting and retaining minorities in STEM doctoral programs. There are selection processes that are biased against the production of minority doctoral scientists. One such process is that the socially constructed culture of science on college campuses is one that encourages a highly competitive academic atmosphere; research shows that in these conditions minorities experience disproportionate attrition (Hurtado et al., 2009). Another element contributing to this systemic bias is that minority students largely do not have the same degree of exposure to science and to postsecondary education (COSEPUP, 2007) and thus require more intensive efforts to provide science capital and program socialization, especially at the doctoral level. The intricate process required to earn a doctorate, which is commonsensical to those with previous exposure to the process, can be confusing or intimidating to those with little science socialization.

In spite of these challenges, there are innumerable benefits to increasing minority participation in the STEM, health, and medical disciplines. For one, minority participation increases diversity in perspectives on addressing some of the nations most pressing social and health problems. The Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline cites that among other benefits (Smith et al., 1997; Anderson, 2008), students trained in diverse academic settings acquire important skills and perspectives enabling them to identify and solve problems of societal importance. Moreover, consistent with other scholars (Page, 2007; Kochan, 2003), COSEPUP argues that diverse groups are more innovative, smarter and stronger than homogenous groups, a contention supported by extensive empirical research (for overviews see Williams and O'Reilly, 1998; and Roberge and van Dick, 2010). More specifically, there are many theories suggesting that underrepresentation of minorities in the scientific and health labor force perpetuates health disparities. Minority participation has been shown to improve access to care for minority groups resulting from improvements in patient-provider communication and greater satisfaction with care received (Smedley, Butler, and Bristow, 2004; Smedly, Stith and Nelson, 2003). Furthermore, as research indicates, there is continued reluctance from minorities to participate in clinical trials. Race-concordance and representative bureaucracy theory suggest that minority researchers will reflect the values of minority patients; thus, egregious abuses such as in the Tuskegee syphilis experiment may be avoided and patients' trust in American medicine can be restored. In sum, increasing minority participation has broad implications, such as: better quality and conceptually creative research; research designs that focus on cultural conceptions and are intimately understood by the researcher; cultural competence in the mechanisms and delivery of health care; and, not to be understated, improving the health life outcomes for the scientists and medical professionals themselves that are retained in doctoral programs.

Given these benefits, it is important to assess how members of underrepresented groups overcome barriers to participation in science. Specifically, two research questions framed by Harper (2010) are useful to this exploration: (1) How do underrepresented scholars thrive and negotiate environments that are culturally foreign, unresponsive, politically complex, and overwhelmingly White? And (2) what strategies do these scholars employ to resist the internalization of discouraging misconceptions about members of their social groups and how do they manage to respond productively to stereotypes they encounter within the institutional setting? These questions require a research framework that does more to highlight the potential solution sets rather than the problems to sustaining minority participation in STEM, health and medical doctoral programs. For its appeal in focusing on assets instead of deficits, the asset bundle theory provides a useful starting point.

The Asset Bundles Model

The asset bundles model is a fusion of the scientific and technical human capital theoretical (STHC) framework and the theory of social identity contingencies (SIC); it was originally developed to target the critical areas in which minority high school and college students would need additional support in pursuit of a career in science. In short, the STHC model postulates that individuals' capacity to conduct research is a function of their technical ability (human capital) and their ability to use this capital through networks and social institutions (social capital) (Bozeman and colleagues, 2001). The SIC theory assumes that institutions send clear signals to individuals that trigger their expectations about the possible experiences (judgments, stereotypes, restrictions, opportunities, or treatment) they may face, based on their social identity (e.g., gender, race, or socioeconomic status) (Purdue-Vaughans and colleagues, 2008). The asset bundles model is grounded on the premise that it is incumbent upon institutions to anticipate and correct the various social cues that may signal devaluation of certain social identities (Johnson and Bozeman, 2012). Asset bundle theory encourages a focus on the resources and advantages of underrepresented scientists, and in doing so, diminishes the perpetuation of negative social cues being sent to members of underrepresented groups by academic institutions.

The asset bundles model, recognizing the array of social backgrounds from which all students come, packages the specific sets of abilities and resources that are developed to help STEM students succeed in educational and professional tasks. The model comprises five asset bundles, all relevant factors to educational achievement: educational endowments, science socialization, network development, family expectations, and material (financial) resources. The authors argue that the factors likely affect the educational achievement of any group, but that the interaction of these variables for those belonging to multiple marginalized social groups is vital for efforts to encourage persistence in academe. The authors expect that students in socially disadvantaged groups may expect to face overlapping and multilayered challenges as they progress through academic institutions that potentially send them negative social cues. Thus, attrition may be more likely for these students owning multiple social identities (Johnson and Bozeman, 2012).

In the following manuscripts, asset bundle logic will be used to help explain the success of underrepresented groups in science. Specifically, the manuscripts will explore social capital transfer to underrepresented scientists and the use of science capital by these scientists. The work concludes with important implications pertaining to how research should be conducted on underrepresented scientists.

CHAPTER 2 – SOCIAL CAPITAL TRANSFERS TO UNDERREPRESENTED SCIENTISTS: UNANTICIPATED FINDINGS[1]

[1] Johnson, J. to be submitted to *The Journal of Higher Education*

Abstract

The family of orientation, or initial kinship unit is the first social institution with which scientists interact and the functional prerequisite of any society. Scientists learn from the family how social identity is situated within society and how this position informs ability to develop and utilize various forms of capital. Given this indispensable role, this manuscript explores social capital theory and the role that families play in the development of scientists in health and biomedical disciplines. Specifically, the manuscript empirically analyzes the effect of the standard operationalization of family habitus found in the literature on the professional outcomes of underrepresented scientists. By performing an empirical analysis on high-achieving health and biomedical doctoral scientists, the author finds that the standard operationalization of habitus is improper for the purpose of understanding the social and cultural capital transferred from the family to successful underrepresented scientists.

Introduction

"[T]he basic and irreducible functions of the family are two: first, the primary socialization of children so that they can truly become members of the society into which they have been born; second, the stabilization of the adult personalities of the population of the society" (Parsons and Bales, 1955, p. 16).

Family Influence on the Development of Scientists

The family of orientation, or initial kinship unit (henceforward referred to as family), is the first social institution with which scientists interact and the functional prerequisite of any society. The family operates to provide a means of reproduction and maintenance (or, hopefully, manipulation) of social structure (Parsons and Bale, 1955;

Bourdieu and Passeron, 1990). Scientists learn from the family how social identity is situated within society and how this position informs ability to develop and utilize various forms of capital (Parson and Bales, 1955). Capital in the most rudimentary sense is the gatekeeper to all scientific outputs (Bozeman and colleagues, 2001). Capital is what provides access to opportunities to consume and produce science. The family institution thus has the first opportunity to shape scientists' perceptions about their social position in relation to the consumption and production of scientific outputs. Accordingly, this socialization process may be observed in a person's choice to pursue (or not) the development and use of science capital. Given this indispensable role, it is timely to assess the role that families play in the development of scientists in health and biomedical disciplines; these scientists have the greatest potential to shape the scientific capital that will reinforce or eliminate social and structural inequity in health outcomes.

A large body of literature demonstrates the influence of capital nested within families on educational choices leading up until entry into post-secondary education and life outcomes (see e.g. Andres and Krahn, 1999; Israel 2001; Knighton, 2002; Sullivan, 2001). Additional works apply this concept to the attainment of science education in a variety of settings (see e.g. Adamuti- Trache and Andres, 2008; Archer et al., 2012; Bellisari, 1991; Cleaves, 2005; Maple and Stage, 1991). Its usefulness in distinguishing reinforced structural and social hierarchies in education leads many works to apply this concept to educational outcomes for politically and economically disadvantaged groups (see e.g. Blickenstaff, 2005; Kalmijn and Kraaykamp, 1996; Lareau and Horvat, 1999; Lopez, 1996; Yan, 1999). Moreover, social capital theory has been used to examine science education outcomes specifically for socially, politically and economically disadvantaged scientists leading to and up until entry into post-secondary education (see e.g. Andrade, 2007; Brown, 2000a; Brown, 2000b; Carlone and Johnson, 2007; Grandy, 1998; Hanson, 2006; Russell and Atwater, 2005). More recently, social capital epistemology has been imported into the development of theoretical frameworks to examine the experiences of racial and ethnic minority students, particularly at the doctoral level, in science, engineering, technology and math (see e.g. Bancroft, 2013), and in health and biomedical disciplines (see e.g. Johnson and Bozeman, 2012). At the time this work was developed, the author was unaware of any related empirical analysis of social capital theory on the development of minority health and biomedical doctoral scientists. Thus, this work, informed by epistemological perspectives of the sociology of education as it relates to science, seeks to empirically examine the relationship between family influence and access to, as well as consumption and production of, scientific outputs for minority health and biomedical doctoral scientists.

Contextualizing Social Capital Theory

The processes by which capital is transferred to students require some disentangling. The research studies presented above all purport to explain social capital transfer; however, the application of social capital transfer theory is not consistent. In some cases, the authors find that the transfer of social capital is somewhat ambiguous (see e.g. Archer et al., 2012), while in other cases authors make definitive claims that social capital is transferred to students (see e.g. Israel 2001). In line with Portes (2000), the author of this paper argues, “much of the controversy surrounding social capital has to do with its application to different types of problems and its use in theories involving different units of analysis" (p.2). For that reason, proper distinction between the two principal theories of social capital, the Bourdieusian (1980) and the Colemanesque (1993), is required to achieve the objective set forth in this paper.

In their review of social capital literature, Dika and Singh (2002) assert that the Colemanesque approach is the more broadly used social capital framework in education literature. The Coleman approach defines social capital in terms of the resources available to parents to facilitate interactions with their children (Dika and Singh, 2002; Portes, 1998; Smith et al., 1995). As noted by Israel (2001), there are two main attributes to Coleman social capital theory, structure and process: "Structure determines the opportunity for interpersonal interactions, as well as for their frequency and duration. Process, on the other hand, represents the quality of parents' involvement in their children's lives. Process not only incorporates parents' nurturing activities but also includes efforts intended to constrain inappropriate behaviors by their children" (Israel, 2001, p.). In this conceptualization there is no clear distinction between resources and the ability to obtain them from within the social structure (Portes, 1998). For example, parent education is a structural characteristic commonly employed in Colemanesque education research. Typically in this application, education, a socially structured resource, informs the opportunity, frequency and duration of socialization with children. Thus, if one is not in possession of this education capital in the first place, it does not seem probable that he will be able to transfer social capital to his child. This circular logic bars the upward movement of those situated lowest in societal stratification.

Moreover, this theory reinforces the values of the dominant culture by delineating the construction of the "correct" structure and process to transfer capital within a family, based on conceptions of how the family unit ought to be structured and the process of delivery within that structure. Education researchers applying Coleman's theory of social capital have used a wide variety of variables that reinforce the opinion that it is nearly impossible to disentangle how access to resources nested in socially structured hierarchies reify the superiority of the dominant culture. In Coleman's own operationalization of his social capital theory, he predicted that lower high school drop-out incidence was positively associated with the greater amount of social capital of three types: presence of two parents in the home, lower number of siblings, and higher parental education expectation and intergenerational closure (Coleman 1988). All three of these variables are developed based on the normative appreciation for the experiences and behaviors of families in dominant cultures.

The appeal of these variables is that they are easy to define and make a theoretical argument about the dynamics of family structure that affords the possibility for transmission of social capital. However, there are grave disadvantages to the application of these variables to groups that do not ascribe to a dominant culture's behaviors, either because they are barred entry or because they choose not to participate. In the first place, as previously stated, these variables discount differential access to education based on the place in which a person is socially situated. To predict that parents' education resources positively affect education outcomes is a wonderful point of departure for empirical work, but analysis should not stop there. For example, research on first-generation college students undermines this aspect of Coleman's theory. These students, in the absence of the parent behaving like the dominant culture (accruing education), have created positive educational outcomes and overcome the structural barriers implicit in this theory.

Secondly, major issues arise from Coleman's preoccupation with defining family strictly based on its construction as a biological unit. As a biological unit, the family comprises a marriage (as indicated by consummation between two procreators; as such, this does not necessarily have to indicate legal marriage) and children (Parsons and Bales, 1955). This biological understanding of the family poses restrictions for social groups with a different conception of the family unit. Such differing conceptions are not new; for example, Parsons and Bales (1955) cite that "the American family has, in the past generation or more, been undergoing a profound process of change" (p. 3). The authors contend that this change provides an opportunity to understand the new structure of family that does not undermine the significance of family (Parsons and Bales, 1955) As Parsons and Bales (1955) explain:

> The most important implication of this view is that the functions of family in a highly differentiated society are not to be interpreted as functions directly on behalf of society, but on behalf of personality … [if] the essentials of human personality were determined biologically, independently of involvement in social systems, there would be no need for families, since reproduction as such, does not require family organization. It is because the human personality is not "born" but is "made" through the socialization process that in the first instances families are necessary (p. 16).

Thus, as a socializing unit the family structure can and does widely vary across cultural groups. Operationalizing family as a biological unit of two parents and a certain number of children undermines what can be understood about the socialization of children within families that are not structured biologically. There are differentiations in the structures of family that require consideration in application of social capital theory, especially if there is to be any meaningful contribution to the literature that helps explain educational outcomes of socially, politically and economically disadvantaged groups.

Moreover, research indicates that groups at the lower end of social stratification tend to have more children than those at the higher end (Willis 1973). Therefore, the correlation between social stratification and number of children may lead to spurious results when family structure is operationalized in this manner. As articulated by Israel (2001), an increase in number of children in the home diminishes opportunities for high-quality, uninterrupted interaction between parent and child. Inherent in Colemanesque ideology is the notion that there is some definable and normative interaction that *ought* be provided to each child. As a consequence, this operationalization reinforces the idea that those situated higher within the culture have the authority to establish the normative behaviors that drive the experiences for all. In sum, the Colemanesque approach to social capital theory inhibits the opportunity to examine the transfer of capital within groups that do not fit within the narrowly defined normative and dominant structure of the American family. In this conceptualization of social capital theory, capital and resources that politically, economically or socially disadvantaged groups accumulate and transfer to their children that progress in the sciences are rendered useless.

Bourdieu's approach is well positioned to examine the transfer of capital as it relates to science educational outcomes in a socially structured society. Three distinct but interacting concepts characterize Bourdieusian social capital theory: habitus, capital, and fields. *Habitus*, as created through social interactions, provides the information about an individual's position in society and their position relative to the position of others. In Bourdieu's words, "[h]abitus is both a system of schemes of production of practices and a system of perception and appreciation of practices. And, in both of these dimensions, its operation expresses the social position in which it was elaborated. Consequently, habitus produces practices and representations which are available for classification" (Bourdieu, 1989, p. 19). Both capital and field inform the classification processes that substantiate habitus. For Bourdieu (1986), the distribution of *capital* (or resources) establishes observed relationships between positions occupied in society. As such, in a hierarchically organized society, certain groups will possess more capital and, consequently, *legitimized* power to establish the nature of relationships between socially constructed groups. Capitals that function as systems of power include economic capital, cultural capital, social capital and symbolic capital. Thus, those that hold capital in its variety of forms are positioned such that they have the symbolic power to establish the normative values, predilections, and dispositions of the social *field.* Put simply, social fields are the social structures and status groups organized between different lifestyles (Bourdieu, 1989). Fields or social classes can be understood as organized groups of people sharing commonalities that, either by choice or by necessity, cluster (Bourdieu, 1989). Summarizing the concepts of Bourdieusian social capital reveals how the interactions of each concept can reinforce social positioning: Social positioning shapes habitus, habitus provides the tools with which to classify and characterize relationships and interactions in society, capital distribution establishes those observed relationships, the observed relationships establish the field and the field informs social positioning. The major criticism espoused above was that Coleman's social capital theory was circular and that economic capital cannot be disentangled from social capital. Bourdieu's social capital theory is owed the same critique. A closer examination of habitus will provide justification for the distinction between the two.

Habitus – A Necessary Point of Departure

Habitus collectively describes the values and ideologies acquired by an individual from their social group in relation to cultural contexts (Claussen and Osborne, 2013). Put more plainly, "habitus provides a practical 'feel' for the world, framing ways of thinking, feeling, and being, such as taken-for-granted notions of 'who we are,' and 'what we do,' and what is 'usual' for 'us'" (Archer et al., 2012, p. 885). It is an inner matrix of dispositions that shape how an individual understands and makes sense of the social world (Archer et al., 2012; Reay et al., 2001). All of an individual's social identities taken together inform habitus; thus, as most individuals belong to multiple social groups, the conceptual possibilities of habitus are boundless. Bourdieu articulates such possibilities; for example, social class can inform habitus (see e.g. Bourdieu, 1984; Bourdieu and Passeron, 1979), as can gender (Bourdieu, 2001). Others have examined the influence of habitus, including institutions (Reay et al., 2001, as cited in Archer et al., 2012) and collective class habitus (Charlesworth, 2000, as cited in Archer et al., 2012). Archer et al. (2012) develop the concept of *family habitus* to examine science education outcomes, defining it by the ways and settings in which families operate to form a collective relationship with science. Wong (2012) makes the distinction eloquently between habitus and capital: "As summarised by Harper (1984, p. 118), 'habitus is the way a culture is embodied in the individual'. Capitals work *alongside* the habitus, constituting the resources available to individuals which can be seen as generating social dis/advantages"

(p. 45). In short, defining habitus first requires an attempt at defining culture and then examining how culture is influenced by cultural capital, social capital and economic capital. With this clarification, habitus through the social conditionings that produce it is not precluded from being informed by culture and social conditions that are inconsistent with dominant and normative culture.

For the purpose of contextualizing habitus, the individual's classification of his own culture is the point of departure. In Bourdieu's (1989) theory,

> agents classify themselves, expose themselves to classification, by choosing, in conformity with their taste, different attributes (clothes, types of food, drinks, sports, friends) that go well together and that go well with them or, more exactly, suit their position. To be more precise, they choose, in the space of available goods and services, goods that occupy a position in this space homologous to the position they themselves occupy in social space. This makes for the fact that nothing classifies somebody more than the way he or she classifies. (p. 19)

Unlike the structure and process attributes of Coleman's social capital theory, Bourdieu's theory does not necessarily require a normative acceptance of the superiority of the dominant culture in society. However, his theory does account for the interaction that dominant culture has on individuals, because the theory dictates that individuals are situated within fields and because the relationships among individuals in this social space are defined by distributions of capital. Thus, Bourdieu's theory does not ignore the hierarchical structuring of societies, but it provides ample space to explore how various social groups classify and define their values and proclivities within social spaces. Bourdieu's theory of social capital is ripe for application in assessing the role that families play in the development of minority scientists, as it can explore the cultural habitus important to minority scientists' success in science education.

Theoretical Background

Habitus Operationalized in Science Education Literature

The literature applying the Bourdieusian concept of habitus to explain the role that families play in the development of scientists is severely limited. Of the three studies available at the time this work was developed, one was a qualitative exploration from the United Kingdom and two were empirical studies. The qualitative case study by Wong (2012) did not fully define habitus for application to minority scientists' outcomes. However, this case study does offer valuable insight and underscores the perspective that defining habitus requires beginning with the culture of the individual. In this study, Wong (2012) examines the cultural experiences of two 13-year-old, high science-achieving female students from working-class, ethnic minority backgrounds. He finds that an educationally oriented habitus does not necessarily sustain interest in science unless the student has expressed an aspiration for a career in the science field. He argues that this aspiration in his two subjects was influenced by a variety of factors, including cultural discourses of family, peers, and teacher expectations (Wong 2012).

The two empirical studies operationalize a classed habitus that, similar to Wong's (2012) work, characterizes habitus from the vantage point of acceptable behaviors consistent with the dominant culture. Edgerton and colleagues (2012) conducted an empirical analysis on 21,948 15-year-old Canadian students to model the relationships between family socioeconomic status (SES), sex, habitus, academic practices, and academic achievement. They find that SES has a strong effect on habitus but not a very strong effect on academic practices. SES also has a moderate direct effect on academic achievement in mathematics, reading and science. They further find that habitus has a strong positive effect on academic practices and academic achievement in math, reading, and science. They operationalize habitus as "an additive index of students' expected level of education, and sub-indices of Likert scale items measuring their 'disposition toward teachers' (e.g. I get along well with teachers. Most of my teachers do a good job of teaching.); and their 'disposition toward post-secondary education' (e.g. I will need to go to college or university to achieve what I want in life. I'm smart enough to do well in university/college.)" (Edgerton et al., 2012, p. 310). Given this operationalization of habitus, their findings are unsurprising, and can be alternatively interpreted as follows:

1. SES has a strong effect on *culture hierarchically organized by SES* ~~habitus~~ but not a very strong effect on academic practices.
2. *Culture hierarchically organized by SES* ~~habitus~~ has a strong positive effect on academic practices and academic achievement in math, reading, and science.

In short, this construction of habitus resembles hierarchal socioeconomic status arrangements. Defining habitus from this perspective reinforces that the behaviors, attitudes, predilections, and values consistent with the dominant culture are a requisite to better outcomes in society. This conceptualization does not allow for much variety in examining the experiences of those that are either prohibited from or wish not to ascribe to the value system of the dominant group. Habitus defined this way cannot provide meaningful interpretations for the outcomes of those that have lower SES but high academic achievement because it disregards other important attitudes, values, practices, etc., that might be useful to low-SES students in spite of the fact that they lack access to the cultural advantages of those in higher SES groups. There are social conditions important to academic achievement other than class and the capital it confers.

Archer and colleagues (2012) conducted a 5-year longitudinal mixed method study of 9,000 elementary school children in England and 160 semi structured interview participants, exploring the influence that habitus and capital play in reinforcing structural inequality and making science a field that middle-class students are better situated to aspire to. The authors recognize that “science aspirations, interest, and identification are strongly facilitated within middle-class families and class privilege can compensate for a lack of science-specific capital” (Archer et al., 2012, p. 889), but then go on to define habitus as the “practice of families weaving science into un/conscious family life (or not)” (Archer et al., 2012 p. 886). In the theoretical development of this work, the authors provide an excellent account of habitus, and admonish that habitus is separate from capital. However, in the operationalization of habitus they reinsert capital (by way of science capital) as a necessary component of habitus. Later in their text, they begin to refer to the family habitus as “familial science capital/habitus.” To reiterate Wong (2012), capital works in conjunction with habitus, but the two are distinct. Capital is the resource, habitus is the culture, and the two work together to explain social advantages and disadvantages but are not synonymous. For families with differential access to material resources, education, and science education in particular, the application of a family science habitus suffers from the aforementioned problems of the Edgerton (2012) work. This work assumes that families with less science capital to start will form a culture through pastimes, activities, leisure, TV, books, topics of conversation, and social networks (Archer et al., 2012) that encourages and fosters science in everyday life.

With this framework the authors found results that are more reflective of capital than anything else.

> 1. "[W]here middle-class family habitus, capital, and a child's identification with science were in alignment in favor of science, the result was particularly powerful, with families able to foster and capitalize on their child's interest, enabling them to occupy a strong and privileged position from which to potentially pursue these aspirations further" (Archer et al., 2012, p.903).
>
> 2. "[W]ithin most working-class families, science was less 'familiar,' being more 'peripheral' to parents' and children's everyday lives. These families tended not to possess the same quantity and quality of economic and science-related capital (cultural and social capital) to provide an equivalent basis for supporting the development of children's science-related aspirations" (Archer et al., 2012, p. 903).

The authors conclude, "Family habitus enabled us to explain how broadly classed patterns of family relationships with science (in which it is experienced as either 'thinkable/natural' or 'unthinkable/unusual') relate to the distribution of particular types of capital and the ways, and extent to which, such capital is deployed within the family life" (Archer et al., 2012, p. 903). Their conclusion reinforces that the habitus defined by these researchers is another operationalization of capital instead of culture. Resultantly, the findings reinforce a common assertion: privilege begets privilege.

The empirical analyses on habitus to date have improperly operationalized habitus for analysis of groups that are not considered privileged compared to the dominant culture or that are in groups with varying levels of economic, social, symbolic and cultural capital. The works have conflated capital with habitus, and thus the findings are hard to interpret and provide little clarity for the proper application of the Bourdieusian social capital theory to members outside of dominant groups. The objective of the present work is to empirically test this assertion. By performing an empirical analysis on high-achieving health and biomedical doctoral scientists, this work will explore the following questions: *Is habitus, defined by access to inequitably distributed capital, sufficient to explain the successes of majority scientists with low SES and minority scientists? How do low-SES majority scientists and minority scientists that develop science interest outside of the family compare to those that have developed it within the family? How do successful scientists that are both minority and from lower SES backgrounds compare to other successful scientists?* Answers to these questions will provide insight into the necessity to develop an operationalization of habitus that does not include measures that directly reflect access to economic capital.

Research Design

Data and Sample Characteristics

The data used in this analysis were collected under Principal Investigator Dr. Monica Gaughan in a National Institute of Health study entitled “Using the Scientific CV to Study the Effects of Interventions on Research Careers.” The study was designed to develop and test the Policy-Academic-Career Outcome Trajectory Model that examines how targeted and untargeted training programs affect the development of careers and achievement of career milestones among biomedical scientists. The target population for analysis is recipients of the Ruth L. Kirschstein National Research Service Award (F31) pre-doctoral fellowship between 1985 and 2012. The intended goal of this prestigious award is to help ensure the availability of a diverse pool of highly trained scientists to address the nation’s pressing biomedical, behavioral and research needs (NIH 2014). The award is granted to applicants that are successfully evaluated for scientific and technical merit through the National Institute of Health peer review system. Thus, recipients of this award are academically able and highly trained scientists.

The focus of this paper is not on the curriculum vitae data but on the survey data collected by the fellowship program between March 2013 and August 2013. The survey was conducted to explore factual and perceptual information about scientists' development and experiences prior to and during high school, undergraduate schools, and graduate programs, and specifically their participation in targeted interventions to increase the number of racial and ethnic minorities in science (including those not sponsored by the National Institutes of Health or National Science Foundation). For example, data gathered on high school educational experiences reflect the type of high school from which the scientist graduated, types and quantity of courses completed, and participation in summer programs and extracurricular activities related to math and science. Data were also collected on the scientists' perceptions of family influence on education and on socio-demographic family characteristics. The greatest part of the survey amassed information on scientists' educational training in science during undergraduate and graduate programs. Data reflect specific details about a wide variety of experiences, such as the number of research semesters in which scientists participated and the composition of financial resources used to pursue scientific training, among many other data.

Data were successfully collected on 506 scientists, reflecting a variety of racial and ethnic groups. 75% of respondents reported themselves as White, while 11% were Black or African American, 8% were Asian, 1% were American Indian or Alaskan Native, and 5% reported being of another race not specified in the response options. Of the 23 respondents listing their race as other, many are among underrepresented minority groups in the sciences, such as Puerto Ricans, Mexicans, Filipinos, and Afro-Caribbean. Respondents identifying as members of minority groups are over-represented in this sample to allow for sufficient analysis. Women make up 65% of respondents and, compared to men, were statistically more likely to respond to the survey. Serving as a proxy for socioeconomic background, recipients of the Federal Pell Grant – which provides need-based grants to low-income undergraduate and certain post baccalaureate students to promote access to postsecondary education – are from a variety of racial and ethnic backgrounds. The distributions for lower socioeconomic backgrounds are as follows: 19% White, 5% Black or African American, 2% Asian, 1% American Indian or Alaskan Native, and 2% Other Race. Respondents earned PhDs or PhD/MDs in one the following four research areas: 6% social science, 30% clinical science, 59% biomedical science and 5% biomedical engineering. All respondents received doctoral training at research universities with high research activity or special-focus institutions such as medical schools and medical centers, as specified by the Carnegie Foundation for the Advancement of Teaching (Carnegie Foundation 2014). At the administration of the survey, 83% of respondents were working in scientific positions in a variety of careers.

Measures

Time to Begin the Doctorate

In the two empirical papers conducted on habitus, the outcome variable of interest was an aspirational measure that detailed a child's intent to pursue a scientific career or to continue science education. Given that the respondents in this sample have all earned a doctoral degree, this analysis will test a scientific outcome as opposed to an aspiration to that outcome. The outcome in this analysis was constructed by computing the difference between the year respondents began their doctoral training and when they completed their bachelor's degrees. It was selected after a review of the sample revealed that minority scientists were statistically more likely to transition between the bachelor's and doctoral degree more quickly than majority scientists in this population. In this sample, minority scientists began their doctoral program after completing a bachelor's degree within 3.5 years, while nonminority scientists took on average 5.9 years; these differences were statistically different at the .001 confidence level. Thus, the outcome variable provides the opportunity to access success among minority scientists as opposed to failure. For example, much of the science education literature uses the time it takes a minority to complete their doctoral training as an outcome variable. Research shows that compared to majorities, minorities typically take longer to complete the degree (Zeiser and Berger 2012). Thus, variables used to predict an outcome variable structured in this way are biased against measuring minority success. Bivariate analysis confirms that in this sample, on average respondents completed the doctoral degree in 5.57 years, however there was a statistical difference at the 95% significance level when comparing nonminority respondents completing their degrees in 5.42 years and minorities completing the doctoral program in 5.94 years.

Class-Based Habitus

The primary variable of interest used to assess the difference between minority and nonminority time to begin the doctoral degree is an index constructed to reflect a class-based habitus. The index is a proxy representing the role that the family can play in supporting a scientist's educational development and pursuit of educational and professional endeavors, based on variables that are informed by economic capital. The additive index includes perceptual data about the support of an influential family member while the respondent was growing up, the priority the respondent's family placed on their children receiving higher education, and the family's potential reaction to the respondent hypothetically not attending college. Table 1.1 provides the specific wording of the "support from an influential family member" questions and distribution of responses.

Table 1.1 Perceptions of Educational Support from the Most Influential Family Member

Please think about the family member who was most influential in your education while they were growing up. To what extent would you agree with the following statements about this person?

	Strongly Disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly Agree (5)	Total	Average Response
Had an education that limited his or her ability to be helpful to me *	213	97	52	89	43	494	3.70
Did not place much of an importance on educational achievement *	380	80	14	13	7	494	4.65
Was focused on making sure I followed the educational path he or she thought was best	130	142	64	110	49	495	2.61
Was useful in helping me navigate my way through the educational system	62	95	99	154	83	493	3.20
Was not able to offer much educational assistance *	162	142	55	87	48	494	3.57
Considered academic achievement to be the most important thing	26	64	90	162	151	493	3.71

* To adjust for the wording of these statements, these variables were reverse coded to be consistent with the construct; higher numbers signifies positive support

Of the six perceptual variables representing support from an influential family member during the respondent's upbringing, minority scientists in this population have statistically different responses on two of those variables. For example, the average response for minority scientists about an influential family member offering educational assistance was 3.36 compared to 3.67 for the average nonminority response. Thus, it can be argued that for those in this sample, influential family members in nonminority families offered more educational support. The attitude toward academic achievement of the influential family member in the minority scientist's life was statistically different than scientists from nonminority families; minorities had a higher report about academic achievement being the most important thing than did non-minorities, a mean of 3.97 compared to 3.60. As educational capital is correlated with economic capital, these six variables represent a habitus constructed on capital.

The remaining two variables that make up the additive index for the family asset bundle do not ask the respondent about a specific family member, but capture the respondent's perception of the respondent's family habitus of higher education in general. The seventh variable of the additive index attempts to capture the priority placed by the family on children receiving higher education. The average response value was 3.54 for both minority and nonminority respondents, indicating that higher education was at least an important priority for the families of these respondents. Table 1.2 provides the specific wording of the priority for higher education question and distribution of responses.

Table 1.2 The Family's Priority for Higher Education		
"How much of a priority did your family place on their children receiving higher education?"		
	Frequency	Percent
Not a priority at all (1)	18	3.63
Not much of a priority (2)	23	4.64
Important, but not a top priority (3)	127	25.60
Top priority (4)	328	66.13
Total	496	100.00

The final variable of the additive index asks the respondents to consider what the hypothetical response of their family would be had the respondents decided not to attend college. Again, the variable attempts to capture information pertaining to familial emphasis on higher education. Table 1.3 provides the specific wording of the hypothetical reaction question and the distribution of responses. The average response for both minority and nonminority respondents was that "My family would have been disappointed."

Table 1.3 Family's Hypothetical Response if the Respondent Did Not Attend College		
"Imagine if you decided not to attend college. What would have been the reaction of your family in response to this decision?"		
	Frequency	Percent
My family would have been very upset (3)	220	44.27
My family would have been disappointed (2)	220	44.27
My family would not have been upset (1)	57	11.47
Total	497	100.00

A pair-wise correlation matrix was examined to determine the strength and the significance of the correlation between these variables. With the exception of one pair, all eight of the variables were significantly correlated with each other at the .01% significance level. After analyzing the pair-wise correlation, factor analysis was performed to determine if the variability among these observed perceptual variables reflected variations in the unobserved family habitus construct. The factor loading values from a confirmatory factor analysis show that most of the variables should be loaded onto a single factor, as the ideal factor load threshold of 0.5 was met for most variables. Subsequently, the 2.23 difference between the first factor eigenvalue and the second also confirm that these variables load onto one factor (Cleff, 2011). Subsequent goodness of fit tests also confirms that these variables represent an unobserved latent construct: Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI), also known as nonnormed fit index. The value for the RMSEA was 0.199 and significant at the .000 level. The CFI is 0.85 and the TLI is 0.795. These measures provide sufficient information about the quality of the summative index. The Cronbach's Alpha estimate of 0.80, which is an estimate of internal consistency in the formulated index, is generally accepted in the literature as good reliability (Tavakol and Dennick 2011). Table 1.4 provides the factor for the computed index.

Table 1.4 Factor Loading for the Family Habitus Summative Index

Response	Factor Loading
The family member who most influential in the respondent's education…	
Had an education that limited his or her ability to be helpful to me *	0.64
Did not place much of an importance on educational achievement *	0.62
Was focused on making sure I followed the educational path he/she thought was best	0.39
Was useful in helping me navigate my way through the educational system	0.68
Was not able to offer much educational assistance *	0.74
Considered academic achievement to be the most important thing	0.42
Family's Priority for Higher Education	0.73
Family's Hypothetical Response if the Respondent Did Not Attend College	0.54

* These variables were reverse coded to be consistent with the construct

The average value of the family asset bundle index was 31.30, with a standard deviation of 6.23. For interpretation of results in this model, the standardized form of the asset bundle was constructed. There was no statistical difference between minority and nonminority groups on this index.

First-Generation Status

The analysis includes two variables that measure whether or not the respondents' parents attended college or earned a doctoral degree. These measures are included as a proxy for potential social capital that could be transferred to the scientist to help them progress more quickly from the bachelor's to doctoral degree. The college generation status variable is a binary variable that is assigned a one if the respondent is a member of the first generation to attend college. 17% of respondents are members of the first generation college attendants. Minority respondents were statistically more likely to be first generation college attendants: 22% for minority respondents versus 15% for nonminority respondents. Additionally, the measure of First-Generation Doctorate was constructed in a similar manner and is assigned a one if neither parent earned a doctorate. Minority scientists in this sample were statistically more likely to earn a doctorate even though neither of their parents did. 77% of minorities were the first doctor, while 67% of nonminorities were.

Minority

In this analysis, the term "nonminorities" is used to indicate those respondents that identified themselves as White or Asian. While Asian Americans are demographically a minority, they are not underrepresented in the sciences (NSF 2013). In fact, Asian Americans are consistently earning more mathematics, physical and biological science degrees in the last decade (NSF 2013). The minority treatment group reflects respondents that identified as Hispanic, Black or African American, American Indian or Alaskan Native, or Some Other Race. As previously noted, many of the respondents that identified "other" as their race classification were among underrepresented minority groups in the sciences.

Controls

The demographic and socioeconomic controls in this analysis include a binary gender variable, with women as the referent group, and mother's and father's highest level of education completed and English literacy, as proxies for socioeconomic status, . The model also includes a binary control reflecting a one if the respondent cited that someone in their family was responsible for stimulating their initial interest in science. This variable is included as yet another variable that is correlated to socioeconomic status and thus possibly measures economic capital. Other controls include a binary variable if the respondent earned a master's degree, a variable based on the disability status of respondents, and a variable to control for when the scientist decided to become a scientist, coded as one if the respondent decided to become a scientist before entering the bachelor's degree.

Research Methods

The essential objective of this research is to determine what affect the class-based family habitus has on scientific career outcomes for high-performing scientists. A hallmark in the higher education literature for analyzing educational and career outcomes for scientists is to use event history or survival analysis to determine what covariates affect the time to the occurrence of career events, such as completion of the doctoral degree. Given the nature of this dataset, this work will follow suit and use survival analysis to examine how the asset bundles model affects the occurrence of completing the doctoral degree. Specifically, this work will compare the effect of the habitus on the time it takes to begin the doctoral program, comparing outcomes for minorities, nonminorities from lower socioeconomic backgrounds, and minorities from lower socioeconomic backgrounds.

Survival analysis models analyze the probability of time passed until the occurrence of an event given a set of covariates. The proportional hazards model estimates an odds ratio of experiencing that event by calculating the hazard function h(t) – the event rate or the probability of having an event at time t, given that the event has not occurred before t (Cleves et al., 2008). "There is a one-to-one relationship between the probability of a survival past a certain time and the amount of risk that has been accumulated up to that time, and the hazard rate measures the rate at which risk is accumulated" (Cleves et al., 2008, p. 8). The hazard function (or rate) or probability of an event occurring in a given population is affected by vectors of covariates, and thus to perform this type of analysis, assumptions about the baseline hazard or the hazard when all covariates equal zero is essential. In short, the shape of the baseline hazard function provides information about the underlying process causing the event to occur.

Given that it is very difficult to specify the parametric shape of the baseline hazard, it is common to use nonparametric survival analysis (Cleves et al., 2008). Nonparametric analysis involves estimating a binary variable for the occurrence or censoring of an event. The major advantage of this approach is that the data determine the shape of the hazard function that best fits them (Cleves et al., 2008). The Cox Proportional Hazard model is the most commonly applied semiparametric survival analysis, as one may choose an underlying baseline hazard for the model, but it is unnecessary. When not specifying a baseline hazard, the Cox proportional hazards model makes no assumption about the shape of the hazard over time and instead "assumes that the covariates multiplicatively shift the baseline hazard function" (Cleves et al., 2008, p. 128). In other words, regardless of the shape of the baseline hazard function, the Cox proportional hazard model assumes that one respondent's hazard is a multiplicative replica of another's (Cleves et al., 2008). Thus, the use of the Cox Proportional Hazards model makes it possible to examine how respondents in this sample compare to each other given the covariates of interest.

Research Findings

The Cox Proportional Hazards analysis was run on three nested models to determine the effect of habitus on the time to begin the doctoral degree for minority scientists. The base model includes variables representing the personal characteristics of the respondent. The next model includes measures of the family's economic capital and the generation variables. The final model includes class-based habitus, family influence on science interest, and the master's degree control.

The results of the full model demonstrate that minorities have a higher hazard and thus begin the doctoral program sooner than nonminorities in this sample. Within the first year of finishing the bachelor's degree, minorities have a 64% increase in the hazard of beginning the doctorate ($\alpha = 0.01$). Compared to women, men have a 74% increase in the hazard of beginning the doctorate sooner ($\alpha = 0.05$). The 1.26 hazard ratio for those respondents who decided to become a scientist before entering a bachelor's degree program demonstrate that compared to others, they begin the doctorate sooner ($\alpha = 0.05$). Economic capital variables are also significant and have a positive effect on the outcomes; for example, a one unit increase in mother's or father's education increases the hazard by 86% ($\alpha = 0.01$) and 93% ($\alpha = 0.05$) of entering a doctoral program soon after the bachelor's, respectively. Lastly, as expected, earning a master's degree has a negative effect on the outcome of interest and decreases the hazard by 66%. While insignificant, the variables that measure generation status demonstrate an increase in the hazard of beginning the doctorate after the bachelor's. Alternatively, for the variables reflecting familial support for educational development and influencing initial science interest result in a decrease in the swift progression of scientists through the pipeline. This first analysis demonstrates that, controlling for the various economic capital variables, minorities have a higher hazard of progressing through the scientific pipeline. The Log-Rank, Wilcoxon, and Tarone-Ware tests all confirm a significant difference in the survival functions for minorities in this sample, suggesting that they progress more quickly than others.

Interactions were created for the significant variables findings to further examine the effect these variables have on minority scientists.

The findings of the interactive model demonstrate that minorities (2.73, $\alpha = 0.05$), men (1.26 $\alpha = 0.10$), and those that decide before the bachelor's to pursue a career in science (1.40, $\alpha= 0.05$), all have a higher hazard of moving from the bachelor's to the doctorate. Interestingly, minorities that decide to pursue a science career before entering the bachelor's have a lower hazard (0.97, $\alpha= 0.05$) of moving quickly to the doctorate. Neither parents' education are significant predictors of moving from the bachelor's to the doctorate for minority scientists. Thus, these findings support the theory that variables primarily measuring inequitably distributed capital are not sufficient to explain why minorities move quickly from the bachelor's to the doctorate. Interestingly, this model suggests that minorities poised to move quickly through the pipeline, as evidenced by their decision to pursue a science career before entering the bachelor's, have a lower hazard than nonminorities with similar aspirations. Table 1.5 provides the hazard ratios for these two models.

Table 1.5 Hazard Ratios and Robust Standard Errors of the Cox Proportional Hazard Models

	Full Model	Interactive Model
Underrepresented Minority	**1.360****	**2.734****
	(0.131)	(0.886)
Male	**1.256****	**1.264***
	(0.126)	(0.167)
Minority Male		**1.037**
		(0.190)
Scientific Aspiration Before Entering the Bachelor's	**1.263****	**1.401****
	(0.126)	(0.168)
Minority Scientific Aspiration Before Entering the Bachelor's		**0.695****
		(0.113)
Disabled	**0.774**	**0.775**
	(0.193)	(0.193)
Mother's Education	**1.140*****	**1.139****
	(0.041)	(0.054)
Minority Mother's Education		**0.979**
		(0.058)
Father's Education	**1.073****	**1.098****
	(0.039)	(0.047)
Minority Father's Education		**0.935**
		(0.051)
Mother's English Literacy	**1.000**	**1.000**
	(0.075)	(0.075)
Father's English Literacy	**0.991**	**0.991**
	(0.085)	(0.085)
First Generation College Student	**1.238**	**1.250**
	(0.197)	(0.199)
First Generation Doctor	**1.221**	**1.241**
	(0.176)	(0.181)
Member of Lower Socioeconomic Group	**1.108**	**1.062**
	(0.110)	(0.108)
Standardized Class Based Habitus	**0.972**	**0.976**
	(0.052)	(0.051)
Family Member Influenced Initial Science Aspiration	**0.955**	**0.942**
	(0.101)	(0.100)
Master's Degree	**0.339*****	**0.351*****
	(0.042)	(0.055)
Minority Master's Degree		**0.898**
		(0.174)
Observations	460	453

* p<0.10 ** p<0.05 *** p<0.01 Reporting Hazard Ratios and Robust Standard Errors

The final analysis examines the experiences of minorities from lower socioeconomic backgrounds. Unsurprisingly, poor minority males have a lower hazard (0.83, α= 0.01) of moving from the bachelors to the doctorate. A one-unit increase in mother's education decreases the hazard (0.99, α= 0.05) for poor minorities to quickly progress through the pipeline, while earning a masters for poor minorities also decreases their hazard (0.56, α= 0.05). A similar model to the poor minority model was run to examine the experiences of poor nonminorities and there were no significant results.

Discussion and Conclusion

As theorized, while parents' education is an important predictors of progression in the full sample, it is insignificant in the analysis of minority scientists and operates in the opposite direction for poor minority scientists. This finding suggests that disparities in capital are important in the analysis of the minority experience in science education but provide a very incomplete picture. Increases in economic capital in this sample, do not correlate with better outcomes. The implication is important: focusing on capital as a measure of success may prove immaterial in the analysis of groups that have traditionally inequitable distributions of it. Further, the primary variable of interest did not significantly explain variations in the outcome variable for minority scientists, lower-SES minority scientists, and low-SES nonminority scientists. For example, a single standard deviation from the mean habitus index did not result in an increased likelihood of beginning the PhD. The author of this work theorized that the construction of habitus based on inequitably distributed capital would be insufficient to explain the roles that families who are not part of the dominant culture play in the scientific outcomes of successful scientists from those families. The analyses tested this theory in three different ways and the results all suggest that a class-based habitus does not predict scientific outcomes in this population. However, that finding is inadequate. “Habitus provides a practical ‘feel’ for the world, framing ways of thinking, feeling, and being, such as taken-for-granted notions of ‘who we are,’ and ‘what we do,’ and what is ‘usual’ for ‘us (Archer et al., 2007). The successful scientists in this analysis must have some culture that empowers them to succeed. They obviously have been socialized to believe that science is something they can do, and that it is congruent with their senses of who they are. The average scientists in this sample decided before the age of 18 that they wanted to pursue a career in science – before they left for college and were likely still in the care of their families. However, minority scientists that decided before the age of 18 to pursue a science career were statistically less likely to progress through the academic pipeline as quickly as others. This finding suggests that possibly the experiences within academic institutions constrain success for the hopeful minority scientist. It is possible that the eager minority scientist faces some challenge within the bachelor’s institution that hampers their progression.

The research implications from these findings suggest that exploring a better conceptualization of habitus is necessary to fully understand the ways in which families affect scientific outcomes. Portes (2001) admonishes “There is a need for both logical clarity and analytic rigor in the study of these processes, lest we turn social capital into an unmitigated celebration of community” (p.12). This work serves as a beginning attempt to provide some logical insight to transfers of social capital. Given what is known about these scientists, the author is hopeful that this work will provide a necessary platform to begin to examine the construction of a proper family habitus informed by the culture of different populations.

CHAPTER 3 – ASSESSING SOCIAL CAPITAL TRANSFERS TO UNDERREPRESENTED SCIENTISTS FROM THE ASSET BUNDLE PERSPECTIVE[2]

[2] Johnson, J. to be submitted to *The Journal of Higher Education*

Abstract

The transfer of social capital from families to underrepresented scientists requires examining the cultural and social contexts in which these transfers happen. This second manuscript explores literature detailing the cultural experiences relevant to the development of underrepresented scientists, and assesses values embedded in the social contexts and relationships that are transferred to underrepresented scientists that aid in their development. It focuses on the roles of underrepresented scientists families and suggests two constructs that could be developed for empirical examination of a family habitus that is informed by social resources available to underrepresented scientists.

Introduction

"There is a need for both logical clarity and analytic rigor in the study of these processes, lest we turn social capital into an unmitigated celebration of community" (Portes, p.12).

As a component of the asset bundle model, proposed by Johnson and Bozeman (2012), the family operates to "encourage or discourage children from pursuing higher education and careers in academic medicine and STEM [science, technology, engineering and math] fields" (p. 1492). The interpersonal family dynamics create opportunities to socialize emergent scientists, as the family is typically the first social institution with which one interacts. The family helps orient the scientist with social structures and facilitates the development of social identity (Parsons and Bale, 1955; Bourdieu and Passeron, 1990). It is within the family unit that scientists first learn of and develop their ability to cultivate and use various forms of capital (Parson and Bales, 1955). Thus, for scientists from underrepresented groups, the ways in which the family interacts with them will likely influence the development of their scientific identity. The education literature is saturated with examples of the correlations between family and the perpetuation of education outcomes (see e.g. Andres and Krahn, 1999; Israel, 2001; Knighton, 2002; Ma, 2009; Sullivan, 2001), and specifically regarding the development of scientists and acquisition of science education (see e.g. Adamuti- Trache and Andres, 2008; Archer et al., 2012; Bellisari, 1991; Cleaves, 2005; Maple and Stage, 1991). Thus, it is clear that families play some important function in the development of scientists; however, it is less clear what that function is in scientists from underrepresented groups.

Social capital theory offers a useful lens with which to examine the role of families in scientific development. Renowned sociologist Pierre Bourdieu advances a social capital theory that explores the "advantages and opportunities accruing to people through membership in certain communities" (Portes, 1996, p. 18). Three distinct but interacting constructs characterizes Bourdieu's social capital theory: habitus, capital and fields. *Habitus*, as created through social interactions, provides the information about an individual's position in society and what that location is relative to the position of others. "Habitus is both a system of schemes of production of practices and a system of perception and appreciation of practices. And, in both of these dimensions, its operation expresses the social position in which it was elaborated" (Bourdieu, 1989, p. 19). Further, habitus, or the values, predilections and ideologies inherited by scientists from social groups with which they are affiliated (such as the family), frame the beliefs and thoughts of scientists in their social contexts. It provides an understanding of the world and social structures within it (Archer et al., 2012; Reay et al., 2001). Stated differently, "habitus provides a practical 'feel' for the world, framing ways of thinking, feeling, and being, such as taken-for-granted notions of 'who we are,' and 'what we do,' and what is 'usual' for 'us'" (Archer et al., 2012, p. 885). Habitus, as it can be informed by any social group, thus may be conceptualized in terms of *family habitus*, has the potential to provide useful information regarding how families inform the perceptions of underrepresented scientists about who they are and what they can do. The second aspect of Bourdieu's theory, capital, provides useful information about the opportunities for underrepresented scientists to mobilize values and practices acquired from the family habitus. For Bourdieu (1989), the distribution of *capital* (or resources) establishes observed relationships between positions occupied in society. As such, in a hierarchically organized society, certain groups will possess more capital and consequently be better positioned to establish the rules characterizing the nature of relationships between socially constructed groups. Capital can take the form of economic resources, cultural resources, social resources and symbolic resources; the conversion of these resources into productive assets within a social construct will be mitigated by the established rules of the dominant group. Thus, those that hold more capital in its variety of forms are positioned such that they have the symbolic power to establish the normative values, predilections, and dispositions of the social *field.* Lastly, the field describes the social environments in which underrepresented scientists are situated. These fields are organized by the lifestyles and status of social groups (Bourdieu, 1989). Within fields, there are rules, normative values and guiding principles that structure the involvement, interaction and experience of those within the field (Bourdieu, 1989). Thus, an underrepresented scientist will develop a sense of the world from their *habiti*, which can inform their opportunities to develop and attempt to employ various forms of *capital*, all while being subjected to the various norms and procedures within multiple *fields*, which are in most cases the various educational institutions through which they matriculate. In this way, the Bourdieusian theoretical framework has great ability to explain the development of social capital theory. Moreover, the concept of *habitus*, as it is distinct from distributions of capital, can bring into focus the various roles of families and other social groups as they inform the development of underrepresented scientists.

Economic sociologist Alejandro Portes, a known critic of the misapplication of social capital theory, argues that intellectuals and policymakers have distorted it by celebrating the theory as *the* key to success in a myriad of domestic issues. In their desire to contribute new ideas and solutions, they identify *a posteriori* similar traits in a community and ascribe the presence or absence of those traits to successes or failures. He argues that there is great danger in doing so, as it produces abundant tautologies, truisms, and stereotypes (Portes, 1996). This sanguine view of social capital theory fails to acknowledge that successes and failures in a hierarchically arranged society are typically more associated with the advantage or disadvantage of objective economic resources. While Portes (1996) is not dismissive of the intellectual merit of social capital theory, he is adamant that it requires better definition and more precise understanding.

> Indeed, the more social capital is celebrated for a growing list of wonderful effects, the less it has any distinct meaning. Social capital now appears poised to repeat the experience suffered by other promising social science concepts in the past: from intellectual insight appropriated by policy pundits, to journalistic cliché, to eventual oblivion. It deserves better. Any rescue effort requires examining what has gone wrong with the idea and its use in recent public debate. (p. 18)

This exposition about the family's role in the development of scientists from underrepresented groups will serve as an attempt to provide a more appropriate application of social capital theory in the science education literature. The objective of this current work is to develop a logical point of departure for future operationalization of familial roles in analytic studies of the development of scientific and human capital of underrepresented successful scientists. To accomplish this objective, the work will review relevant literature about the role of underrepresented scientists' families, discuss what can be learned from these sources and conclude by offering recommendations for empirically studying these concepts.

Literature Review

The Perceived Role of Families in the Development Underrepresented Scientists

One body of the science education literature focuses on the family's role in the development of science identities for underrepresented groups. However, upon closer inspection, this sample of literature does not provide new insight, as it reflects and underscores the prevailing social construction of society: those that have the types of capital consistent with values of those in the dominant positions within social fields have better outcomes. For example, in an analysis on parent-child conversation among children in Mexican-descent families in the US, Tenenbaum and Callanan (2008) find that engaging in scientific discourse within the family promotes scientific development in children. The modes of discourse varied by parents' education, but in sum, the authors found that for Mexican-descendant children in families with better-educated parents, the nature of the conversation encouraged those children to think critically about science content by explaining causal reasoning and making predictions about scientific observations. Studies such as this demonstrate that the promotion of a scientific identity can be related to the presence or absence of parents' educational capital, which is commonly associated with economic capital. Educational capital in the social context of the U.S. is a precursor in many cases to other forms of capital, and most often is inequitably distributed. In line with Tenenbaum and Callanan (2008), Adamuti-Trache and Andres (2008) demonstrate that the majority of female high school students who complete physical science, mathematics and engineering courses are children of university-educated parents. Further, they cite that students with university-educated parents had well-defined, early plans to continue post-secondary education. "Early decisions provide an advantage to those who have the ability and interest in pursuing science-related careers that require long and focused trajectories" (Adamuti-Trache and Andres, 2008, p. 1576). In short, they underscore that early-accumulated advantages propel students in science.

In a study of 9,000 elementary school children in England, Archer and colleagues (2012) set out to specifically operationalize *family habitus* as it relates to the science aspirations of children along the socioeconomic gradient. In the study, *family habitus* was defined by the ways in which families consciously or unconsciously wove science into the social fabric of the family to form relationships with science among children. In the 5-year longitudinal mixed method analysis, they identify that *family habitus* was partly responsible for reinforcing structural inequality in science. They found that science disciplines are better situated for the aspirations of middle-class students as opposed to lower-class students. Further, they acknowledged that social class privilege compensated for lacks in social and cultural capital related to science among middle class families. In these cases, it was argued that middle-class families activated the parenting style of "concerted cultivation," coined by sociologist Annette Lareau, to detail the practices that middle-class families employ to stimulate development and foster children's talents and skills through the deployment of middle-class capital (Archer et al., 2012). In sum, Archer and colleagues (2012) operationalize a class-based habitus to reiterate the prevailing knowledge about the structure of inequity within societies. Implicit in the findings is the reality that classed structures greatly constrain aspirations and outcomes for those lowest in the structure.

Similarly, in an analysis of teenage Canadian students, Edgerton and colleagues (2012) find that socioeconomic status strongly affects habitus and moderately affects academic achievement in mathematics, reading and science. They argue that habitus has a strong positive effect on academic practices and achievement. Like Archer and colleagues (2012), the authors operationalized a class-informed habitus, one that assigns attributes to behaviors that are valued by the dominant class culture, such as a pro-school family orientation as it relates to the potential for a future return on investment. Findings such as these are also reproduced in Australian high-achieving physics and chemistry students. The students from families that advocated and supported interest in science influenced students' decisions to pursue science (Lyons, 2006).

These examples from the literature that attempt to explain the disparities in science outcomes for members of underrepresented groups inappropriately assign culpability to the family for failing to *definitively* shape science identity and aspiration to science as measured by their role in encouraging scientific engagement or discourse. The primary focus on this one-dimensional role of underrepresented families and failure to account for other relevant functions in the development of underrepresented scientists, devalues the various cultural and family resources essential to their overall and scientific identity development. Science education in this sample of the literature seems to be valued for its exchange value and the institutional capital that it produces for use by the dominant society (Claussen and Osborne, 2013). Accordingly, aspirations to sciences are seen as socially valuable and necessary for potential elevation from one social standing to the next, thus it is assumed that underrepresented groups *should* aspire to science because it is valued by the dominant culture and that their families *should* work to specifically cultivate a science identity. However, by framing the role of families solely in terms of what is valued by the dominant culture, it is evident that these scholars are (un)consciously influenced by Bourdieu's theory of cultural reproduction that explains how cultural experiences are sustained over time (Sullivan, 2001). As advanced by Bourdieu (1986, 2000) capital transfers in the forms of practices, norms, attitudes, values and dispositions from parent to child result in the reproduction of the dominant culture as the inequalities that inform these views are converted into differential academic pursuits/attainments and corresponding social status. The patterns of differential outcomes in science education attainment may be in part due to family values; however, the values and behaviors of dominant groups might be more culpable for these disparities, as dominant groups dictate the structure of positions, power, normative values and guiding principles that affect the experiences and differential outcomes for others in society. In short, it is the dominant culture that through their privilege construct the science education institutions such that privilege begets privilege and those not deemed privileged are either barred entry or, when granted entry, are prohibited from full inclusion and meaningful engagement to reinvent the structure. In spite of such dominant structures, there are some underrepresented scientists that can and do persist into science education; the derivation of resources and values they use to develop this sense of persistence are worth exploring. As such, it is important to glean the accurate function of families in the development of underrepresented scientists' persistence by examining the cultural and social values, norms and behaviors associated with these groups.

The Actual Role of Families of Underrepresented Groups in Science and Higher Education

Supporting, Encouraging and Offering Positive Feedback Relevant to Persistence

A large body of the empirical literature on the function of families of underrepresented scientists identifies family support as important to the persistence of these scientists in the academic pipeline (see e.g. Ratelle et al., 2005); however, the precise functions of support vary by culture. For example, some identify support broadly as encouragement (see e.g. Hanson, 2007), while others specify that encouragement to pursue whatever careers they choose and to be who they desire to be is important (Hanson, 2007). In a study of African American women in science, Hanson (2007) cites that the family supported many of these women by allowing them to develop in the ways that were consistent with whom they wanted to be in or outside of science. One interviewee in Hanson's study identified that this approach instilled a sense of independence in her that proved valuable for her persistence in science. The respondent explained that in the science world, she faced opposition and because of the value of independence that was instilled in her by her mother, she does not become too preoccupied with what others think of her (Hanson, 2012). Further, the survey respondents cited that positive feedback about science interests shaped who they wanted to be in science (Hanson, 2012). Coming to a related conclusion about the significance of family support, Cantu (2012) articulates how some Chicana scientists were encouraged to develop a sense of adventure (not necessarily related to science) that proved to motivate the scientists and give them a desire to learn. Because their families instilled a sense of wonder, curiosity and adventure, it allowed these women to progress in science.

Others identify support for the emotional benefits that it confers; for example, having a family member with whom to vent frustrations and challenges to allow for a tension release, while being able to receive love and encouragement helped progression through the graduate degree (Roberts and Plakhotnik, 2009). Encouragement, as detailed by those in this study, included general admonition to persist in spite of challenges, admonition to explore alternative explanations, and to not lose focus on the objective (Roberts and Plakhotnik, 2009). Similar types of encouragement support were also identified by Sweitzer (2008), who noted that general family support could be in the form of motivational speech, such as "Don't lose balance," "Do what makes you happy," "Be the best you can be," and "Don't forget about the importance of family."

Lastly, others identify *practical support and interest*; for example, ensuring a quiet place in which the scientist could complete homework, even though the parent was unable to help with homework because of disparities in education (Robb et al., 2007). Alternatively, showing apparent interest in the underrepresented scientist's work was found to be another source of practical support, even when the family was not familiar with the scientist's work (Holley and Gardner, 2012). Though informed by culture, the types of support demonstrated by families of underrepresented scientists do not operate to reinforce and reproduce cultural inequalities even though the support provided may not be related specifically to educational and science related values.

Providing Motivation to Overcome Imposed Cultural Barriers

In work from England on socioeconomically disadvantaged and immigrant students considering attending medical school, the authors found that these young scientists possessed a sense of civic duty to repay their family for the sacrifices afforded for the development of their education. Moreover, in the development of their scientific identity there is a strong desire to optimize the science degree's utility, as these scientists were motivated to overcome the labor-intensive and minimum wage positions of their family members (Robb et al., 2007). The authors note that a positive influence on these scientists was a meta-narrative defined by the desire to restore the social position of immigrant families in their country of origin. They were aware that the educational opportunities available to them had been denied to their parents and family in their home country and were determined to make the most of them (Robb et al., 2007). For the economically disadvantaged, the amount of sacrifices that they witnessed from their families served as a significant motivator to persist in the science pipeline. This motivation was derived by the lack of capital, but did not necessarily constrain their pursuit of capital. Moreover, although education was seen as a vehicle to financial security, the students were not pushed by their families but developed an "internalized academic ethos" as a function of necessity (Robb et al., 2007, p. 752). This academic ethos was driven by the sense of injustice and the desire to redress the injustices that relegated their families to the lowest social positions in society (Robb et al., 2007). In sum, the explicit function of the family to encourage the aspiration of science is not clear, but the implicit function was that of motivation.

For some first-generation scientists and those from lower socioeconomic backgrounds, the opportunity to be the first was both a positive and negative motivation (Holley and Gardner, 2012). Being among the first to accomplish a career in science was not only a source of pride for the scientist, but also for the family and community from which the scientist originated (Holley and Gardner, 2012). It motivated first-generation scientists to overcome odds and barriers, but in some instances simultaneously discouraged them as they experienced a cultural divide, separating them from their families (Holley and Gardner, 2012). Moreover, first-generation scientists feel a strong sense of not wanting to disappoint their families (Holley and Gardner, 2012), possibly contributing to pressures and anxieties. As first-generation scientists often come from family backgrounds with lower socioeconomic status, they see progressing in science as a potential to create a better lifestyle for themselves and their posterity, affording them more job security and autonomy (Holley and Gardner, 2012).

Asserting Cultural Values as a Priority Over Other Values

While the primary themes in the literature about the role of families in the development of underrepresented scientists are positive, there are cultural values that are seemingly orthogonal to science persistence for some populations. This potential antagonism is particularly highlighted in the literature pertaining to Hispanic women, where the family culture poses great opposition to the development of successful scientists (Espinoza, 2010; Leyva, 2011). Espinoza (2010) cites that the cultural value of *familismo* that establishes the strong identification with and attachment to the nuclear and extended family can also conflict with the school obligations for first-generation Latina students. However, these connections to family are important to the Latina students' ability to academically progress. Espinoza (2010) explores two roles that Latina graduate students employ to manage family expectations and obligations: integrators and separators. Integrators explicitly communicate with their families about the nature of their school demands and solicit support to enhance their academic persistence. Alternatively, separators actively avoid interrelation of their professional and personal lives. This minimizes tension and conflict and protects their family relationships. The author argues that both roles require a high level of biculturalism and the ability to juggle contradictions between their social worlds (Espinoza, 2010). Thus, the cultural value of familismo provides a source of support for integrators, but potentially a source of opposition for segregators.

Similarly, Leyva (2011) argues that obtaining a college degree shifted ethnic identity for some first-generation Latina graduate students, as their attempts to become a scientist were seen as oppositional to building financial assets for their families. Some of the Latina graduate students' families saw continued pursuit of degrees as an effort to get out of the real work associated with women and to help support the family (Leyva, 2011). Thus, on the one hand, the family can play a supportive role that is hopeful that the scientist will accomplish more but sometimes doubtful about the process, especially the length of time it takes to actualize success. Ong and colleagues (2011) provide a broader review of the literature, citing similar examples of families' opposition to the pursuit of science for women from Native American, African American and Asian American women.

Toward Empirical Investigation – Contextualizing Family Habitus for Underrepresented Scientists

The objective of this current manuscript is to develop constructs useful in future empirical analysis of underrepresented scientists' outcomes as they relate to familial and social experiences. As was demonstrated in the first chapter of this dissertation, and exemplified in the above sample of the literature, the family can play a valuable role in the development of scientists; however, these roles vary greatly by group. Additionally, the literature sample brings into focus that the structure of families may include more than the nuclear family accepted by the dominant culture for underrepresented groups. For example, as these groups are largely socially disadvantaged, they may rely on resources within a larger familial structure, not necessary for others. In short, empirical research on family habitus should not impose the values of the dominant culture by delineating the construction of the "correct" structure and process to transfer capital within a family, based on conceptions of how the family unit ought to be structured and the process of delivery within that structure.

Empirical quantitative investigation of mixed groups of underrepresented scientists necessitates the development of constructs that can explore their experiences in a cohesive manner. The author of this work, informed by the asset bundle theory, attempts to provide practical insight on the development of such a construct of family habitus. In this attempt, the author desires to explicitly state the intent to steer clear of reiterating tautologies, truisms and stereotypes. Thus, the author critically analyzed the literature and attempts to move beyond the *prima facie* evidence offered therein. Stated more clearly, the construction of the following family habitus that may be useful in future empirical analysis was developed to avoid misapplications of social capital theory that reinforce the following:

1. The tautological observation that initial capital disparities in various forms result in future capital disparities for underrepresented scientists.
2. The truism statement that underrepresented scientists have access to less capital and therefore face challenges in acquisition of future capital.
3. The stereotypical image that the families of underrepresented scientists do not cultivate identities that are consistent with desires to pursue higher education and / or aspire to science.

It is the author's expectation that the development of such constructs will provide a meaningful basis for the exploration of the family's function in the development of the successful underrepresented scientist that is disentangled from the pervasive issues in social capital theory espoused above. Furthermore, it is hoped that such development will help to diminish the prevailing cultural reproduction ideology that legitimizes the perpetuating of structural inequality in science education.

As outlined in the literature sample, there are at least three broad themes that detail the roles of families in the development of underrepresented scientists. Two of these seem to obviously relate to persistence in science, as the family provides a source of support, encouragement and positive feedback, and alternatively delineates an impetus to overcome challenges. The third theme, which is related to the second, seems to suggest that the family functions as oppositional to persistence in science. While the literature sample provided does not nearly reflect all the available literature on the family's role in the development of underrepresented scientists, it does provide a useful starting point for identifying emergent themes in the development of a family habitus suitable to explore the role of underrepresented scientists' families.

Construct One: Psychosocial Support and Practical Support

As there is a great potential for underrepresented minorities to face intense social identity contingencies in academic institutions (Murphy et al., 2007), and particularly in science (as evidenced by the exclusionary practices of each), psychosocial support from families may prove to be an invaluable function of underrepresented scientists. The literature points to a variety of needs for psychosocial support; for example, Hanson (2007) demonstrates that even though African American women feel less welcome in the sciences, some persist because of the support garnered from their families. Family support is even more necessary when, as Malone and Barabino (2007) demonstrate, "being the only one" develops feelings for minority scientists of isolation, marginalization, and invisibility at a research university. In their roles as confidants (Rogers 2006), families may provide a useful outlet to vent frustrations about the challenges within the academy. Alternatively, the families of underrepresented scientists can provide practical support simply by listening to underrepresented scientists talk about their research (Holley and Gardner, 2012). This has the potential to sharpen the scientist's presentation skills and offer them an opportunity to improve their scientific communication skills, because they will likely have to remove science jargon to talk to families without a science background. Sharon and Baram-Tsabari (2013) suggest that scientists use less jargon when communicating outside of their scientific peer group. As habitus is informed by the lower social positions underrepresented groups occupy, this construct examines resources embedded within the social experiences that provide a platform for families of underrepresented scientists to offer support. While the families of underrepresented scientists might not have the same experiences as the scientists, they likely have a sense of the feelings of isolation and marginalization that characterize the academic experiences for underrepresented scientists. This empathy has the potential to explain differences in emotional support structures and may help mitigate the sting of social identity contingencies in science education.

Construct Two: Cultural Experience and Expectation Mobility

The resources and values transferred from the families of underrepresented groups to scientists vary by culture but are also bound by a common theme: either explicitly or implicitly, the social position of the families of underrepresented scientists has the potential to frame scientists' perception about their ability, and at times necessity, to traverse the rifts in the academic science pipeline. By witnessing and experiencing the social dimensions affiliated with their group membership, those scientists that aspire to persist and those that actually persist commonly use experiences in their social context as motivation to defy odds against them within the greater social context (see e.g. Robb et al., 2007) or within a smaller cultural context (see e.g. Leyva, 2011). For first-generation students and students from low socioeconomic groups, the sacrifices made by their families (necessitated by their social position) were a motivation to persist in science. Some Latina graduate students informed by limited gendered expectations used this as motivation to persist in higher education in order to resist the bounds put on their potential by cultural expectations (Leyva, 2011). Although the context and cultures vary greatly, these two accounts are examples of how the motivation to attain an alternative social position to their family's position can serve as motivation for persistence, both in science and more broadly in higher education. Thus, social position can provide an unexpected source of motivation for scientists.

Conclusion

Studying the family's role in the development of underrepresented scientists is vital as it may help inform who they are, what they do and why. Approaching family habitus from the perspective that is solely related to capital valued by the dominant culture is wrongheaded and misguided because it only assesses values embedded within social relationships that are material to the dominant culture. The constructs of family habitus proposed above are *informed* by the social contexts in which scientists are socialized, but do not require value judgments by the dominant culture regarding the utility of those resources in the larger context. The essential argument put forth herein is not that families of minority scientists do not have a role in the development of usable social capital, but rather that understanding the assets of those who are not part of the dominant culture may prove invaluable for the development of research models to explore the social identities of underrepresented groups in the science setting.

The constructs also call into question whether development of capital as valued by the dominant society requires an initial endowment of capital from the dominant culture. As will be demonstrated in the next manuscript, there is not a clear causal link between the initial capital endowments and the production of equal opportunities for successful outcomes in the biomedical and health sciences. Although these factors may be correlated, much more exploration is needed to explore how assets of underrepresented scientists manifest in successful outcomes.

Rather than focus negatively on the challenges inherited from an underrepresented scientist's social position, it is more useful to identify how their social position may provide sources of motivation. It is not the expectation of this author, that simply because these challenges can serve as motivators that institutions should continue to perpetuate them. Rather, it is the expectation that by analytically exploring the function of social relationships important to successful underrepresented scientists, institutions can design structures to make use of these resources. Moreover, this requires that the dominant communities in academic institutions acknowledge the values embedded within social dimensions that they do not explicitly control. Put simply, the acknowledgement of alternative value systems than those of the dominant culture can diminish the intentional reproduction of cultural inequity. Lastly, studying habitus from the asset bundle perspective and how it positively informs the development of underrepresented scientists is fruitful for dismantling the threat of social identity contingencies. The educational literature and broader culture both often reiterate what is wrong or lacking in these groups, which reinforces hostility towards them in academic institutions. Deficit thinking does not improve the experiences of anyone; instead, exploration of areas in which to leverage potential may prove invaluable.

One great advantage of the asset bundle theory is that it encourages an institutional adjustment and response to redress inequitable outcomes in science. Rather than focusing on the perceived disadvantages and capital deficits, the asset bundle theory encourages institutions to structure environments suitable for the meaningful engagement of all scientists, not environments based on stereotypes or experiences contingent upon social identity (Johnson and Bozeman, 2012). As argued by Steele and Aronson (1995), stereotypes not only afflict those of less dominant groups, they also afflict those of the dominant group. Structuring organizations to be supportive of the development and advancement of underrepresented scientists does *not* require an assumption that all underrepresented groups have one-dimensional experiences. Instead, it requires institutions to consider the variety of experiences and cultivate values and assets institutionally that do not require underrepresented scientists to abandon their social ties in order to engage in the scientific culture.

CHAPTER 4 - ASSESSING THE CONVERSION OF SCIENCE CAPITAL INTO ECONOMIC CAPITAL FOR UNDERREPRESENTED SCIENTISTS[3]

[3] Johnson, J. to be submitted to *The Journal of Higher Education*

Abstract

To explore the use and development of science capital, this work uses asset bundle theory to underscore the need to better explore the institutional conditions in which underrepresented scientists develop. The paper empirically explores the correlation between endowments of science assets and the potential for economic outcomes, finding little correlation between the two for underrepresented scientists. The focus of this work, is to further contextualize how underrepresented scientists are able to convert capital into educational outcomes situated within academic institutions. By performing an empirical analysis on high achieving health and biomedical doctoral scientists this work will explore the following questions: *What science capitals are significant predictors of success for members of underrepresented groups, those members of minority and lower socioeconomic groups, in the sciences? Of the significant predictors of success for these scientists, how are these related to educational success and potential occupational outcomes for underrepresented scientists? What role does the institution or field play in educational success and potential occupational outcomes for underrepresented scientists?*

Introduction

"[Education] is in fact one of the most effective means or perpetuating the existing social patterns, as it both provides an apparent justification for social inequalities and gives recognition to the cultural heritage, that is, to a social gift treated as a natural one" (Bourdieu, 1974, p. 32; in Sullivan, 2001).

Bourdieu (1991) asserts that within the academy, scientific capital, though separate from social and economic capital, is inextricably linked to them. In a critique of Bourdieu, Sullivan (2001) argues that only through empirical investigation of which cultural attributes constitute capital can research clearly identify and define cultural capital: "the term cultural *capital* implies an analogy with economic capital, and therefore, a return. The return on cultural capital takes the form of educational credentials, and ultimately, occupational success" (p. 895). Sullivan's criticism of Bourdieu's early application of his theory provides a fruitful point of departure to empirically test if the cultivation of science capital among members of underrepresented groups has the same return as the cultivation of dominant groups in science. Research indicates that some social groups have differential access and ability to activate capital for educational attainment and career development (Israel and colleagues, 2001); thus, the primary objective of this work is to assess whether scientific exposures for underrepresented groups reflects capital and implies a return on investment.

Bourdieusian social capital theory is well positioned to examine the transformation of science capital into educational and occupational successes. While even its own developer has improperly operationalized it, the subsequent criticisms and development have sharpened the theory for proper application. This theory requires examination of three separate but interacting concepts that explain socially structured societies: habitus, capital and fields. As Bourdieu states,"[h]abitus is both a system of schemes of production of practices and a system of perception and appreciation of practices. And, in both of these dimensions, its operation expresses the social position in which it was elaborated. Consequently, habitus produces practices and representations which are available for classification" (Bourdieu, 1989, p. 19). In other words, habitus is created through social interactions that allow for classification of an individual's position within society relative to others.

The concepts of capital and field inform these classification processes. According to Bourdieu (1986), the relationships between various positions in society are determined by the distribution of *capital* (or resources). In a hierarchically organized society – such as in the United States, and particularly in academia – this capital is unevenly distributed, with certain groups possessing more and others less. Those groups with more capital possess, in Bourdieu's words, "legitimized" power, allowing them to determine and define the nature of the relationships between all groups. Therefore, those who possess capital in its variety of forms, including economic, social, and cultural, occupy a position of symbolic power in which they can establish and legislate the normative values of the social *fields*, or classes (Bourdieu, 1989). For Bourdieu, each field is structured with its own set of rules, normative values and guiding principles that structure the interactions of social groups within the field (Bourdieu, 1989).

In the first manuscript of this dissertation, the author of this work focused on habitus as it relates to the outcomes of scientists from underrepresented groups. The findings of that work suggest that habitus, when properly operationalized, can provide meaningful insight into educational attainment for underrepresented scholars. The focus of this work, however, is to further contextualize how underrepresented scientists are able to convert capital into educational outcomes situated within the academic institution *field*. Bourdieu (1986) argues that greater intrinsic sense of economic capital is connected to students' beliefs that they can succeed within the academic institution. Furthermore, without sufficient social capital, certain individuals can be denied entry into the dominant group's culture despite a significant amount of science capital (Bourdieu 1991). The present work will test this assertion. By performing an empirical analysis on high achieving health and biomedical doctoral scientists this work will explore the following questions: *What science capitals are significant predictors of success for members of underrepresented groups, those members of minority and lower socioeconomic groups, in the sciences? Of the significant predictors of success for these scientists, how are these related to educational success and potential occupational outcomes for underrepresented scientists? What role does the institution or field play in educational success and potential occupational outcomes for underrepresented scientists?* Answers to these questions will provide insight into how the science academic institution constrains success for underrepresented groups. The work concludes with policy recommendations.

Literature Review

Understanding the Field in which Underrepresented Scientists Develop

The doctoral institution is the primary *field* that can encourage or constrain an underrepresented scientist's ability to convert science capital into economic capital. As espoused by Bourdieu (1991), the *field* establishes the rules, organizes the relationships, and *defacto* structures the outcomes of certain social groups. The science education literature is replete with examples of how the academic institutions structure the field. As suggested by Gay (2004), there are processes that marginalize[4] minority doctoral scientists:

> [Graduate students of color] have to function in an alien and often-hostile environment, consistently encounter irrelevant curriculum, and frequently are taught by culturally insensitive and uncaring instructors. Most of their professors and mainstream peers assume that these students 'have it

[4] For Gay (2004), marginalization "deals with goodness-of-fit issues between the needs, interests and skills of students of color, and institutional priorities and protocols; cultural, racial, ethnic and social differences; prejudices and discrimination; lack of culturally relevant academic and social support systems; and maintaining one's ethnic identity and cultural integrity" (p. 267).

> made,' and can 'write their own tickets' in the job market. In fact, most graduate students of color exist on the periphery of the academy, and their career trajectories are not as unencumbered as many think. (p. 266)

Gay (2004) identifies that a large expense of existing in the periphery is often physical, intellectual and cultural isolation, which all have adverse effects on persistence in a doctoral program. Integration into the academic and social culture could prove more challenging for underrepresented students. As will be demonstrated by Tinto's 1993 model of doctoral persistence, persistence is as much about the interactions that students have in a department as it is about their academic ability. For example, research indicates that a lack of diversity in the viewpoints presented in STEM curriculum alienates underrepresented science students, as they perceive the curriculum to be irrelevant to their society (Anderson, 1990). Further, Haley and colleagues (forthcoming) suggest that minority students are likely to pursue research agendas that align with their cultural identity; thus, curriculum that fails to promote societal relevance further isolates these students. Lastly, in many departments and particularly in STEM, the working culture is one that encourages a highly competitive atmosphere; research shows that in these conditions minorities experience disproportionate attrition (Hurtado et al., 2009). Combined with the already established vulnerability to attrition facing all students, academically able minority students are potentially marginalized because their interests and needs are not neatly aligned with the departments in which they are expected to develop.

Moreover, earning a doctorate is a complex process: doctoral students are expected to progress through three entirely different stages: (1) transition and adjustment, (2) attaining candidacy and developing research competence, and (3) completing independent research/doctoral dissertation (Tinto, 1993). Arguably, each stage is characterized by different sets of rules, expectations, interactions and processes to which doctoral students must readily adapt. Tinto (1993) argues that several normative reference groups (e.g., the students, faculty and administration), the structural character of the specific field of study, and the judgments that describe acceptable performance, all influence program persistence and frame the community into which a student seeks to integrate. Tinto's theory about the development of doctoral level scientists provides a clear understanding of the *field* and the rules accompanying it. The progression through each phase is shaped by past experiences, and these experiences shape a doctoral scientist's expectations about future events; it is not a stagnant model, but each event instead informs the next and then shapes expectations and future experiences. Offered below is an examination of the rules of the *field* during each stage.

The transition stage, usually the first year of study, is shaped by formal and informal social interactions, as students have the task of establishing membership in the academic community. At this stage, minority doctoral students have to weigh the costs and benefits of involvement and consider how to assimilate into an academic community that may or may not reflect their own values and interests (Tinto, 1993). The first stage in the doctoral persistence model is characterized largely by the academic and social interactions that students have within the department and institution. At this stage, persistence is influenced by at least three things: 1) affiliations that minority students can successfully create within the department; 2) judgments these students make about the nature of the department (e.g., whether the departmental norms are consonant with the student's own); and 3) the student's perception of the relevance of institutional programs to career goals (Tinto, 1993). In this manner, persistence is heavily influenced by the "desirability of gaining membership and the likely costs and benefits of further involvement" (Tinto, 1993, p. 236).

The second stage, leading to doctoral candidacy, is defined by individuals' development of competencies and acquisition of knowledge necessary to competently and successfully conduct doctoral research. The critical concern at this stage is the recognition and judgment of individuals' competencies by peers and departmental faculty; thus, "interactions within the classroom and department/program pertaining to issues of academic competence are likely to play a central role in student persistence" (Tinto, 1993, p. 236). Interestingly, Ampaw and Jaegar (2011) conducted an event history analysis on the stages of doctoral program persistence and found that the main differences in persistence for non-minority and minority students occurred mainly at this stage. The authors suggested that at this stage, isolation, marginalization and poor interactions with faculty are particularly salient to attrition. This stage is particularly vulnerable to issues arising from social identity contingencies. As Tinto further explains, assessments of competence are conditioned by social judgments that peers and faculty have about minority students both inside and outside of the classroom. Institutions, and faculty within those institutions, must be very careful not to signal to students that they are being assessed by anything other than academic merit. If minority doctoral students perceive they are being judged by criteria, other than merit, over which they have no control, they may become vulnerable to attrition.

The final stage of doctoral persistence, or the time between gaining candidacy and completing the doctoral dissertation, reflects not only individual abilities but also the behaviors of individual faculty members, namely the mentors and dissertation advisor(s) that have considerable discretion over the completion of this stage and early occupational steps (Tinto, 1993). The final stage of doctoral persistence will be most influenced by the intense focus and commitment that is required to see the independent research through to completion. At this point the primary social interactions that doctoral students have are with their advisors and research committee. Because of this significance, experiences and interactions with this select group of individuals have large implications for a student's completion of the program. For some students, the role of external communities (e.g., familial considerations) also plays an important role in persistence. The commitments that students have to outside communities can compete for their time and make the difference between success and failure (Tinto, 1993).

In addition to students' faculty and personal relationships, access to material resources to conduct the research and maintain a minimal standard of living is of particular importance to persistence at this stage. Doctoral students who have to fund their own research may be particularly vulnerable to attrition because a) funding research can be extremely expensive and financially exhaustive, and b) finding funding either through applying for grants or through working takes away considerable time that could be devoted to research. Noticeably, the model of doctoral persistence speaks to the larger point that although these students are academically able, "the contextual conditions that shape the existential experiences of learning and living in academe" have huge implications on their persistence (Gay, 2004, p. 266).

Given the structure of the *field* as detailed by the Tinto Model for Doctoral Program Persistence, this work will examine the possibility for the conversion of science capital into economic capital. First, it explores which scientific exposures are important to attain successful entry into the doctoral program for underrepresented scientists. It then examines how these exposures predict the time it takes to transition through the doctoral program, as research shows that shorter times to complete doctoral science degrees are correlated with higher job satisfaction and better salary (Potvin and Tai 2012).

Research Design

Data and Sample Characteristics

As noted previously in this dissertation, the data used in this analysis were collected from a National Institute of Health study entitled "Using the Scientific CV to Study the Effects of Interventions on Research Careers." The target population for Gaughan's analysis was recipients of the Ruth L. Kirschstein National Research Service Award (F31) pre-doctoral fellowship between 1985 and 2012. This prestigious award is intended to help ensure and increase diversity among the talent pool of highly trained scientists in order to address the biomedical, behavioral and research needs of the nation (NIH 2014). Recipients of this award are therefore extremely well trained and academically able scientists.

Specific to this analysis, data were gathered regarding high school educational experiences reflect a variety of elements: the type of high school from which the respondent graduated, the types and quantity of courses completed in the course of study, and any participation in summer programs and extracurricular activities related to math and science. The scientists also responded to questions regarding their socio-demographic family characteristics and on their perceptions of the influence their family exercised on their education. The largest part of the survey gathered information on the educational training in science that respondents received during undergraduate and graduate programs. Among other things, these data reflect specific details about a wide range of experiences, including the number of research semesters in which scientists participated and the types and origin of financial resources used by respondents to pursue scientific training.

Measures Analyzing Successful Entry into the Doctoral Degree

Time To Begin the Doctorate

In different manuscripts in this dissertation, the author of this work demonstrates that the asset bundle theory, which focuses on the assets instead of deficits of underrepresented scientists, is a useful starting place for meaningful analysis of this population. The outcome in this analysis was constructed by computing the difference between the year respondents completed their bachelor's degree and when they began their doctoral training. This outcome was selected after a review of the sample revealed that unrepresented or underrepresented scientists were statistically more likely to take less time transitioning between the bachelor's and doctoral degree than majority scientists in this population. In this sample, minority scientists began their doctoral program within 3.5 years of completing a bachelor's degree, while nonminority scientists took on average 5.9 years; these differences were statistically different at the .001 confidence level. The outcome variable thereby provides the opportunity to access and examine success among minority scientists, rather than the more typically examined failure.

Science Exposures

The primary variables of interest in this analysis are scientific exposures along the academic pipeline. Respondents were asked a number of questions to indicate the types of science exposures they experienced as they developed as scientists. As proposed in the literature, the quantity (Burkam & Lee, 2003; Trusty, 2002) and rigor (Adelman, 2006; Horn & Kojaku, 2001; Trusty, 2002) of STEM courses during high school lead to better outcomes for minority scientists, as do hands-on laboratory experiences (Myers and Fouts, 1992). The literature also indicates that at the collegiate level, laboratory research experiences (Astin, 1999; Hathaway et al., 2002; Hunter et al., 2007; Merkel, 2001) and apprentice-style research or scientific internships (Lopatto, 2004, 2007; Russell et al., 2007; Seymour et al., 2004) are important to minority outcomes in science. As demonstrated, the literature espouses the many potential benefits of a wide variety of science exposures that lead to better outcomes for minority scientists. Thus, an essential objective in this analysis is to determine which of these types of variables is more important in predicting outcomes for minority scientists than others. Table 2.1 provides the summary statistics for the science exposures, the primary explanatory variables.

Table 2.1: Summary Statistics of Primary Explanatory Variables

	Mean	Std. Dev	Min	Max
High School Science Exposures				
Summer Math or Science Programs	0.21	0.41	0	1
Math or Science Extracurricular Activities	0.32	.047	0	1
Number of Advanced Science Courses	1.40	1.97	0	12
Undergraduate Science Exposures				
Semesters of Supervised Science Research	2.37	2.33	0	10
Number of Science Focused Internships	0.21	0.60	0	6
Participation in Targeted Interventions				
High School	0.05	0.21	0	1
Undergraduate	0.18	0.38	0	1

Bivariate analysis indicates that minority scientists in this population are statistically more likely to participate in summer math or science programs during high school; 34% of minority scientists participated in these programs as opposed to 16% of nonminority scientists. Minority scientists are also more likely at the collegiate level to participate in more semesters of supervised research and research internships compared to nonminorities. On average, minority scientists completed approximately three semesters of supervised research while nonminority scientists completed two. Lastly, 33% of minority scientists held science-focused internships, while only 17% of nonminority scientists held similar positions.

First-Generation Status

As with the paper discussing *habitus* in this dissertation, this analysis includes two variables that measure whether or not the respondents' parents attended college or earned a doctoral degree. These measures are utilized as a proxy for potential social capital held by the family that could be transferred to the scientist in order to help accelerate their progress from the bachelor's to doctoral degree. The first binary variable, College Generation Status, is assigned a one if the respondent is a member of the first generation to attend college; 17% of respondents were first-generation college attendants, and, significantly, minority respondents were statistically more likely to be first-generation college attendants: 22% of minority respondents versus 15% of nonminority respondents. The second variable, First Generation Doctorate, was constructed in a similar manner and is assigned a one if neither one of a respondent's parents earned a doctoral degree. Even if neither parent earned a doctorate, minority scientists in this sample were statistically more likely to earn a doctorate than nonminorities: 77% of minorities were the first doctors in their families, while 67% of nonminorities were.

Minority

In this analysis, “nonminorities” include those respondents who indicated their racial background as White or Asian. While Asian Americans are demographically a minority, they are not underrepresented in the sciences (NSF 2013). In fact, Asian Americans are consistently earning more mathematics, physical and biological science degrees in the last decade (NSF 2013). The group treated as “minority” in the present work reflects respondents who identified as Hispanic, Black or African American, American Indian or Alaskan Native, or Some Other Race. As previously noted, many of the respondents who identified their ethnic/racial background as “other” were also among underrepresented minority groups in the sciences.

Lower Socioeconomic Background

This is a binary variable reflecting if the respondent received the Federal Pell grant. The receipt of the Federal Pell Grant serves as a proxy for socioeconomic background.

Controls

As with other papers in this dissertation, the demographic and socioeconomic controls in this analysis include a binary gender variable, with women as the referent group. This variable serves as a proxy for three factors: socioeconomic status, parents’ highest level of education completed, and parents' literacy in English. The model also includes a binary control that reflects a one if the respondent indicated that their initial interest in science was instigated by someone in their family. This variable is included because it is possibly correlated to socioeconomic status, and thus serves as a proxy for economic capital. A variable is included to control for the time period during which the respondent decided to become a scientist, coded as one if the respondent made this decision before commencing the bachelor's degree. Other controls include a binary variable if the respondent earned a master's degree, and a variable regarding the disability status of respondents.

Measures Analyzing Conversion of Science Exposures into Potential Capital

Time to Completion of the Doctorate

Research shows that shorter times for doctoral students to complete their degrees are correlated with higher job satisfaction and better salary (Potvin and Tai, 2012). Thus, this variable will be used as a proxy for potential occupational successes. It was constructed by taking the difference between the year respondents began their doctoral training and the year they completed it and subsequently assigning a value of one if the completion event had occurred. At the time the survey was conducted, four individuals had yet to complete the doctoral degree and thus were censored at year 2013. Censoring these individuals at the time at which the survey was conducted allows their data to be used in the estimation of the model. Table 2.2 shows frequency of the time to completion used to construct the outcome variable.

Table 2.2: Frequency of the Outcome Variable – Time to Complete Doctoral Degree in Years

Time to PhD	Frequency	Percent
2	3	0.62
3	27	5.58
4	70	14.46
5	152	31.40
6	122	25.21
7	60	12.40
8	35	7.23
9	13	2.69
10	2	0.41
Total	484	100.00

Science Capital

The significant variables from the first analysis that were assets for underrepresented groups to quickly transition into the doctoral program will be included in this analysis. The explanatory power of these variables will determine if the assets of the underrepresented scientist are useful for potential occupational outcomes and thus are in effect capital, with a return on investment.

Value Concordant Mentoring

It has been argued that doctoral students build positive social capital through mentoring, among other activities (Johnson and Bozeman, 2012). The social capital available to students through mentoring relationships may prove a significant factor influencing the time it takes a doctoral candidate to progress through the academic pipeline. The mentor, often the dissertation advisor, can help orient the doctoral student with the *rules* of the academic institution, helping them navigate the process of gaining membership into the academic culture of the social field. Weidman and Stein (2003) suggest that when the nature of the mentoring relationship is supportive of the doctoral student, it helps prepare them for the roles deemed suitable by the *field*, which are in most cases academic or scholarly occupations. Johnson and Bozeman (2012) review literature on race disconcordant mentoring relationships, citing that when the mentor is of the dominant group and the protégé is of the minority group it has a positive influence on occupational outcomes. However, this argument reinforces that dominant groups – represented in this case by the mentor – can leverage the various forms of capital for better outcomes than are usually available to members of minority groups; it does not address the underlying problem of imbalanced power.

The author of this work instead measures *value concordant mentoring*, defined by significant alignment in work, career, and professional expectations between both the mentor and protégé. As defined by Bozeman and Feeney (2007), mentoring is a process for the informal transmission of knowledge, social capital, and psychosocial support perceived by the recipient as *relevant* to work, career, or professional development. Thus, *value concordant mentoring* can provide useful information about the social interactions of doctoral candidates with their mentors and the support they did (or did not) receive in preparation for occupations. This will serve as a proxy for the presence of social capital necessary to convert science exposures into science capital.

The mentor congruence variable was constructed by examining the match between the respondent and the respondent's dissertation advisor on occupational expectations. Respondents were asked, "As you were finishing your doctoral degree, what was your preferred career choice?" Response options included: A position in industry, a position in government, a postdoctoral position, a non-tenure-track academic position, a tenure-track faculty position in a research intensive environment, or a tenure-track faculty position in a teaching intensive environment. The respondents were then asked to indicate which position their advisors advised them to seek. Table 2.3 shows the distribution of responses for the scientists and their advisors. The value concordant measure is a binary variable that represents if the respondent's career expectation was on par with the mentor's advice, and this variable will serve as a proxy for support within the institution. On average, there was a statistical difference between value concordance between minority scientists and their advisors, versus nonminority scientists and their advisors.

Table 2.3: Respondent Career Preferences and Dissertation Advisor's Career Advice

	Respondent Preference	Dissertation Advise
A position in industry	7%	3%
A position in government	2%	2%
A postdoctoral position	33%	45%
A non-tenure-track academic position	4%	3%
A tenure-track faculty position in a research intensive environment	37%	38%
A tenure-track faculty position in a teaching intensive environment	9%	5%
Other	8%	3%

In this population, 68% of nonminorities were congruent with their advisor in their occupational preferences, while only 49% of minority respondents were. These statistics demonstrate that the minority respondents were much less supported in their aspirations beyond the doctorate. There was no statistical difference between respondents from lower socioeconomic backgrounds compared to those of higher backgrounds.

Controls

The demographic and socioeconomic controls in this analysis include a binary gender variable, with women as the referent group, as a proxy for socioeconomic status and parents' highest level of education completed. The model also includes a binary control reflecting a one if the respondent cited a family member as instrumental in prompting their initial interest in science. Other controls include the disability status of respondents and the discipline in which the doctoral degree was awarded, as the social structure among disciplines substantially varies; the referent discipline is social science. A proxy for the scientists' intrinsic motivation is also included in the analysis. The categorical variable, "Scientific Intent," represents the age and corresponding level of school in which the respondent decided he or she wanted to become a scientist. The categories are as follows: preschool (corresponding to ages 2 through 4); elementary school (corresponding to ages between 5 and 10); middle school (corresponding to ages 11 through 13); high school (corresponding to ages 14 through 17); undergraduate school (corresponding to ages 18 through 21); graduate school (corresponding to ages 22 through 25); and nontraditional graduate school (corresponding to ages over 25). Bivariate analysis demonstrates that minority scientists in this population were more likely to decide at a younger age (16 years) that they wanted to become scientists, while nonminority scientists in this population decided at about 19 years of age. Thus, minority scientists decided during high school, while nonminority scientists decided during college.

This information is valuable because the early decision to pursue a science career could potentially afford the sciences more resources to use in progressing through the scientific pipeline. In the literature review of the Tinto theoretical model, it was argued that access to material resources to fund the doctoral research was important to completion of the final stage. While this is important and should be considered in other analyses, the nature of this sample population does not require this control as the respondents in this sample received the NRSA.

Research Methods

The essential objective of this research is to determine what affect the *field* has on the capacity for underrepresented groups to convert science exposures into science capital. To achieve this objective, first an analysis must be performed to decipher the science assets important to successful matriculation into the doctorate for underrepresented groups. By identifying these significant resources, the author proposes that these measures are empirically important to this population. Next, an analysis will examine the conversion of the science assets into potential capital by examining the time it takes underrepresented groups to complete the doctorate. The author hypothesizes that after controlling for a variety of factors that might influence the completion of the doctorate, if the science exposures variables have no effect on completion, then there is some unobservable institutional effect constraining the conversion of resources into capital.

Both outcomes will be modeled using survival analysis, which analyzes the time to the occurrence of an event measured by the hazard function, which is the event rate or the probability of having an event at time t, given that the event has not occurred before t (Cleves et al., 2008).

Research Findings

Measures Analyzing Successful Entry into the Doctoral Degree

Analysis on the full population demonstrates that the risk of moving quickly into a doctoral program after completing the bachelor's degree is increased for males (1.21, α=0.05), respondents with more highly educated mothers (1.08, α=0.05), those who participated in high school summer programs in math or science (1.28, α=0.05), and those with more undergraduate semesters of supervised science research (1.19, α=0.01).

To determine if these variables were important science exposures for minorities, an interaction model was developed that looked specifically at minority science capital exposures. The variables that increased the risk of moving quickly into the doctoral program were slightly different. Minorities had a higher hazard of transitioning into the doctoral degree compared to nonminoirites (2.23, α=0.05) Participation in a high school math or science summer program (1.01 α= 0.05), participation in undergraduate research (1.13 α=0.10) or a targeted intervention to increase racial and ethnic minorities (1.30, α=0.10) during the respondents' undergraduate program all increased the risk of moving quickly into the program. Interestingly underrepresented scientists that participated in a summer internship did not transition as quickly into the doctorate (0.93= 3.50, α= 0.05). A similar analysis was run on lower socioeconomic groups but results were inconclusive. The results of these models are shown in Table 2.4 below.

Table 2.4 Hazard Ratios and Robust Standard Errors of the Time to Begin the Doctoral Degree

	Full Model	**Interactive Model**
Underrepresented Minority	**1.191**	**2.233****
	(0.139)	(0.730)
Male	**1.210****	**1.165**
	(0.108)	(0.132)
Lower Socioeconomic Background	**1.110**	**1.103**
	(0.106)	(0.102)
Minority Male		**1.110**
		(0.192)
Scientific Aspiration Before Entering the Bachelor's	**1.058**	**1.055**
	(0.103)	(0.101)
Disability Status	**0.808**	**0.801**
	(0.173)	(0.173)
Mother's Education	**1.079****	**1.107****
	(0.035)	(0.044)
Minority Mother's Education		**0.947**
		(0.045)
Father's Education	**1.042**	**1.038**
	(0.035)	(0.036)
First Generation Doctor	**1.083**	**1.092**
	(0.147)	(0.147)
Family Member Influenced Initial Science Aspiration	**1.082**	**1.085**
	(0.109)	(0.113)
Number of Advanced High School Science Courses	**0.978**	**0.985**
	(0.033)	(0.039)
Minority Number of Advanced High School Science Courses		**0.976**
		(0.051)
Participation in Math or Science High School Summer Program	**1.277****	**1.509****
	(0.135)	(0.207)
Minority Participation in Math or Science High School Summer Program		**0.672****
		(0.132)
Participation in High School Math or Science Extracurricular Programs	**1.066**	**1.066**
	(0.132)	(0.132)
Minority Participation in High School Math or Science Extracurricular Programs		**0.994**
		(0.189)
Participation in a Targeted Program in High School to Increase Minorities in Science	**0.771**	**0.885**
	(0.128)	(0.140)
Number of Undergraduate Semesters of Supervised Science Research	**1.189****	**1.197*****
	(0.023)	(0.028)
Minority Number of Undergraduate Semesters of Supervised Science Research		**0.943**
		(0.034)
Participation in an Undergraduate Science-Focused Internship	**1.021**	**1.206****

	(0.061)	(0.110)
Minority Participation in an Undergraduate Science-Focused Internship		**0.768****
Participation in a Targeted Program in Undergrad to Increase Minorities in Science	**1.175**	**1.302***
	(0.145)	(0.182)
Master's Degree	**0.356**	**0.375*****
	(0.042)	(0.055)
Minority Master's Degree		**0.826**
		(0.173)
Observations	474	453
* p<0.10 ** p<0.05 *** p<0.01 Reporting Hazard Ratios and Robust Standard Errors		

Analyzing Conversions of Science Exposures into Potential Capital

The Cox Proportional Hazard model was used to determine if the science exposures that were developed early in respondents' science careers were correlated to potential occupational outcomes. The outcome of interest was the time it takes an individual to complete the doctoral training, as this is significantly related to the amount an individual potentially would earn (Potvin and Tai, 2012). Those that participated in a targeted intervention to increase racial and ethnic minorities (0.65, α=0.01) during the respondents' undergraduate program were negatively correlated with progressing through the doctoral program. This finding certainly requires further investigation as it was highly correlated with successful matriculation into the doctorate but negatively correlated with progression through the doctorate. Although insignificant, other science exposures associated with swift matriculation into the doctorate failed to be correlated with successful matriculation through the doctorate. Also, compared to women in the sample, men took longer to progress through the doctorate (0.86, α=0.05). The results of this analysis are shown in Table 2.5 below.

Table 2.5 Hazard Ratios and Robust Standard Errors of the Time to Complete the Doctoral Degree

Underrepresented Minority	**0.866**
	(0.117)
Male	**0.851****
	(0.071)
Lower Socioeconomic Background	**1.104**
	(0.101)
Scientific Aspiration Before Entering the Bachelor's	**0.987**
	(0.027)
Disability Status	**0.622*****
	(0.116)
Mother's Education	**1.033**
	(0.029)
Father's Education	**1.012**
	(0.033)
First Generation College Attendant	**1.095**
	(0.166)
First Generation Doctor	**0.954**
	(0.119)
Family Member Influenced Initial Science Aspiration	**0.986**
	(0.088)
Number of Advanced High School Science Courses	**0.991**
	(0.019)
Participation in Math or Science High School Summer Program	**0.876**
	(0.110)
Minority Participation in Math or Science High School Summer Program	**1.057**
	(0.198)
Number of Undergraduate Semesters of Supervised Science Research	**0.999**
	(0.026)
Minority Number of Undergraduate Semesters of Supervised Science Research	**1.011**
	(0.041)
Participation in an Undergraduate Science-Focused Internship	**1.064**
	(0.096)
Minority Participation in an Undergraduate Science-Focused Internship	**1.221**
	(0.183)
Participation in a Targeted Program in Undergrad to Increase Minorities in Science	**0.652*****
	(0.085)
Mentor Congruency	**0.910**
	(0.073)
Clinical Sciences	**0.947**
	(0.173)
Biomedical Sciences	**0.821**
	(0.151)
Engineering Sciences	**1.151**
	(0.274)
Observations	444
* p<0.10 ** p<0.05 *** p<0.01 Reporting Hazard Ratios and Robust Standard Errors	

Multivariate analysis of variance (MANOVA) was used to test the significance of group differences between minorities and nonminorities on the time it takes to matriculate into the doctorate and the time it takes to complete the doctorate. In short, the analysis was used to determine if minority status affected both time to begin the doctorate and time to complete the doctorate, controlling for correlations between the two outcomes. Initial results from the analysis demonstrate a significantly different experience on both outcomes for minority scientists compared to nonminority scientists. The adjusted predicted value for entry into the doctorate was lower for minorities (margin = 3.50, α= 0.01) and higher for nonminority scientists (margin = 5.88, α= 0.01), while adjusted predicted values for progression through the doctorate were higher for minorities (margin = 5.94, α= 0.01) and lower for nonminorities (margin = 5.42 α= 0.01). The difference of means was calculated for the entry into the doctorate (difference = -2.37 α= 0.01) and progression through the doctorate (difference = 0.52, α= 0.01) indicating that both were statistically different between the groups. Thus in this sample, minority status was correlated with both quicker entry into the doctorate and slower progression through the doctorate.

Discussion

The results of the analyses require further exploration. The first analysis on the full population demonstrates that participation in high school summer math or science programs is positively associated with quicker matriculation into a doctorate, suggesting that these science exposures in some ways support the progression of scientists through the pipeline. Moreover, the second analysis suggests that high school summer math or science programs, participation in undergraduate research and participation in an undergraduate targeted intervention to increase underrepresented groups in science all were important and useful for getting underrepresented scientists into doctoral programs. In sum, these programs appear to be working as expected, they seemingly are orienting and priming underrepresented scientists for advancing through the science pipeline. Alternatively, minority participation in a science-focused internship is negatively associated with matriculating quickly into the doctorate. It is possible that this experience oriented minority scientists to careers outside of the academy for which a doctorate was not necessary.

When these significant science exposures were used to analyze matriculation through the doctorate, only participation in a targeted intervention was correlated with the outcome of interest. This finding is alarming and may partially suggest that the programs that prepared underrepresented scientists for matriculation into the doctorate, failed to prepare them for experiences in the pursuit of the doctorate. Alternatively, it is plausible that scientists advancing through the scientific pipeline on their own volition and without targeted interventions may be better prepared to progress through the doctorate than those who do participate in such interventions. Thus, specific information regarding the design of the targeted interventions is necessary to sufficiently interpret this result. Finally, the other science exposures that seemingly were important to initiate the pursuit of the doctorate failed to be important with the rate of obtaining the doctorate.

Conclusion

The author notes the limitations of these analyses, as it is very difficult to illustrate the potential conversion of capital with a retrospective study albeit a longitudinal one. Further, the author acknowledges the potential selection effects and recall biases associated with the implementation of the survey design, thus these findings should not be used to make inferences about the general population of scientists. However, these findings point to interesting future research questions and policy implications regarding the development and transitions of underrepresented scientists through the scientific pipeline and beyond.

First, the MANOVA analysis uncovers an important policy implication concerning the matriculation of underrepresented talent through the scientific academic pipeline and into potential career outcomes. The results of the analysis reveal a negative correlation between swift matriculation into the doctorate and slower progression through the doctorate, both of which are significantly correlated with being a minority scientist. For that reason, while there seemingly is great policy desire to quickly cultivate talented underrepresented doctoral scientists, this desire must be responsive to the need to provide continuity in support for completion of the doctorate on par with underrepresented scientists' academic peers so that they have similar career and economic opportunities, lest underutilization of underrepresented talent remain unresolved. As Potvin and Tai (2012) demonstrate, shorter completion times are correlated with higher job satisfaction and better salary. Related, Bozeman and Gaughan (2011) find that STEM faculty working at research-intensive universities are more satisfied with their jobs when they perceive that they are paid what they are worth. Further, minority faculty temptations to leave academic medicine are correlated with lower salary satisfaction and overall job satisfaction (Chisholm-Burns et al., 2012). In sum, remedying the potential for differential economic capital outcomes succeeding the doctorate is critical to the policy goal of cultivating scientific talent to address the nation's most pressing concerns. To develop underrepresented scientific talent, only to have those scientists dissatisfied and potentially leave their professions does not resolve the underutilization of scientific talent. In short, it is insufficient to support entry into the doctorate without adequate support to maintain momentum through the program and beyond.

Second, the findings of all three analyses suggests a need to better design targeted interventions such that they possess both the ability to recruit minority scientists into the doctoral program, as well as, the ability to promote their advancement on par with their peers through the program. Specifically, the finding that participation in undergraduate targeted inventions was positively correlated with swifter matriculation into the doctorate, but negatively correlated with swifter progression to complete the doctorate, call into question the nature and design of these interventions. The findings suggest that these intervention programs may be short sighted and fail to fully consider the long-term investment necessary to advance underrepresented scientists through the pipeline. Initial recruitment into the doctorate ought to be coupled with sustained investment during the doctorate for underrepresented scientists.

Third, given the finding that matriculation into the doctorate was slower for underrepresented scientists that participated in a science focused undergraduate research internship, it seems likely that the possibility for other experiences might be important in the decision to begin the doctorate. These minorities ultimately matriculated into the doctorate but took additional time possibly to mature professionally and personally and possibly were better equipped to pursue the doctorate. Although insignificant, their hazard of completing the doctorate was 1.29. Thus, perhaps quick matriculation from the bachelors to the doctorate is not a necessary requisite to the successful cultivation of talented underrepresented scientists. This finding, serves as a caution to policy interventionists that attempting to swiftly push talented minority scientists through the academic pipeline may limit their preparation to persist in the doctorate.

Lastly, the finding that increased science exposures were important for quicker matriculation into the doctorate for minorities, but were not important for quicker matriculation through the doctorate, suggests the need for more research on what constrains the ability to convert these resources into potential capital. Specifically, future research should address: What occurs during the doctoral program that slows the progression of and advancement of underrepresented scientists in the academic pipeline? If these scientists were seemingly on a fast trajectory, what caused them to slow down? Bancroft (2013) argues that capital is temporal and must be accumulated over time. If this is plausible, then one could expect the underrepresented scientists to continue accumulating capital that would be useful in progression through the doctorate. The final analysis is limited in that it does not include accumulation of additional science exposures that may be correlated with matriculation through the doctorate. However, it is theorized that even with those additional measures the findings would be similar. The author concludes that these findings partially support the hypothesis that the *field* in which underrepresented scientists develop constrain their advancement and success even in the presence of potential sources of social and science capital.

The first goal of this analysis was to determine which scientific exposures mattered in the development of scientific capital for underrepresented groups. This analysis provides some evidence that at the undergraduate level, participation in science-focused internships is important for the successful outcomes of underrepresented scientists. Additionally, participation in summer math or science programs in high school is important for entry into the doctorate program. Internships provide students with an opportunity to be socialized into the world of science. As such, it can be argued that minority scientists participating in these opportunities are provided with some skill set and socialization process that might help propel them forward in the scientific pipeline.

However, the second objective was to determine how underrepresented scientists, situated in the science academic *field*, convert resources into capital. It is important to note that the underrepresented minorities in this population were academically able and "outperformed" others in matriculating into the doctoral program. Even when controlling for earning a master's degree, these scientists in a sense had more advantages than those in dominant groups, but seemingly those advantages stopped there. The question still remains: Is there something about the institution that converts high-performing minority scientists into less highly performing scientists? This is a question that this author will continue attempting to answer.

.

CHAPTER 5 – CONCLUSIONS AND IMPLICATIONS FOR POLICY AND FUTURE RESEARCH

The predominant findings from this dissertation highlight that talented underrepresented doctoral scientists potentially have unique structures of social assets and exposures to science assets that provide useful information about how they navigate and persist in the scientific pipeline. An implicit argument throughout is that the failure of science education institutions to acknowledge the advantages and assets held by underrepresented scientists reinforces the cultural reproduction of inequity in science outcomes. Policies and procedures crafted from this deficit perspective are negatively biased against encouraging the success of underrepresented scientists.

> Evidence suggests that academic scientists express 'implicit' biases, which reflect widespread cultural stereotypes emphasizing white men's scientific competence. Although likely unintentional, implicit biases undermine skilled female and minority scientists, prevent full access to talent, and distort the meritocratic nature of academic science. To address these issues, the science community should adopt diversity interventions that reduce both implicit and explicit biases and require empirical evidence that such interventions are effective (Moss-Racusin et al., 2014, p. 615).

To address the implicit and explicit biases that undermine skilled underrepresented scientists and prevent their full participation in the science pipeline, an individual, institutional and discipline specific research and policy approach is required that assesses and encourages open discussion about the social and science capital of underrepresented scientists. As detailed in the 2008 summary of the National Academy of Science's annual conference, Understanding Interventions That Encourage Minorities to Pursue Research Careers, policy interventions can become unfocused when they broadly try to address diversity rather than specifically and individually examining the experiences of members of underrepresented groups (Depass and Chubin, 2008). Further, it is detailed that while the norm is to avoid talking about ethnicity entirely in predominantly white departments, this norm needs redress (Depass and Chubin, 2008). As ethnicity informs the experiences of underrepresented scientists, ignoring it entirely undervalues the assets conferred by it. "Cultural influences can have a powerful effect on educational outcomes. Researchers thus need to look at the institutional environment and at organizational cultures in assessing the factors that affect student achievement. Students need cultural capital- the cumulative background, skills, attitudes, and confidence- to succeed educational" (Depass and Chubin, 2008, p. 53). This cumulative experience for each underrepresented scientist should be taken as a whole and policy interventions developed should address aspects of his or her background where feasible. In sum, this work discourages a one size fits all intervention model that does not fully assess the social and science capital relevant to each scientist.

The objective of this dissertation was to explore the development strategies for successful underrepresented scientists with a specific focus on their acquisition and use of social capital and science capital. As argued within, the ability to convert resources into capital poses various challenges for successful underrepresented scientists, not because of their own failures, but because of failures of the academic and specifically the science academic institutions. Exploring the experiences of successful scientists, as evidenced by their receipt of one of the most prestigious national doctoral research awards, provides a useful platform to unearth how these scientists developed and progressed. Particularly, it provides information about the development of underrepresented scientists in spite of the challenges and oppositions they potentially faced in response to their race or socioeconomic status. All three manuscripts argue a similar point; science education does not have to be an institution defined by cultural reproduction of inequality.

The first manuscript's critique of social theory application in science education literature identifies that through research on underrepresented groups, those contributing to understanding the development of successful underrepresented scientists have produced tautologies that are less helpful in moving the conversation forward. The reiteration of the idea that underrepresented groups possess less capital and therefore have inequitable outcomes related to capital, certainly provides a research foundation, but the current state of affairs requires a paradigmatic shift in the exploration of capital. The current research paradigm imposes normative values defined by the dominant culture as necessary requisites for the scientific success of underrepresented groups. For example, the authors of these works legitimize structured inequality in science education, and in some ways perpetuate the status quo by assuming that the practices, norms, attitudes, values and dispositions transferred from the families of underrepresented scientists result in differential science outcomes because they do not duplicate the values that reinforce the privilege of the dominant culture. Within this paradigm it is assumed that the cultural experiences and identities of underrepresented groups are irrelevant to their outcomes, an assumption that clearly is flawed.

Thus, the task of the second manuscript was to identify the ways in which the paradigm could be shifted, by focusing on the positive ways in which the cultural experience and identity of underrepresented groups are relevant to their success. As social capital theory in its many forms identifies: each individual is informed by their social position in society. This assertion is logical and unavoidable, however, dismissing what can be learned from the occupation of these lower social positions essentially attempts to confine individuals to those lower positions. Suggesting that the inequities in outcomes are intentional and that discourse surrounding removing structural barriers is rhetoric; it is doubtful that this is the case. However, well-intentioned research is not superior to prudent research. As social positions inform the experiences of underrepresented scientists, it is indecent to ignore how those experiences constructively work to inform the outcomes of these groups. In short the second manuscript implores the use of asset thinking to explore the ways in which underrepresented scientists develop in spite of the structural deficits they encounter.

The exploration of institutional deficits is the goal of the final manuscript. The paper seeks to empirically find a correlation between initial assets and future outcomes. The work explores how initial endowments of science assets are converted to successful outcomes. Given assumptions of social capital theory and evidence in the science education literature, it is expected that underrepresented scientists with a reasonable amount of science capital will be able to convert this capital into economic capital on par with others. However, the last manuscript fails to confirm that expectation. In fact, the work finds that successful underrepresented scientists that outperformed other scientists in initial progression from the bachelors to the doctorate were unable to maintain this outperformance for completing the doctorate. Thus, the work begs the question: What experiences during the doctorate caused them to change pace? Future exploration of this question is necessary to determine how science education institutions may constrain the successes and performance of underrepresented scientists. In sum, the three manuscripts highlight the need to further explore the institutional design flaws that make the scientific pipeline as permeable as it is during the doctoral experience, the author proposes the use of the asset bundle model as it encourages a focus on the advantages of underrepresented scientists.

REFERENCES

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.

Adelman, C. (2006). The toolbox revisited: Paths to degree completion from high school through college. Washington, DC: U. S. Department of Education.

Alvarez, C., Edwards, D., & Harris, B. (2010). STEM Specialty Programs: A Pathway for Under-Represented Students into STEM Fields. *NCSSSMST Journal*, *16*(1), 27-29.

American Council on Education. (2006). Increasing the Success of Minority Students in Science and Technology. Washington, D.C.: American Council on Education.

Ampaw, F. D., & Jaeger, A. J. (2012). Completing the Three Stages of Doctoral Education: An Event History Analysis. *Research in Higher Education, 53*(6), 640-660.

Anderson, B. (1990). Minorities and mathematics: The new frontier and challenge of the nineties. Journal of Negro Education, 59(3), 260–272. Retrieved from http://www.jstor.org/stable/2295562.

Anderson J. (2008). Driving Change Through Diversity And Globalization: Transformative Leadership In The Academy. Sterling, Va.: Stylus Pub.

Andrade, E. J. (2007). Latino college students: A study of collaboration and community building in a math first year experience. Doctoral dissertation. Retrieved from ProQuest Dissertations and Theses database, Publication No. 304771202.

Andres, L., & Krahn, H. (1999). Youth pathways in articulated postsecondary systems: Enrolment and completion patterns of urban young women and men. Canadian Journal of Higher Education, 29(1), 47–82.

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.

Astin, A. W. (1993). What matters in college? Four critical years revisited. Jossey-Bass.

Bancroft, S. (2013). Capital, Kinship, & White Privilege. *Multicultural Education, 20*(2), 10-16.

Bellisari, A. (1991). Cultural influences on the science career choices of women. Ohio Journal of Science, 91(3), 129–133.

Blickenstaff, J.C. (2005). Women and science careers: Leaky pipeline or gender filter? Gender and Education, 17(4), 369–386.

Bourdieu, P. (1984). Distinction. A social critique of the judgement of taste (R. Nice, Trans.). Cambridge, MA: Harvard University Press. (Original work published 1979)

Bourdieu, P (1986) The Forms of Capital. In J. G. Richardson (ed.), Handbook of Theory and Research for the Sociology of Education. Westport, Conn.: Greenwood Press.

Bourdieu, P (1987) What Makes a Social Class? On the Theoretical and Practical Existence ofGroups.Berkeley Journal of Sociology. 32(1), 1–17.

Bourdieu, P. (1989). Social Space and Symbolic Power. Sociological Theory, 7(1), 14-25.

Bourdieu, P., & Passeron, J. (1990). Reproduction in education, society, and culture / Pierre Bourdieu and Jean-Claude Passeron ; translated from the French by Richard Nice ; with a foreword by Tom Bottomore. London ; Newbury Park, Calif. : Sage in association with Theory, Culture & Society, Dept. of Administrative and Social Studies, Teesside Polytechnic, 1990.

Bourdieu, P. (1991). Language and symbolic power. Harvard University Press.

Bourdieu, P. (2000). Pascalian meditations (R. Nice, Trans.). Stanford, CA: Stanford University Press. (Original work published 1997)

Bourdieu, P. (2001). Masculine domination (R. Nice, Trans.). Stanford, CA: Stanford University Press. (Original work published 1998)

Bozeman B, Dietz J, Gaughan M. Scientific and technical human capital: An alternative model for research evaluation. International Journal of Technology Management. 2001;22(7/8):716.

Bozeman, B. & Feeney, M. (2007). Toward a Useful Theory of Mentoring A Conceptual Analysis and Critique. Administration & Society, 39(6), 719-739.

Bozeman, B., & Gaughan, M. (2011). Job Satisfaction among University Faculty: Individual, Work, and Institutional Determinants. The Journal of Higher Education(2), 154.

Brazziel, M. E., & Brazziel, W. F. (2001). Factors in decisions of underrepresented minorities to forego science and engineering doctoral study: A pilot study. Journal of Science Education and Technology, 10(3), 273-281.

Brown, S. V. (2000). The preparation of minorities for academic careers in science and engineering: How well are we doing? In G. Campbell, R. Denes, & C. Morrison (Eds.), Access denied: Race, ethnicity, and the scientific enterprise (pp. 239–269). New York: Oxford University Press.

Brown, S. W. (2000). Female and male Hispanic students majoring in science or engineering: Their stories describing their educational journeys. Doctoral dissertation. Retrieved from Pro- Quest Dissertations and Theses database, Publication No. 304615391.

Brown, L., & Watson, P. (2010). Understanding the Experiences of Female Doctoral Students. *Journal of Further and Higher Education*, *34*(3), 385-404.

Burkam, D. T., & Lee, V. E. (2003). Mathematics, foreign language, and science coursetaking and the NELS:88 transcript data (NCES 2003-01). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Cantú, N. (2012). Getting There Cuando No Hay Camino (When There Is No Path): Paths to Discovery Testimonios by Chicanas in STEM. Equity & Excellence in Education, 45(3), 472-487.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of success-ful women of color: Science identity as an analytic lens. Journal of Research in Science Teaching, 44(8), 1011–1245.

Carnegie Foundation for the Advancement of Teaching (2014). Institution Lookup. Available at http://classifications.carnegiefoundation.org/lookup_listings/institution.php

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

Chisholm-Burns, M. A., Spivey, C. A., Billheimer, D., Schlesselman, L. S., Flowers, S. K., Hammer, D., . . . Vaillancourt, A. M. (2012). Multi-institutional study of women and underrepresented minority faculty members in academic pharmacy. *American Journal Of Pharmaceutical Education, 76*(1), 7-7. doi: 10.5688/ajpe7617

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

Cleff, T. (2011). Exploratory Data Analysis in Business and Economics: An Introduction Using SPSS, Stata, and Excel. New York: Springer 2011.

Cleaves, A. (2005). The formation of science choices in secondary school. International Journal of Science Education, 27(4), 471–486.

Cleves, M., Gould, W., & Gutierrez, R. (2008). An introduction to survival analysis using Stata. Stata Press.

Coleman, J. S. (1993). The rational reconstruction of society: 1992 presidential address. American sociological review, 1-15.

Coleman, J. S. (1988). Social Capital in the Creation of Human Capital. The American Journal Of Sociology, (1), doi:10.2307/2780243

Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline (COSEPUP). Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. Washington, D.C.: The National Academies Press; 2007. http://www.nap.edu/catalog.php?record_id=11463#orgs. Accessed July 23, 2012.

DePass, A.L., & Chubin, D. E. eds (2008). Building a Community of Research and Practice. Understanding Interventions That Encourage Minorities to Pursue Research Careers: American Society of Cell Biology, Atlanta Georgia.

Dika, S. L., & Singh, K. (2002). Applications of Social Capital in Educational Literature: A Critical Synthesis. *Review of Educational Research*, *72*(1), 31.

Edgerton, J. D., Roberts, L. W., & Peter, T. (2013). Disparities in academic achievement: assessing the role of habitus and practice. Social indicators research, 114(2), 303-322.

Espinoza, R. (2010). The Good Daughter Dilemma: Latinas Managing Family and School Demands. *Journal of Hispanic Higher Education*, *9*(4), 317-330.

Gay, G. (2004). Navigating Marginality en Route to the Professoriate: Graduate Students of Color Learning and Living in Academia. *International Journal of Qualitative Studies in Education*, *17*(2), 265-288.

Grandy, J. (1998). Persistence in Science of High-Ability Minority Students: Results of a Longitudinal Study. *Journal of Higher Education, 69*(6-), 589-620.

Hanson, S. L. (2006). African American women in science: Experiences from high school through the post-secondary years and beyond. In J. M. Bystydzienski & S. R. Bird (Eds.), Removing barriers: Women in academic science, technology, engineering, and mathematics (pp. 123–141). Bloomington: Indiana University Press.

Hanson, S. L. (2007). Success in Science Among Young African American Women The Role of Minority Families. *Journal of Family Issues*, *28*(1), 3-33.

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

Hathaway SR, Nagda AB, Gregerman RS. The relationship of undergraduate research participation to graduate and professional education pursuit: An empirical study. Journal of College Student Development. 2002;43(5):614–631

Hill, S. T., and Green, M. M. (2007) Science and Engineering Degrees, by Race/Ethnicity of Recipients: 1995–2004. Arlington, Va.: National Science Foundation.

Holley, K. A., & Gardner, S. (2012). Navigating the pipeline: How socio-cultural influences impact first-generation doctoral students. *Journal of Diversity in Higher Education*, *5*(2), 112.

Horn, L., & Kojaku, L. K. (2001). High school academic curriculum and the persistence path through college (NCES 2001-163). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Hunter, A. B., Laursen, S. L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. Science Education, 91(1), 36-74.

Hurtado, S., Carter, D. F., & Kardia, D. (1998). The Climate for Diversity: Key Issues for Institutional Self-Study. *New Directions for Institutional Research*, *1998*(98), 53-63. doi: 10.1002/ir.9804

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

Hurtado, S., Cabrera, N. L., Lin, M. H., Arellano, L., & Espinosa, L. L. (2009). Diversifying science: Underrepresented student experiences in structured research programs. *Research in Higher Education*, *50*(2), 189-214.

Israel, G. D., Beaulieu, L. J., & Hartless, G. (2001). The Influence of Family and Community Social Capital on Educational Achievement. [Article]. *Rural Sociology, 66*(1), 43-68.

Johnson, J and Bozeman, B. (2012) Perspective: Adopting an Asset Bundles Model to Support and Advance Minority Students' Careers in Academic Medicine and the Scientific Pipeline. Academic Medicine. doi: 10.1097/ACM.0b013e31826d5a8d

Kalmijn M. and Kraaykamp G., (1996).Race, culturac lapital, and schooling: Ananalysis of trends in the United States. Sociology of Education 6,9,22-34.

Knighton, T. (2002). Postsecondary participation: The effects of parents' education and house-hold income. Education Quarterly Review, 8(3), 25–32.

Kochan T, Bezrukova K, Thomas D, et al. The effects of diversity of business performance: Report of the Diversity Research Network. Human Resource Management. 2003;42(1):3-21.

Lareau, A., & Horvat, E. M. (1999). Moments of social inclusion and exclusion race, class, and cultural capital in family-school relationships. Sociology of education, 37-53.

Leyva, V. L. (2011). First-Generation Latina Graduate Students: Balancing Professional Identity Development with Traditional Family Roles. *New Directions for Teaching and Learning*(127), 21-31.

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): first findings. Cell biology education, 3(4), 270-277.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. CBE-Life Sciences Education, 6(4), 297-306.

Lopez, E. (1996). Social capital and the educational performance of Latino and Non-Latino youth(11). San Luis Obispo, CA: Julian Samora Research Institute.

Lyons, T. (2006). The puzzle of falling enrolments in physics and chemistry courses: Putting some pieces together. Research in Science Education, 36(3), 285 – 311.

Malone, K. R., & Barabino, G. (2009). Narrations of race in STEM research settings: Identity formation and its discontents. Science Education, 93(3), 485-510.

Maple, S. A., & Stage, F. K. (1991). Influences on the choice of math/science major by gender and ethnicity. American Educational Research Journal, 28(1), 37–60.

Merkel, C. A. (2001). Undergraduate research at six research Universities. *Pasadena, CA: California Institute of Technology*.

Metcalf, H. (2010). Stuck in the Pipeline: A Critical Review of STEM Workforce Literature. *InterActions: UCLA Journal of Education & Information Studies, 6*(2), 1-20.

Moss-Racusin, C. A., van der Toorn, J., Dovidio, J. F., Brescoll, V. L., Graham, M. J., & Handelsman, J. (2014). Scientific Diversity Interventions. Science, 343(6171), 615-616.

Murphy, M. C., Steele, C. M., & Gross, J. J. (2007). Signaling threat how situational cues affect women in math, science, and engineering settings. Psychological Science, 18(10), 879-885.

Myers, R. E., & Fouts, J. T. (1992). A cluster analysis of high school science classroom environments and attitude toward science. Journal of Research in Science Teaching, 29(9), 929 – 937.

National Action Council on Minorities in Engineering. Confronting the 'New' American Dilemma, Underrepresented Minorities in Engineering: A Data-Based Look at Diversity. White Plains, N.Y.: National Action Council on Minorities in Engineering, 2008.

National Institute of Health. (2014) Ruth L. Kirschstein National Research Service Award Individual Predoctoral Fellowship to Promote Diversity in Health-Related Research (Parent F31 - Diversity). Available at: http://grants.nih.gov/grants/guide/pa-files/PA-14-148.html

National Science Foundation (2007). Women, Minorities, and Persons with Disabilities in Science and Engineering. Arlington, Va.: National Science Foundation.

National Science Foundation, National Center for Science and Engineering Statistics. 2013. Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013. Special Report NSF 13-304. Arlington, VA. Available at http://www.nsf.gov/statistics/wmpd/

Nettles, M. T., Millett, C. M., Spencer Foundation, C. I. L., & National Center for Postsecondary Improvement, S. C. A. (1999). The Human Capital Liabilities of Underrepresented Minorities in Pursuit of Science, Mathematics, and Engineering Doctoral Degrees.

Ong, M., Wright, C., Espinosa, L. L., & Orfield, G. (2011). Inside the Double Bind: A Synthesis of Empirical Research on Undergraduate and Graduate Women of Color in Science, Technology, Engineering,and Mathematics. *Harvard Educational Review, 81*(2), 172-209.

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.

Page, S. E. (2008). The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies (New Edition). Princeton University Press.

Parsons, T., & Bales, R. (1955). American family: its relation to personality & the social structure.

Population Division of the US Census Bureau. Percent of the Projected Population by Race and Hispanic Origin for the United States: 2010 to 2050 August 2008. http://www.census.gov/population/www/projections/summarytables.html# . Accessed July 24, 2012.

Portes, A., & Landolt, P. (1996). The downside of social capital. The American Prospect, 26, 18-21, 94.

Portes, A. (1998). Social Capital: Its Origins and Applications in Modern Sociology. *Annual Review of Sociology, 24*(1), 1.

Portes, A. (2000). The Two Meanings of Social Capital. [Article]. *Sociological Forum, 15*(1), 1.

Potvin, G., & Tai, R. H. (2012). Examining the Relationships among Doctoral Completion Time, Gender, and Future Salary Prospects for Physical Scientists. *Journal of Chemical Education, 89*(1), 21-28.

Purdie-Vaughns, V., Steele, C. M., Davies, P. G., Ditlmann, R., & Crosby, J. R. (2008). Social identity contingencies: how diversity cues signal threat or safety for African Americans in mainstream institutions. Journal of personality and social psychology, 94(4), 615.

Ratelle, C. F., Larose, S., Guay, F., & Senécal, C. (2005). Perceptions of parental involvement and support as predictors of college students' persistence in a science curriculum. *Journal of Family Psychology, 19*(2), 286.

Reay, D., David, M., & Ball, S. (2001). Making a difference?: Institutional habituses and higher education choice.

Roberge M, van Dick R. Recognizing the benefits of diversity: When and how does diversity increase group performance? Human Resource Management Review. 2010;20(4):295-308.

Roberts, N. A., & Plakhotnik, M. S. (2009). Building social capital in the academy: The nature and function of support systems in graduate adult education. *New Directions for Adult and Continuing Education*, *2009*(122), 43-52.

Robb, N., Dunkley, L., Boynton, P., & Greenhalgh, T. (2007). Looking for a better future: Identity construction in socio-economically deprived 16-year olds considering a career in medicine. *Social science & medicine*, *65*(4), 738-754.

Russell, M. L., & Atwater, M. M. (2005). Traveling the road to success: A discourse on persis- tence throughout the science pipeline with African American students at a predomi- nantly white institution. Journal of Research in Science Teaching, 42(6), 691–715.

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. Science(Washington), 316(5824), 548-549.

Schmidt, P. (2008). Longer Road to Ph.D.'s for Women and Minority Members. *Chronicle of Higher Education*, *55*(4), A10-A10.

Seymour, E., Hunter, A. B., Laursen, S. L., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three- year study. Science Education, 88(4), 493-534.

Sharon, A. J., & Baram-Tsabari, A. (2013). Measuring mumbo jumbo: A preliminary quantification of the use of jargon in science communication. Public Understanding of Science, 0963662512469916.

Smedley, Butler and Bristow (2004). In the Nation's Compelling Interest: Ensuring Diversity in the Health-Care Workplace. Washington DC: The National Academies Press.

Smith, D. G. (1997). Diversity works: The emerging picture of how students benefit. Assn of Amer Colleges.

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. American psychologist, 52(6), 613.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. Journal Of Personality And Social Psychology, 69(5), 797-811. doi:10.1037/0022-3514.69.5.797

Sullivan, A. (2001). Cultural Capital and Educational Attainment. [Article]. *Sociology*, *35*(4), 893-912.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. International journal of medical education, 2, 53-55.

Tenenbaum, H. R., & Callanan, M. A. (2008). Parents' science talk to their children in Mexican-descent families residing in the USA. *International Journal of Behavioral Development*, *32*(1), 1-12. doi: 10.1177/0165025407084046

Tinto, V. (1993). *Leaving College: Rethinking the Causes and Cures of Student Attrition. Second Edition*.

Trusty, J. (2002). Effects of High school course-taking and other variables on choice of science and mathematics college majors. Journal of Counseling and Development, 80, 464 – 474.

Tsui, L. (2007). Effective Strategies to Increase Diversity in STEM Fields: A Review of the Research Literature. *Journal Of Negro Education*, *76*(4), 555-581.).

U.S. Census Bureau. (2008). National population estimates: Characteristics. Retrieved from http://www.census.gov/popest/national/asrh/NC-EST2005-asrh.html

Williams, K. Y., & O'Reilly, C. A. (1998). Demography and diversity in organizations: A review of 40 years of research. Research In Organizational Behavior. VOL 20, 1998, 20, 77-140.

Willis, R. J. (1973). A new approach to the economic theory of fertility behavior. Journal of Political Economy 81 (2 Pt. 2): S14-S64. March-April 1973.

Yan, W. (1999). Successful African American students: The role of parental involvement. Journal of NegroEducation,68(1), 5-22.

Zeiser, K. and Berger, A.R., (2012). How Long Does it Take? STEM PhD Completion for Underrepresented Minorities. Broadening Participation in STEM Graduate Education. Available at http://www.air.org/sites/default/files/downloads/report/AIR_STEM_Issue_Brief_Time_to_Completion_12_2012_0.pdf