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Exploring Science Attitudes and Achievement in US Children

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Exploring Science Attitudes and Achievement in US Children

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF ARTS

in Social Ecology

by

Manuella Oliveira Yassa

Thesis Committee:
Professor Nancy Guerra, Chair
Professor Kirk Williams
Professor Chuansheng Chen

2022

DEDICATION

To my daughters Isabella and Olivia and to my partner Mike

for your endless trust and patience, love and support.

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ABSTRACT OF THE THESIS

Exploring Science Attitudes and Achievement in US Children
by
Manuella Oliveira Yassa
Master of Arts in Social Ecology
University of California, Irvine, 2022
Professor Nancy Guerra, Chair

The health of the U.S. economy and its position as a global leader is intimately tied to innovation in science and technology. While abundant evidence has shown that diverse teams working together and capitalizing on innovative ideas and distinct perspectives outperform homogenous teams and despite the millions of dollars invested in STEM education each year, the United States has not been able to achieve STEM workforce diversity goals. Using nationally representative data from the first wave of the High School Longitudinal Study (2009), this study explores the science self-efficacy and achievement of 9th graders with a focus on differences across race/ethnicity. As expected based on prior work, average science and math achievement of individuals from groups underrepresented in science (namely Hispanic and Black students in this study) are lower than that of those overrepresented in science (White and Asian in this study). Surprisingly, the science self-efficacy of Black students was found to be higher than that of all other groups except Asian. This miscalibration calls into question whether interventions focused on increasing science self-efficacy in Black high school students would be as effective at increasing achievement as it is in the other ethnicities studied. These results have far-reaching implications for educational interventions and strongly suggests that culture and context-specific strategies should be employed rather than more generalized approaches.

INTRODUCTION

The current size and composition of the US STEM workforce are concerning. While STEM positions continue to grow, the number of skilled workers available to fill those positions does not meet demand (Carnevale et al., 2013). These unfilled STEM positions pose a great risk to the nation's status as a global leader since the health of our economy is intimately tied to innovation in science and technology. Education scholars and practitioners including teachers, researchers, interventionists and program evaluators have dedicated their careers to understanding and tackling this important and urgent problem. How do we, as a nation, begin to understand how we might generate a larger STEM workforce and one whose composition reflects our that of our people? While the incentive to invest in solving this problem is clear and the resources available, understanding how to efficiently allocate these valuable resources is a topic of much work in the education field.

The 'pipeline model' has emerged as a useful tool to understand how we might tackle the challenge of increasing the size and diversity of the US STEM workforce. First introduced by Sue Berryman in her 1983 report *Who will do science? Minority and Female attainment of science and mathematics degrees: Trends and Causes* (Berryman, 1983), the pipeline model conceptualizes the scientific trajectory as a pipe with an opening, or entry point, on the left, several openings throughout where individuals 'leave' the trajectory, and finally a collection bucket on the right to capture the individuals who are said to persist through the trajectory to obtain degrees in STEM and enter the STEM workforce. The 'leaky pipeline' metaphor has helped researchers and policymakers understand potential targets for intervention. Berryman proposed two factors that influence the makeup of the STEM workforce: career choices of adolescents, or entry into the pipeline, and persistence in the pipeline. By analyzing the volume and characteristics of individuals at various points along the pipeline, Berryman suggested that, while all groups are susceptible to leakage from the pipeline, the rate at which we lose individuals is higher for some groups than for others. Both entry into and persistence through the STEM academic pipeline have been studied extensively with many factors contributing to whether individuals pursue studies in STEM after high school and whether they persist to earn college and graduate degrees in STEM (Cleaves, 2005; Tai, 2006). Research to understand the factors that are associated with student interest, achievement, and persistence in STEM disciplines guides the design of education interventions and directs resource allocation. Unfortunately, the drive to generalize findings and design one-size-fits-all interventions that are effective and scalable often promotes oversimplification of important contextual characteristics that might provide valuable insight.

Drawing from social cognitive career theory and value-expectancy theory of motivation and using the socioecological model as a framework, this thesis explores science achievement and science-related attitudes such as science self-efficacy and identity in a nationally representative sample of US 9th grade students. While we know intuitively that students exist not in a vacuum but rather in complex and interrelated systems, studies of factors related to science attitudes, behaviors and achievement often lack analysis and discussion of important contextual factors that should be considered when designing interventions. Importantly, this thesis explores how these factors might differentially impact individuals from different racial/ethnic backgrounds. This thesis explores 3 questions:

1. Are there significant differences in the average achievement scores of students from different racial/ethnic backgrounds?
2. Are there significant differences in the science self-efficacy of students from different racial/ethnic backgrounds?
3. Is the relation between self-efficacy and achievement moderated by racial/ethnic background?

CHAPTER 1: WHY WORRY ABOUT DIVERSITY IN STEM?

The concern for the disparities that exist today in education across racial and ethnic groups are not new and have been documented for several decades (Bradley, 1997). While abundant evidence has shown that diverse teams working together and capitalizing on innovative ideas and distinct perspectives outperform homogenous teams (Hong & Page, 2004), and despite the millions of dollars invested in STEM education each year, the United States has not been able to achieve STEM workforce diversity goals. This has been largely attributed to the failure of the "academic pipeline" to recruit and retain students from diverse backgrounds, a phenomenon described as the "leaky pipeline" (Berryman, 1983). One nationally representative study on college students found that between 2003 and 2009, 48 percent of students pursuing bachelor's degrees in STEM did not persist in that major through graduation (Chen, 2014). The demographic composition of the those in the STEM workforce who hold at least a bachelor's degree remains a topic of concern.

A 2015 study by Byars-Winston, Fouad and Wen compared census data from 1970 and 2010 to understand whether, as more women and racial/ethnic minorities entered the workforce, their entry into different occupations was proportional to their population distributions. They found that although the number of women and racial/ethnic minorities in the workforce increased between 1970 and 2010, they did not enter the available occupations at proportional rates. Specifically, women and racial/ethnic minorities were underrepresented in the population of engineers, scientists, and pharmacists (Byars-Winston et al., 2015).

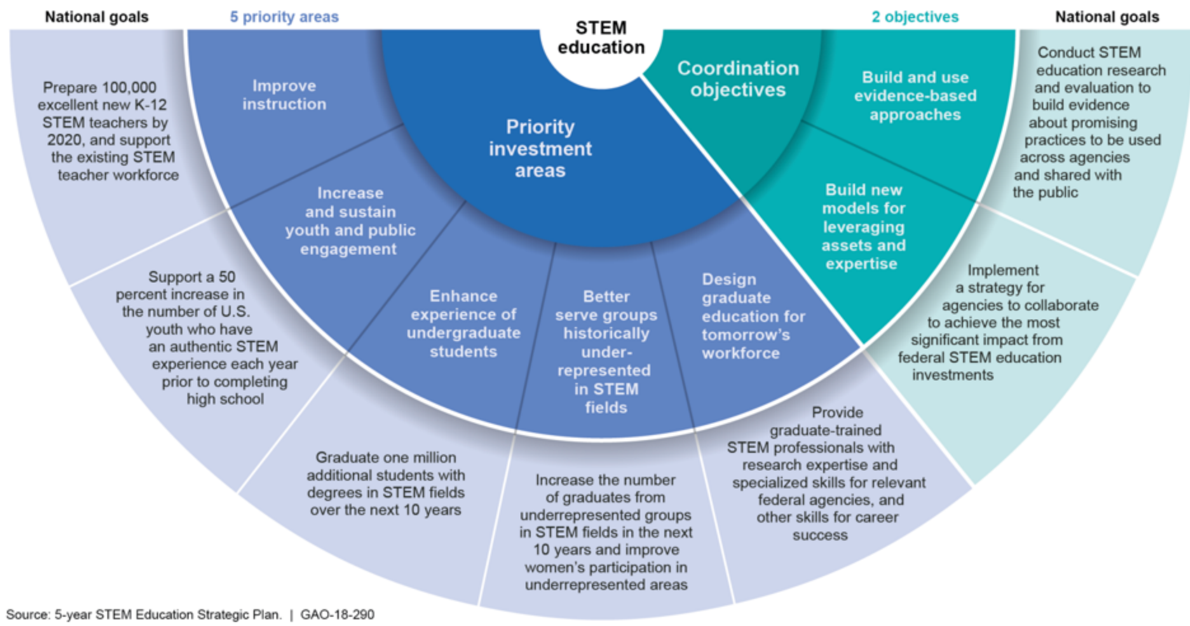
To address this lack of diversity in our STEM pipeline and workforce, government agencies and private foundations have allocated significant resources fund STEM education STEM education interventions (Atkinson & Mayo, 2010).

In 2004 alone, federal agencies (mostly the National Science Foundation and the National Institutes of Health) reported spending $2.8 billion on education programs in STEM. The 2005 Government Accountability Office (GAO) report included a concern over the lack of emphasis placed evaluation of the programs and thus a paucity of data on the effectiveness of the funded programs. (Government Accountability Office, 2005). Given the challenges that come with evaluating education programs, it is not surprising that without a requirement from the funding agency for rigorous evaluation, the programs went mostly unevaluated. This lack of data regarding the return on these federal investments was concerning to many including Jeffrey Mervis who wrote a commentary in *Science* in 2006 discussing the lack of rigor in the evaluation of programs intended to increase the diversity of the biomedical research field. In the piece, he expresses frustration for the use of anecdotal evidence in place of "hard data" and calls for action in this area (Mervis, 2006).

The 2018 GAO report provides a more current summary of the federal STEM education programs including a 5-year STEM education strategic plan (see Figure 1) which highlights serving groups historically under-represented in STEM and engaging in youth and public engagement as two of the five priority areas. Included in the report is a recommendation to require information on the participation rates of individuals under-represented in science. Though participation rates and tracking information can tell us that a program might be working, they give little insight into the why or how. While is abundantly clear that increasing the diversity of the STEM pipeline and workforce are investment priorities, how to invest those dollars is not as clear.

Figure 1

Government Accountability Office 5-year STEM Strategic Education Plan



Source: 5-year STEM Education Strategic Plan. | GAO-18-290

As a nation, we have been after a one-size-fits-all solution that improves the outcomes of our public education system for every child. We seek programs that are cost effective, generate positive outcomes that are resistant to fadeout effects and are scalable to every school in the nation. This pressure result in interventions that are not only ineffective but also lack the specificity required to improve outcomes for specific children in specific contexts. In an effort to help everyone, these programs end up helping no one. To understand the importance of taking a more granular and deliberate approach to designing interventions, it is valuable to remember the motivation for the work. The motivation for this thesis to understand how we can intervene along the science academic pipeline to create a science workforce whose ethnic/racial composition is reflective of the that of our nation.

Today, when we compare the racial/ethnic composition of the United States with that of the science workforce we find that some racial/ethnic groups are overrepresented (meaning the percentage of people from that group that are in the science workforce is greater than the percentage of people from that group that are in the U.S.) and some that are underrepresented. While Black and Hispanic people make up 14.2% and 21.3% the U.S. population, they compose only 8.1% and 8.4% of the awarded doctoral degrees in science and engineering. White and Asian people, on the other hand, make up 54.4% and 6.6% of the U.S. population and 69.1% and 10.6 % of the awarded doctoral degrees in science and engineering (National Science Board, 2022). Due to their common low participation in science, we usually group those from Black and Hispanic backgrounds together and those from White and Asian backgrounds together. By doing so, we simplify discussions and analyses to comparing those from under-represented minority backgrounds (URMs) to those not from under-represented minority backgrounds (non-URMs). Though this may seem like a trivial and practically sound move, the creation of the term "URM" has stifled our progress in education because it merges groups whose individuals have vastly different life experiences and thus likely respond differently to intervention. As this thesis reveals, analyzing data using the URM vs non-URM classifications blinds researchers to factors that may be fruitful targets for intervention.

CHAPTER 2: LITERATURE REVIEW

Adolescence is a unique phase of human development that is characterized by important biological and psychological changes that, over several years, transition the individual from child to adult. In addition to managing the physical and psychological changes that develop with the emergence of puberty, adolescents are also confronted with a novel level of social and educational agency. They must develop new skills in areas related to self-regulation, self-monitoring, time management and self-evaluation. (Pajares & Urdan, 2005)During their middle and high school years, adolescents begin to consider their future careers and make choices related to those goals. Research on adolescents highlights the relation between adolescent personal efficacy and the development of their career goals. Specifically, higher perceived efficacy is related to higher motivation and persistence. Even when factors such as performance, prior level of academic achievement and career interests are controlled for, efficacy beliefs predict career choices and achievement related to the educational requirements to attain those career goals(Lent et al., 1993; Pajares & Graham, 1999)

Science-related attitudes and behaviors during the high school years have been shown to predict achievement and persistence in science during the undergraduate years and beyond (Bonous-Hammarth, 2000; Crisp et al., 2009). Positive science identities such as seeing oneself as a scientist has been found to be correlated with positive academic behaviors such as attendance and course-taking. Science self-efficacy, or a person's expectations for success in a science-related task, has been shown to be correlated to academic achievement as well as likelihood to enroll in advanced science classes (Bandura, 1986; Gilmartin et al., 2006; Jacobs et al., 2004) Science self-efficacy has thus become a popular target for interventions that aim to improve outcomes in achievement and persistence in science. (Pajares & Graham, 1999; Schunk & Meece, 2006)m 2013).

Adolescent development and the development of science-related attitudes occurs not in a vacuum but rather in the context of culture, families, schools, and classrooms. To understand the multifactorial interactions that shape the development of science-related attitudes, researchers have used Urie Bronfenbrenner's Ecological Systems Theory as a framework. Bronfenbrenner situates the child at the center of a series of five nested interconnected systems (Bronfenbrenner, 2005). Though this thesis explicitly explores factors at the level of the individual, interpretation of the results is guided by factors at the microsystem, mesosystem, exosystem and even macrosystem levels. Future work will include analysis of factors outside of the individual level.

This thesis is also guided by the Social Cognitive Theory which posits that knowledge is acquired through social interactions and experiences and that behavior is influenced by personal and environmental factors (Bandura, 2012). Social cognitive career theory (SCCT), which is based on Bandura's general social cognitive theory postulates that self-efficacy and outcome expectations lead to career interests which in turn lead to career choices (Lent et al., 1994). Self-efficacy has been postulated to be an important factor in predicting behavior of students as they develop their career plans (Gainor & Lent, 1998). Researchers have used the SCCT model as a framework to study self-efficacy as it relates to persistence and performance in STEM. For example, Lent et al. found evidence for a relation between self-efficacy and academic achievement, showing that students who reported high self-efficacy persisted longer in technical and/or science majors over the following year than did those with low self-efficacy (Lent et al., 1984). Lent later found self-efficacy to serve as a precursor of outcome expectations, interests and goals in engineering students (Lent et al., 2008). Betz and Hackett studied the relation between self-efficacy and the extent to which students selected science-based college majors and found, also using the SCCT model, that indeed self-efficacy expectations were significantly related to selection of science-based majors (Betz & Hackett, 1983).

Because SCCT accounts for the background and contextual factors that contribute to career development, it has been used to understand the career development process across diverse populations (Byars-Winston et al., 2010) as well as specifically in Mexican Americans (Flores et al., 2010), and African Americans (Gainor & Lent, 1998). Studies have identified increasing self-efficacy as a way to increase achievement and persistence in STEM (Ballen et al., 2017; Lent et al., 1997) and have thus identified self-efficacy as a target for interventions aimed at patching the leaky pipeline.

The relation between self-efficacy and individual factors has also been investigated with findings suggesting that, in general, males show higher self-efficacy than females. Analyzing data from the 2006 Program for International Student Assessment which surveyed students in 50 countries, Sikora and Pokrepek found science self-efficacy to be higher in boys than girls in almost every country, even after controlling for science performance (Sikora & Pokropek, 2012)

Since the ultimate goal of this thesis is to explore self-efficacy as a potential target for educational interventions, it is critically important to distinguish self-efficacy from other similar constructs. The first important distinction is that self-efficacy refers to an individual's perceived ability to perform an activity and not on personality characteristics or identities. When we evaluate self-efficacy, we are asking individuals to judge how well they can do something. Self-efficacy is often confounded with self-concept and self-esteem but in fact are unique constructs.

Bandura makes the distinction that general judgements of how good an individual is at something is measured by self-concept whereas self-efficacy specifically refers to judgements on abilities to complete specific tasks or activities. For example, while we may measure self-concept by asking students to rate the phrase "I am good at science", we would measure self-efficacy by asking them to rate "I am confident I can do well in this science class/assignment/test". This distinction has been studied in the college population of mathematics students where researchers aimed to understand the relation between self-efficacy, self-concept and academic performance (math skills). Compared to self-concept, self-efficacy was a better predictor of academic performance. Self-concept also seemed to partially mediate the relation between self-efficacy and performance (Pajares & Miller, 1994)These data suggest that higher self-efficacy can increase performance directly but can also increase self-concept which in turn increases performance.

The distinction between self-efficacy and self-esteem is particularly important when studying adolescents since self-esteem changes are common during this developmental stage. While self-esteem is an affective, noncognitive judgement that measures how a person feels about themselves, self-efficacy aims to measure a cognitive judgement about their ability to complete a task (Wigfield & Krpathian, 1991). This distinction was empirically explored in a sample of college students who were tested before three exams in one semester. While self-esteem was not found to be a predictor, self-efficacy predicted up to 14% of the variance in performance (Mone et al., 1995).

CHAPTER 3: METHODS

This study used public-use data from the base year of the High School Longitudinal Study of 2009 (HSLS:09) which is sponsored by the National Center for Education Statistics (NCES) (Ingels, Dalton, et al., 2011). The goal of the HSLS:09 was to explore the transition into and out of science, technology, engineering, and mathematics (STEM) as well as the development and progression of postsecondary transition plans. The study additionally explored the educational and societal experiences involved. The base year data used in this study was collected in the fall term of the 2009-2010 school year. The data is representative of 9th grade students in public and private schools in the United States in 2009. Within each of the 944 participating schools, a stratified random sample of students was selected based on race/ethnicity. An average of 27 students per school were selected, and the total number of students who participated in the study was 21,444. Data were collected during the fall of the 9th grade year. For this study, the analytic sample was reduced to the group of Black, Hispanic, White and Asian students who had no missing values for the variables of interest, described below.

Data Collection

Recruitment of school districts and schools for participation in this study began in 2008, one year before data collection began. A school coordinator was identified at each school and served as the point of contact for the study. A total of 940 high schools participated in the 2009 wave of this study, with data collection occurring from September 2009 through February of 2010. All in-school sessions were conducted electronically on computers and data was stored in encrypted files and transferred after each session.

Data was collected through a stratified, two-stage random sample design. The primary sampling unit was defined as the schools which were selected at the first stage. Students were randomly selected from the sampled schools during the second stage. The target school population included regular public schools, public charter schools and private schools in the 50 United States and the District of Columbia. Only schools that provided instruction to both 9th graders and 11th graders were included. A total of 944 schools participated in the study (from a total of 1,974 sampled and 1,889 eligible) with 51.3% identified as public schools and 44.9 identified as private schools.

Once schools were identified, students were randomly selected from the sampled schools. A total of 26,210 students were sampled from the 940 schools and a total of 25,210 were deemed eligible for participation in the study. From these, 21,440 completed the questionnaire, with 550 identified as questionnaire-incapable and 3,210 non-responders. Demographic information for the 21,440 students was as follows: 10,890 male (50.77%), 10,560 female (49.23%), 223 American Indian/Alaska Native (1.04%), 2,140 Asian/Pacific Islander (10.00%), 2,680 Black/Black (12.52%), 3,520 Hispanic (16.40%), 12,630 White (58.90%), 250 other race/more than one race/missing value (1.15%).

For the current study, the sample was further reduced to a total of 14,272 to include only students who identified as White (9069/63.5%) Black (1454/10.19%) Hispanic (2440/17.1%) or Asian (1309/9.2%) and who had no missing values on all variables of interest. The sample included 7084 female students (49.6%).

Variables

The variables for this study were chosen based on the SCCT framework and the literature on the factors that influence science self-efficacy and STEM career intent in adolescents. They include student's science self-efficacy, science identity, standardized math score, science GPA, socioeconomic status and sex.

Student Science Self-Efficacy: The student science self-efficacy scale (X1SCIEFF) was used in this study as a measure of the student's science self-efficacy. The variable is a composite of four constructs: S1STESTS, S1STEXTBOOK, S1SSKILLS, S1SASSEXCL. The composite variable was created through principal components factor analysis, weighted by the base year student analytic weight (W1STUDENT) (Ingels, Pratt, et al., 2011). The scale was standardized to a mean of 0 and standard deviation of 1. High score on the composite variable X1SCIEFF represent higher science self-efficacy. Only students who provided responses to all of the constructs were assigned a score on the composite scale. For this study, the following items were re-coded as system missing: -7 (item legitimate skip/NA), -8 (unit nonresponse/component not applicable), and -9 (missing). The reliability of the scale was measured with a Cronbach's alpha and determined to be 0.88. The composite scale is made up of the following variables which all ask students to answer the question "How much do you agree or disagree with the following statements about your fall 2009 science course?" on a scale of 1(strongly agree) to 4(strongly disagree).

S1STESTS: You are confident that you can do an excellent job on tests in this course.

S1STEXTBOOK: You are certain you can understand the most difficult material presented in the textbook used in this course.

S1SSKILLS: You are certain you can master the skills being taught in this course.

S1SASSEXCL: You are confident that you can do an excellent job on assignments in this course.

Student Science Identity: The student science identity score (X1SCIID) was used in this study as a measure of the student's science identity. The variable is a composite of two constructs: S1SPERSON1 and S1SPERSON2 which ask the student to rate the degree to which they agree(1) or disagree(4) with the statements "I see myself as a science person" and "Others see me as a science person" during the Fall of 2009. The composite variable was created through principal components factor analysis, weighted by the base year student analytic weight (W1STUDENT) (Ingels, Pratt, et al., 2011). The variable is standardized to a mean of 0 and standard deviation of 1. Higher scores indicate more agreement with the statements, or higher level of science identity. Only students who provided responses to both of the constructs were assigned a score on the composite scale. For this study, the following items were re-coded as system missing: -7 (item legitimate skip/NA), -8 (unit nonresponse/component not applicable), and -9 (missing). The reliability of the scale was measured with a Cronbach's alpha and determined to be 0.65.

Academic Achievement: This study uses two measurements of academic achievement: math standardized score and science GPA. The student's **math standardized theta score** (X1TXMTSCOR) provides a norm-referenced measurement of achievement in math relative to the HSLS:09 student population. This score was computed by rescaling the theta (ability) estimate to a mean of 50 and standard deviation of 10. All items in the mathematics item pool were field tested to evaluate the effectiveness of each item and determine the placement of items on the tests. The IRT-estimated reliability of the test was determined to be 0.92 (Ingels, Dalton, et al., 2011). The mathematics assessment was administered by computer in the form of a 40-question test. The data were examined to look for possible indicators of lack of motivation (e.g. answering all of the questions with the same response letter, or patterns in answering the questions). Through this process, 108 records were deleted because the student attempted fewer than 6 items. An additional 67 record were deleted for pattern marking (same answer options or repeated patterns). A mathematics quintile score variable (X1TXMQUINT) was calculated as a norm-referenced measure of achievement. The quintile score is calculated by dividing the weighted achievement distributions into five equal groups with quintile 1 representing the lowest-achieving fifth of the population and quintile 5 representing the highest-achieving fifth.

The **student's science GPA** (X3TGSPASCI) is obtained from the student's final high school transcript and is used as a measure of student performance in science classes. It is calculated by computing the mean GPA of all life and physical sciences the student completed.

Sex: The student's sex (X1Sex) was obtained from student and/or parent questionnaire or from the school-provided roster. The variable was dummy coded with 'female' coded as '0' and 'male' coded as '1'.

Socioeconomic Status: The student's composite socioeconomic status score (X1SES) was used to measure socioeconomic status. The variable was calculated using the parent/guardian's education, parent's occupation, and family income. Higher values indicate higher socioeconomic status.

All analyses were completed using IBM SPSS Statistics version 28.

CHAPTER 4: RESULTS

This thesis aims to explore the science self-efficacy of 9th graders and the relation between science self-efficacy and achievement among individuals from different races/ethnicities. The thesis specifically asks three questions.

1. Are there significant differences in the average achievement scores of students from different racial/ethnic backgrounds?
2. Are there significant differences in the science self-efficacy of students from different racial/ethnic backgrounds?
3. Is the relation between self-efficacy and achievement moderated by racial/ethnic background?

Evidence suggests that there are significant differences in the average achievement scores of students from different racial/ethnic backgrounds.

The first aim of this study was to evaluate the academic achievement of this nationally representative sample of 9th grade students. Achievement was assessed using two measures in this study; math standardized test score and science GPA. Both variables were converted to z-scores for the purpose of analysis.

An analysis of variance (ANOVA) test was used to understand whether there are any significant differences among the achievement scores of individuals from different races/ethnicities. In particular, a Welch's ANOVA was conducted since the achievement data in this study violates the assumption of homogeneity of variance indicated by a significant Levene's test at α=05, [F(3,14268)=14.45, p<.001]. Ethnicity (White, Black, Hispanic and Asian) was included in this analysis as the predictor variable and achievement as measured by the standardized theta math score was the outcome variable. A Welch's ANOVA revealed that it is not the case that the mean achievement of students in the four different ethnic groups is the same [$F(3,3351.18)=418.64$, $p<.001$]. Given the unequal group sizes, post hoc pairwise comparisons were conducted using the Games-Howell correction. The pairwise comparisons revealed significant differences in achievement among each of the ethnicities when compared to each other in the following order and as depicted in figure 1a: Asian students (M=.69, SD=1.05) had the highest average achievement scores followed by White students (M=.06 SD=.95) then Hispanic students (M=-.31 SD=.93) and Black students (M=-.48, SD=.93).

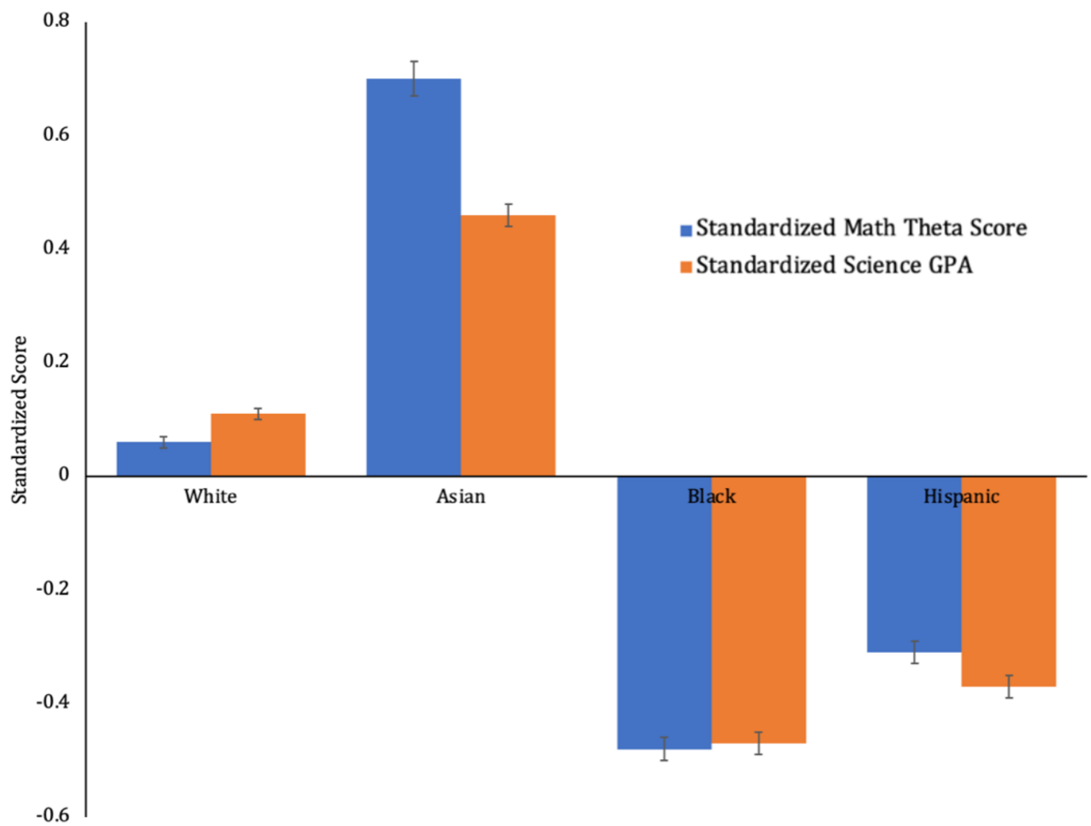
Table 1

Descriptive Statistics

	White (9069)		Asian (1309)		Black (1454)		Hispanic (2440)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Socioeconomic status composite	0.24	0.73	0.42	0.88	-0.07	0.73	-0.33	0.73
Standardized math score	0.06	0.95	0.70	1.10	-0.48	0.93	-0.31	0.93
Standardized science GPA	0.11	0.97	0.46	0.88	-0.47	0.95	-0.37	0.97
Science self-efficacy	0.05	1.00	0.22	0.95	0.12	0.99	-0.12	0.99

Figure 2

Mean standardized scores for science GPA and standardized math test.



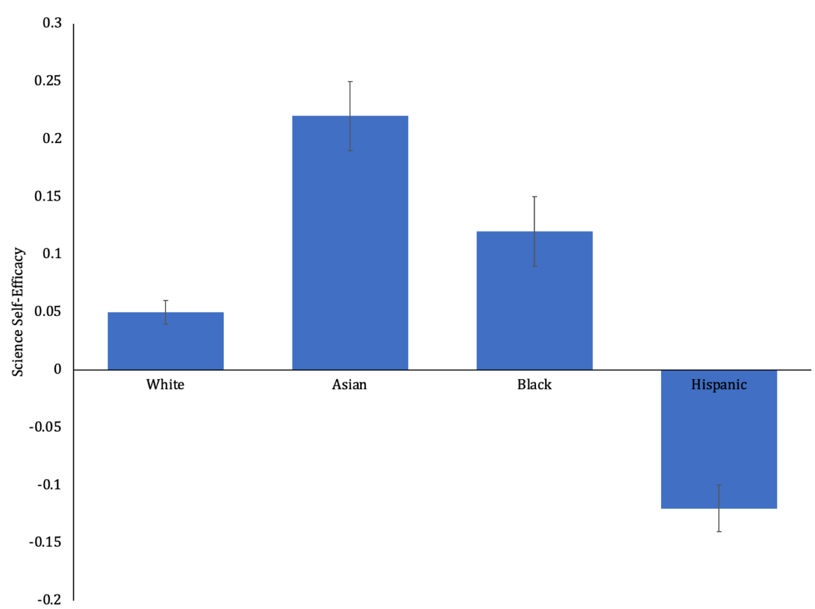
Note. Mean standardized math scores and standardized science GPA (*N*= 14272)

Evidence suggests that there are significant differences in the average science self-efficacy scores of students from different racial/ethnic backgrounds.

A one-way analysis of variance (ANOVA) was conducted, with ethnicity (White, Asian, Black, Hispanic) as the predictor variable and science self-efficacy as measured on the composite scale as the outcome variable. The test assumed homogeneity of variances based on the results of a Levene's test of homogeneity of variances [$F(3, 14268)=2.49$, $p=.059$) The omnibus result indicated that it is not the case that the science self-efficacy is the same among the four groups [$F(3, 14268) = 39.24$, $p<.001$]. At a .05 alpha level, we have sufficient evidence to reject the null hypothesis that the average self-efficacy is the same for White, Asian, Black and Hispanic 9th graders in this sample. Follow-up tests were conducted to determine which groups were responsible for the significant omnibus finding. Post hoc comparisons using the Tukey Honestly Significant Difference (HSD) test indicated that the mean science self-efficacy of Asian students (*M*=.2213, *SD*=.95) was significantly higher than that of all other groups: Black (*M*=.2213, *SD*=.99), White (*M*=.05, *SD*=1.0) and Hispanic (*M*=-.12, *SD*=.99). Notably, all of the pairwise comparisons were significant at the .05 alpha level except the difference between science self-efficacy of White students and Black students which were not significantly different from each other at the α=.05 level. The science self-efficacy of Black students (*M*=.2213, *SD*=.99) was significantly higher than the science self-efficacy of Hispanic students (*M*=-.12, *SD*=.99) as shown in figure 3.

Figure 3

Mean Science Self-Efficacy Scores

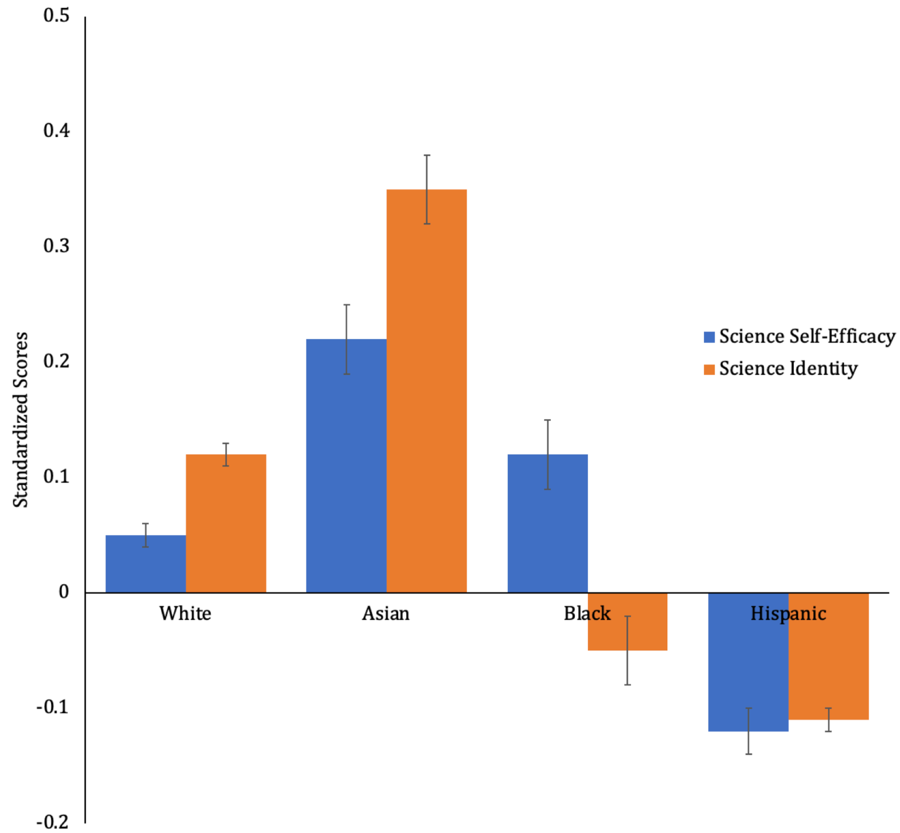


Note. Average science self-efficacy scores of 9th grade students (*N*= 14272)

To understand whether this pattern was unique to self-efficacy or universal across all science-related attitudes, I additionally explored science identity. A one-way analysis of variance (ANOVA) was conducted, with ethnicity (White, Asian, Black, Hispanic) as the predictor variable and science identity as measured on the composite scale as the outcome variable. The test assumed homogeneity of variances based on the results of a Levene's test of homogeneity of variances [$F(3, 14268)=4.9$, $p=.002$) The omnibus result indicated that it is not the case that the science identity is the same among the four groups [$F(3, 14268) = 76.21$, $p<.001$]. At a .05 alpha level, we have sufficient evidence to reject the null hypothesis that the average science identity is the same for White, Asian, Black and Hispanic 9th graders in this sample. Follow-up tests were conducted to determine which groups were responsible for the significant omnibus finding. Post hoc comparisons using the Tukey Honestly Significant Difference (HSD) test indicated that the mean science identity of Asian students (M=0.12, SD=1.0) was significantly higher than that of all other groups: Black (M=-0.05 SD=1.0), White (M=0.12, SD=1.0) and Hispanic (M=-0.11, SD=0.98). Notably, all of the pairwise comparisons were significant at the .05 alpha level except the difference between science identity of Black students and Hispanic students which were not significantly different from each other at the α=.05 level.

Figure 4

Mean Science Self-Efficacy and Science Identity



Evidence suggests that students' self-efficacy scores predict their achievement.

Two simple linear regressions were fit to the data to test whether self-efficacy predicts achievement in this sample of 9th graders, the first using math standardized test scores as the outcome variable and the second using science GPA as the outcome variable. Results indicate that science self-efficacy is a positive significant linear predictor of achievement using both standardized math test scores [b = 0.26, 95% CI (0.24,0.27), $t(14270) = 31.56$, $p < .001$] and science GPA [b = 2.70, 95% CI (0.25,0.29), $t(14270) = 33.31$, $p < .001$] as the outcome variable. In particular, for every one-unit increase in self-efficacy as measured by the science self-efficacy composite scale, there is a .26 unit increase in achievement as measured by the math standardized theta score. The standardized regression coefficient of 0.26, which is equivalent to a correlation coefficient of the same strength, indicate that self-efficacy is a moderately strong predictor of achievement. For comparison, meta analyses on self-efficacy and academic outcomes have found effect size estimates of 0.38 (Multon et al., 1991) and 0.33 (Holden et al., 1990). Self-efficacy also explains a significant proportion of variation in achievement using both standardized math test scores [R^2 = .07, R^2_{adj} = .07, $F(1, 14270)$ = 996,130, p <.001] and science GPA as outcome variables [R^2 = .07, R^2_{adj} = .07, $F(1, 14270)$ = 1109.99, p <.001]. In particular, self-efficacy explains 7% of the variation in achievement in a model where science self-efficacy is the only predictor.

Table 2

Multiple Linear Regression

Predictor	Unstandardized *b*	*t*	*SE*	95% CI Lower	95% CI Upper	*Standardized b**
Constant	0.09	9.74*	0.01	0.08	0.11	
White	0.28	28.11*	0.01	0.26	0.3	0.27
Asian	0.31	10.92*	0.03	0.25	0.36	0.09
Black	-0.58	-22.02*	0.03	-0.63	-0.53	-0.18
Hispanic	-0.44	-20.43*	0.02	-0.48	-0.4	-0.16
Self-efficacy x Asian	-0.03	-0.91	0.03	-0.08	0.03	-0.01
Self-efficacy x Black	-0.09	-3.47*	0.03	-0.14	-0.04	-0.03
Self-efficacy x Hispanic	-0.04	-1.73	0.02	-0.08	0.01	-0.02

Note. **p*<.001. Dependent variable is standardized science GPA. *N*= 14272.

Evidence suggests that the effect of self-efficacy on achievement is significantly moderated by student's race/ethnicity.

To understand whether the relation between science self-efficacy and achievement are moderated by the student's race/ethnicity, a multiple linear regression was fit to the data. The model was specified with achievement (as measured by the science GPA) as the outcome variable, self-efficacy (as measured by the composite science self-efficacy scale) as the focal predictor and ethnicity (White, Asian, Black, Hispanic) as the moderator. Self-efficacy was mean-centered and ethnicity was dummy coded with White as the reference group.

As expected based on the results above, the average achievement of White students (0.1) was significantly different from the average achievement of each of the other groups at the sample average science self-efficacy. The average achievement of Black students (-0.49) was significantly lower than the average achievement of White students (0.1) at the average self-efficacy [b = -0.58, 95%CI (-0.63, -0.52), t(14271) = -22.02, p <.001]. The average achievement of Asian students (0.4) was significantly higher than the average achievement of White students (0.1) at the average self-efficacy [b = 0.31, 95%CI (0.26, 0.29), t(14271) = 10.92, p <.001]. Lastly, the average achievement of Hispanic students (-0.34) was significantly lower than the average achievement of White students (0.1) at the average self-efficacy [b = -0.43, 95%CI (-0.48, -0.39), t(14271) = -20.42, p <.001].

Self-efficacy was found to be a significant predictor of achievement within each of the ethnic groups. Among White students, self-efficacy is a positive, significant predictor of achievement [b = 0.28, 95%CI (0.26,0.30), t(14271) = 28.11, p<.001]. In particular, for every one unit increase in self-efficacy as measured on the standardized self-efficacy composite scale, there is a predicted 0.28 unit increase in achievement as measured by the math standardized theta score. Among black students, self-efficacy is also a positive, significant predictor of achievement [b = 0.18, 95%CI (0.14,0.23), t(14271) = 7.44, p<.001]. In particular, for every one unit increase in self-efficacy among Black students, there is a predicted 0.18 unit increase in achievement. Among Hispanic students, self-efficacy was also a positive, significant predictor of achievement [b = 0.24, 95%CI (0.20, 0.28), t(14271) = 12.54 p<.001]. In particular, for every one unit increase in self-efficacy among Hispanic students, there is a predicted 0.24 unit increase in achievement. Lastly, among Asian students, self-efficacy was also a positive, significant predictor of achievement [b = 0.25, 95%CI (0.20, 0.30), t(14271) = 9.24, p<.001]. In particular, for every one unit increase in self-efficacy among Asian students, there is a predicted 0.25 unit increase in achievement. Thus, though self-efficacy was a positive and significant predictor of achievement in all ethnic groups, the strength of prediction was strongest for White (b=0.28), followed by Asian (b=0.25), then Hispanic (b=0.24) and lastly Black (b=0.18). Next, I tested the interactions to evaluate whether these differences were significant.

Indeed, ethnicity significantly moderated the relation between science self-efficacy and achievement. In particular, I found a significant interaction (at the .05 alpha level) between Black and White students [b = -0.09, 95%CI (-0.14, -0.04), t(14271) = -0.35, p<.001]. The relation between self-efficacy and achievement is not the same for Black and White students. Specifically, self-efficacy is a statistically significantly stronger predictor for achievement in White students than it is in Black students.

This multiple regression model including science self-efficacy and ethnicity as well as their interactions as predictors explains a significant proportion of variation in achievement [R^2_{multiple} = 0.14, Adj. R^2_{multiple}= 0.14, F(7, 14264) = 325.43, p<.001]. In particular, these two predictors together explain 14% of the variation in achievement.

I further specified the model by adding two variables that have been traditionally implicated in predicting achievement, namely socioeconomic status and gender. Doing so in a hierarchical multiple regression revealed that socioeconomic status explains a significant proportion (15.5%) of variation in achievement [R^2 = 0.15, Adj. R^2=0.15, F(1, 14270) = 2608, p<.001]. Gender explains a significant proportion of variation (2.6%) above and beyond socioeconomic status [ΔR^2=0.03, ΔF(1, 14270) = 451.6, p<.001]. Lastly, self-efficacy and ethnicity explain a significant proportion of variation (8.2%) above and beyond socioeconomic status and gender [ΔR^2=0.08, ΔF(7, 14262) = 255.72, p<.001]. The final model including socioeconomic status, gender, science self-efficacy, and ethnicity explains 26.2% of the variation in achievement [R^2_{multiple} = 0.26, Adj. R^2_{multiple}=0.26, F(7, 14262) = 225.72, p<.001].

CHAPTER 5: DISCUSSION

This thesis reports four major findings. First, I show evidence for significant differences in the average achievement scores of students from different racial/ethnic backgrounds, with Asian students scoring highest on achievement, followed by White students, then Hispanic students, then Black students. Second, I present evidence for significant differences in the average science self-efficacy scores of students from different racial/ethnic backgrounds with Asian students scoring highest on science self-efficacy, followed by Black students, then White students, then Hispanic students. Third, I find evidence to suggest that students' self-efficacy scores predict their achievement. Lastly, I present evidence that the relation between self-efficacy and achievement is not the same for individuals of all ethnicities, suggesting that race/ethnicity moderates this relation.

In 2012, The President's Council of Advisors on Science and Technology (PCAST) presented a comprehensive report on the current state of STEM education and a strategy for improving STEM education in college. The group found that to meet the economic demands as a nation, we would need approximately 1 million more STEM college graduates in the following decade than was projected. This translates to a necessary 34% annual increase in the number of undergraduates who receive STEM degrees (of Advisors on Science & (PCAST), 2012) Fewer than 50% of all students who begin their college careers with intentions to major in STEM disciplines complete degrees in STEM. The persistence rates are even lower for students from traditionally underrepresented backgrounds (Chen, 2014).

Many national reports have emphasized the importance of diversifying the STEM workforce. By 2050, adolescents from ethnic/racial minority backgrounds are projected to make up 62% of school-aged children. By 2025, the US population is expected to be 21% Hispanic, 58% White, 12% Black, 6% Asian, 1% Pacific Islander and 2% other. While is clear that our schools are becoming more diverse, STEM fields are not including students from underrepresented minorities at the rate that is necessary to meet our national goals. In 2013, Black individuals accounted for 12% of the US population but only 3% of the science and engineering fields workforce. Hispanics accounted for 16% of the population but only 4% of the science and engineering workforce (NSF, 2013).

Diversifying our STEM workforce is critical to our success as a nation in tackling the world's greatest challenges. Researchers have studied many factors that are thought to be related to the attitudes toward, achievement in and persistence in STEM in children and adolescents and have linked the attitudes and behaviors of children and adolescents to later persistence in STEM careers. This thesis aimed to understand the relation between self-efficacy and achievement in a nationally representative sample of 9th graders with a focus on the role that the student's ethnicity plays in the relationship between self-efficacy an achievement.

The Achievement Gap

The achievement gap in education is one of the most widely studied types of disparities in the United States(Christopher et al., 1998) This difference in academic performance between groups wherein one group or set of groups outperforms the other group or set of groups has been well documented in students of all ages. I began this thesis by exploring the achievement of 9th graders as indicated by their math standardized test scores and science GPA. Results presented here provide further support for the existence of the achievement gap among students of different ethnicities, with Asian students having the highest average scores, followed by White students, then Hispanic students and lastly Black students. The gap shows a clear divide with White and Asian students scoring higher and Black and Hispanic students scoring lower. These two groupings align with the traditional dichotomization of ethnicity in STEM, namely "URM" and "non-URM", with "URM" referring to students from backgrounds traditionally underrepresented in STEM. The achievement gap persists when we take into account the student's socioeconomic status as measured by the composite socioeconomic status score which supports prior research in this area (Brown-Jeffy, 2009; Hanushek & Rivkin, 2009; Harris & Herrington, 2006). Because we know that achievement in STEM is a strong predictor of persistence and degree attainment in STEM, understanding the achievement gap in education has sparked much work aimed at closing the gap. Most of work in his area has followed the URM vs non-URM dichotomization wherein students traditionally underrepresented in STEM (Black, Hispanic, Native American/Pacific Islander) are grouped together and those not traditionally underrepresented in STEM (White, Asian) are grouped together. When researchers subsequently propose targets of interventions based on this work, they do so with the goal of closing the achievement gap between URMs and non-URMs. Practically speaking, the dichotomization in our analyses and interpretations make sense, but what if by ignoring the identities and cultural backgrounds of the individuals that make up each of the subgroups, we are masking important differences that exist between the subgroups? In other words, what if not all subgroups who make up the "URM" group behave the same way? And in particular, what if they don't respond in the same way to interventions?

Understanding specific differences in science-related attitudes of individuals from different ethnicities has the potential to guide resource allocation and promote the design of interventions that are more efficacious. Those differences may lie in one of the predictors of achievement: self-efficacy.

The Self-Efficacy Gap

Self-efficacy is an individuals' judgement of their own abilities to successfully cope with a task at hand (Bandura, 1986). Self-efficacy has been found to enhance performance but has also been found to be a product of academic achievement, wherein higher academic achievement has a positive influence on one's self-efficacy (Bandura & Locke, 2003). Results presented here show that unlike achievement, where the groups traditionally grouped together and labeled URM (Hispanic and Black students) are the lowest-ranking and those traditionally labeled non-URM (White and Asian students) are the highest performing, the pattern for self-efficacy is a bit more nuanced and perhaps unexpected. Here I find that although the average achievement scores of both Black and Hispanic students are below the sample average (as expected based on prior research), the average science self-efficacy for Black students is above the sample average for science self-efficacy and significantly above the average science self-efficacy for both White and Hispanic students. These results reveal a mismatch, or miscalibration, between self-efficacy and achievement specifically for Black students wherein their science self-efficacy is high but their achievement is low. I explored this further by testing whether self-efficacy differentially predicted achievement for students of different ethnicities.

Does Self-Efficacy Predict Achievement?

One of the goals of this study was to understand whether, in this nationally representative sample of 9th graders, self-efficacy predicted achievement. Additionally, I was interested in understanding whether the relation between self-efficacy and achievement differed depending on the ethnicity of the student. Prior research has associated high self-efficacy with higher academic performance and goals of majoring in STEM fields and subsequent higher rate of employment in STEM fields. Lack of self-efficacy, on the other hand, has been documented as an explanation for the low representation of racial/ethnic minorities in science (Navarro et al., 2007).

To understand whether self-efficacy was a significant predictor of achievement in this sample of 9th graders, a linear regression model was fit to the data with self-efficacy as a predictor and achievement as the outcome. Results indicate that indeed, self-efficacy was a significant predictor of achievement, which makes sense given the wealth of data in the field implicating self-efficacy as one of the many predictors of achievement. Results here corroborate previous research suggesting that in general, as students' beliefs in their own ability to succeed increases, so too does their performance. Education interventions have thus targeted the enhancement of science self-efficacy as a method to increase achievement in STEM. But is this link universal across all students? Surely if it is not, then we expect that this type of intervention would work for some and not others.

To understand whether this relation between self-efficacy and achievement changes as a function of ethnicity, I included ethnicity as a moderator in a multiple linear regression. At the average sample self-efficacy, the average achievement scores of each ethnic group was significantly different from each of the others. The results, as expected, indicated that the average achievement scores for Asian students was highest, followed by White students, then Hispanic students, then Black students. Additionally, for each ethnic group, self-efficacy was a positive significant predictor of achievement. Interestingly, the degree to which self-efficacy predicted achievement was not the same across the various ethnicities. Specifically, self-efficacy was found to predict achievement with the greatest strength in White students, followed by Asian students, then Hispanic students, then Black Students. A statistically significant interaction between White and Black students reveals that whereas a one-unit increase in science self-efficacy predicted a .28 unit increase in GPA in White students, the same increase in science self-efficacy predicted only a 0.18 unit increase in GPA in Black students. Taken together, this suggests that while increasing self-efficacy in all children is associated with a predicted increase in achievement, the degree to which self-efficacy increases achievement is not the same across students from different ethnicities.

Limitations

There are several limitations to be mentioned. First, this study uses mathematics standardized test scores (taken in 9th grade) and overall high school science GPA as measures of achievement. Both are used because each have their limitations. The study focuses on science self-efficacy which in this survey is a composite score made up of questions that measured the student's judgement of their confidence in being able to do an excellent job in their current science class. The ideal outcome variable to use would be grade in that specific science class, which is unfortunately not available. I will instead justify the use of the two imperfect outcome variables that were used here. Math standardized test scores are used because they are a measure of STEM achievement that was acquired during the same term that the survey was administered. It is imperfect because it measures math and not science and measures performance on a standardized test rather than a course. Science GPA was used because it more closely aligns with the science self-efficacy judgements which refer to the students' confidence in their ability to do well in the science course in which they were enrolled. It is imperfect because it captures that science course's grade but in addition also captures the science class grades for the entire high school transcript. For those individuals for whom the 9th grade science course grade was not representative of their overall high school science GPA, this measure may not accurately capture the relationship between science self-efficacy and achievement.

This study utilizes data from the first wave of the HSLS:09, administered in the Fall of 2009 and thus is cross-sectional in design. This presents a limitation due to the inability of the data to determine temporal links between science attitudes and achievement.

CHAPTER 6: IMPLICATIONS, CONCLUSIONS AND FUTURE DIRECTIONS

Student self-efficacy in science has been identified as a target of intervention in efforts aimed at closing the achievement gap and increasing the number and diversity of students entering and persisting in STEM disciplines and careers in the United States. Much of the previous research designed to understand self-efficacy has failed to account for ethnicity or has examined the phenomenon within individual ethnic groups. Few have compared self-efficacy among individuals from different ethnic backgrounds and those that have taken ethnicity into consideration have dichotomized the various groups into two: those groups that make up the underrepresented minority (URM) in STEM and those that don't (non-URM). If we follow the traditional dichotomization of ethnic groups into URM and non-URM, where we group Black and Hispanic students together, and White and Asian students together, and we compare their average on science self-efficacy, we find significant differences: non-URM students have higher self-efficacy than URM students. This is not surprising and has been shown before. Researchers, educators and policy makers have taken this data as an indication that self-efficacy is lacking in individuals who make up the "URM" group, and thus have designed interventions and policies aimed at increasing self-efficacy among students from ethnic backgrounds traditionally underrepresented in STEM. But the story may not be as clear as it seems. When we look closer at each of the subgroups that make up the often-used URM and non-URM groups, as was done in this study, we uncover important differences that have valuable implications for educators and policy makers. Contrary to what one might imagine given the low average achievement scores of Black students and the long history of oppression and systemic racism that exists in the United States, we find that Black students are actually not lacking in science self-efficacy. In fact, this study shows that Black 9th graders' science self-efficacy is not only higher than that of Hispanic students, it is also higher than that of White students. While several reports have compared self-esteem among White and Black students and have found self-esteem to be equal or higher in Black students than White students (Bachman et al., 2011; Crocker & Major, 1989) these comparisons in domain-specific self-efficacy are lacking. Here I report that on average, while increasing self-efficacy in a White child by one unit might increase their achievement by almost .3 GPA points, doing the same with a Black child will only increase their achievement by almost .1 point.

Even though Black students have one of the highest average scores on science self-efficacy, their achievement scores are the lowest of any of the groups. How can this be, if self-efficacy has been known for many years over many studies to be a positive predictor of achievement? When I explored the relation between self-efficacy and achievement, I found that strength of the relation between the two was not the same across the four ethnic groups. Whereas self-efficacy is a very strong predictor of achievement in White students, it is a moderate predictor of achievement in Asian and Hispanic students and a weak predictor of achievement in Black students. Though self-efficacy was still a significant positive predictor of achievement in Black students, the strength of the prediction was significantly weaker for these students than for White students. To understand why this might be the case, it is worthwhile to return to an exploration of the mechanisms by which self-efficacy is thought to be related to achievement. Self-efficacy has been though to play an important role in the initiation and maintenance of behavioral change (Bandura, 1986; Hill et al., 1987; Locke et al., 1984). Bandura posits that optimistic self-efficacy, or "overconfidence" in abilities to complete a task promote achievement, incongruence between self-efficacy and achievement can be problematic. In his discussion of self-efficacy calibration in students with learning disabilities, Klassen suggests that optimistic self-efficacy may “lead to poor preparation, ineffective self-advocacy and a lack of awareness of one’s own strengths and weaknesses” (Klassen, 2006) Self-efficacy judgements are metacognitive activities that require awareness and knowledge of the self and of the task at hand and perhaps this in this metacognitive awareness lies a potential target for intervention for individuals who display this miscalibration between self-efficacy and achievement.

Self-regulated learning was defined by Zimmerman in 1986 as the process by which students are “active participants” in their learning (Zimmerman, 1986). For a belief in one’s ability to accomplish a task (self-efficacy) to translate into performance, or academic achievement, students must be able to monitor their performance and use that information to reassess and perhaps modify their self-efficacy, goals and strategies (Dent & Koenka, 2016; Zimmerman, 1990). It is possible that the mismatch that we find in this study between self-efficacy and achievement is a function of a miscalibration in this feedback loop wherein negative performance does not lead to re-evaluation of self-efficacy and modification of goals and strategies.

Research on cultural differences in the attributions that students make for their performance may also shed light to the mismatch between self-efficacy and achievement found here. Much of the work in this area has used self-esteem, not self-efficacy but some have investigated academic self-esteem which seems to be a closer correlate to self-efficacy (Van Laar, 2000). Weiner’s attributional theory of achievement, motivation, and emotion proposes that attributing low performance to external causes rather than internal causes protects self-esteem (Weiner, 1985). Experimental studies have shown that self-esteem can be protected when individuals attribute negative feedback to external causes rather than internal ones (Crocker et al., 1991; Dion, 1975). It is possible that the unique pairing that we are seeing, of high self-efficacy but low achievement in Black 9th grade students might be due to their attributing low achievement to external factors, which may protect their self-efficacy. Future studies should explore the relation between science self-efficacy and achievement through the lens of attribution theory.

This thesis was guided by the urgent need to increase the size and diversity of our U.S. STEM workforce. While the intention to tackle this problem from educators, funding agencies and policymakers exists and the resources are available, knowing how to affect change of this magnitude in something as complex as education in a country with over 50 million children enrolled in public schools is not an easy feat. The 'leaky pipeline' metaphor has been a useful tool to understand where in the academic trajectory to focus our efforts. Theories of human and career choice development additionally guide intervention work by helping us to understand factors that may be viable targets. Unfortunately, the pressure to produce significant outcomes at scale promotes a one-size-fits-all approach. By ignoring the many complex contextual factors and interconnected systems in which the student develops, we risk missing the very factors that, if manipulated, could make the most impact.

I have shown in the work presented here that the impact of science self-efficacy on achievement is moderated by race/ethnicity. This effect persists after controlling for gender and socioeconomic status. Specifically, increasing self-efficacy among Black high school students is not associated with the same level of increase in achievement as in White, Hispanic and Asian high school students. Further, Black high school students in this sample had the second-highest average scores on self-efficacy and the lowest average scores on achievement. This miscalibration calls into question whether interventions focused on increasing science self-efficacy in Black high school students would be as effective at increasing achievement as it is in the other ethnicities studied. These results have far-reaching implications for educational interventions and strongly suggests that culture and context-specific strategies should be employed rather than more generalized approaches. This work is an important step in understanding the complex relations among determinants of STEM achievement across cultures. Future studies should attempt to understand the race-specific educational developmental trajectories for self-efficacy that would allow us to develop tailored educational interventions for increasing achievement and persistence in STEM. Longitudinal analysis and work that includes not only the factors at the individual level but also incorporates factors related to the parents, peers, teachers and school would be immensely valuable to the development of interventions.

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