Representation and Retention in the Sciences
Investigating Inequities at a Minority-Serving Institution

BY

STEPHANIE M. WERNER
B.S., University of Iowa, 2015

THESIS

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Defense Committee:

Mike Stieff, Chair and Advisor
Donald Wink
Laura Anderson
Sue Farruggia, Student Affairs
Yue Yin, Educational Psychology

Dedicated to my loving mother and best friend

Maureen F. Werner

For always supporting my dreams, wherever they take me

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LIST OF ABBREVIATIONS

AIAN	American Indian/Alaska Native
ASCIv2	Attitudes towards the subject of chemistry inventory, version 2
CSWS	Contingencies of self-worth scale
DBER	Discipline-based education research
DEI	Diversity, equity, and inclusion
DFW	Proportion of grades that are a D, F, or W(withdraw)
HBCU	Historically Black colleges and universities
HSI	Hispanic-serving institution
ITI	Implicit theory of intelligence
MSI	Minority-serving institution
NHPI	Native Hawaiian/Pacific Islander
NSF	National Science Foundation
STEM	Science, technology, engineering, and mathematics
URM	Underrepresented minority

SUMMARY

Using a mixed-methods design, I conducted three studies to understand why marginalized students, specifically Black/African American and Hispanic/Latinx, leave the sciences. Specifically, I present two sides of the persistence (or lack of) story: the institution and the student. Study 1 focuses on the institution and the three science disciplines under study, chemistry, biology, and physics. Study 2 and 3 follow up by focusing on the students, their attitudes towards science and themselves, and their perspective on the state of diversity and inclusion in the sciences.

To accomplish the institution-related goals of this dissertation, I collected and analyzed registrar data from a Hispanic-serving institution in Study 1. Study 1 consisted of a three-tier analysis of science degrees awarded, science majors, and introductory science courses. In the degree-level analysis, I found that representation of science degrees awarded every year to marginalized students varies wildly, whereas science degree representation among White students was more stable over thirteen years across chemistry, biology, and physics. Additionally, female students were more likely to attain a degree in biology, rather than chemistry, compared to their male peers. Most notably, physics had significantly less degrees awarded every year than the other two science disciplines, with no Black/African American female physics degree holders in the dataset. In the major-level analysis, I found that Hispanic and Black/African American female students were leaving all science majors investigated at a higher rate than other demographic groups and going largely to non-STEM majors. Finally, in the course-level analysis, I found that marginalized students were statistically more likely to fail all twelve introductory science courses than their White peers. When investigating two tracks to complete the introductory chemistry sequence, marginalized students were significantly less retained from course to course compared to their White peers.

Study 2 began the investigation into the students and how they view science as being diverse and inclusive. I designed a 60-item survey measuring affective constructs including attitudes towards science, science identity, self-worth, self-doubt, and theory of intelligence. A total of 377 undergraduate science students from twelve introductory chemistry, biology, and physics courses completed the survey in Spring and Fall 2019. I analyzed student responses two ways. First, I analyzed how students different on affective measures as a function of their self-reported midterm grades (pass vs. fail). I found that students who were passing their science course scored higher on emotional satisfaction of science and science identity, whereas students who reported failing grades scored higher on self-doubt. The second analysis completed consisted of a cluster analysis of all affective constructs. This grouped students together based on shared affective characteristics, with six distinct clusters formed. I found that students in two clusters differed significantly on several factors. The *Science Enthusiasts, High Contingency* cluster had significantly higher proportions of students with passing midterm grades and higher proportions of students coming from high income households. The Science Neutral, Low Contingency cluster had significantly higher proportions of students who reported failing midterm grades, low/median household incomes, and no high school influences to major in science. This study showed associations between affective traits and science course grades, which in turn gives way to linking affect to persistence.

The final study of this dissertation turned to individual students and their experiences within science courses and majors. In Study 3, I interviewed five women of color who had all received a D, F, or withdrew from an introductory chemistry, biology, or physics course. Using constant comparative analysis, I coded the interview transcripts. From these codes I found five emergent themes contributing to the departure of these women from their science courses: sense

of belonging, social capital and influences, instructor and TA interactions, and college readiness. The fifth theme, chemistry compared to biology and physics, was applied by me and not the interview subjects' experiences because of the multi-disciplinary focus of this dissertation. Though all these students cited both positive and negative experiences that contributed to their persistence or departure from a science course or major, the main finding from this study was that no subject cited one specific instance that made them leave the sciences. Rather, it was the culmination of many adverse experiences with course content, people from academia, and environmental factors that made them leave the sciences. Overall, this dissertation accomplished its goals of investigating inequities marginalized students face in the sciences. The institution and the individual student play different roles in the persistence of students and are both important in understanding the large disparities marginalized students endure in the scientific community.

CHAPTER I: OVERVIEW

Problem Statement

The issue of persistence is not one sided. Indeed, there are several factors that contribute to the pushing or pulling out of marginalized students in science, technology, engineering, and mathematics (STEM). Societal systemic racism infiltrating the education system and scientific community has built barriers for marginalized students to disallow equitable access to resources and opportunities, which effect student's views of science more broadly. Identifying the problems in institutions and correcting the injustices of inequities on students brings promise of an inclusive and diverse scientific community where all voices are heard. Increasing diversity in STEM has been a "hot topic" for various educational, research, and governmental groups for some time. Expansive reports warn of a potential lack of global competitiveness because of the underrepresentation of underrepresented minority (URM) students in STEM.[1–4] However, there is still substantial inequity in the representation, retention, and persistence of marginalized groups in the sciences.

Though the United States has become more diverse in recent decades, the STEM fields have not kept up with the everchanging landscape. As of 2016, the U.S. Census Bureau reported that the racial/ethnic minority population of the United States is 17.8% Hispanic or Latino and 13% Black or African American.[5] However, the National Science Foundation (NSF) reported that as of 2016, of bachelor's degrees awarded in physical sciences, students that identify as Hispanic/Latinx make up 9.3% and Black or African American students 4.6% of the degrees. For biological sciences, students that identify as Hispanic make up 11.5% and Black or African American students 6.5% of the bachelor's degrees awarded.[6] While URM representation in the sciences in 2016 was at its highest, there is still room for significant improvement. When only

considering gender, the same data shows that, regardless of race or ethnicity, women are better represented in the biological sciences than the physical sciences, with just less than 60% of women represented in biological sciences compared to 40% of women represented in the physical sciences. Moreover, within the physical sciences, women represent only 19% of the degrees awarded in physics.[6]

The scarceness of diversity in STEM results from diverse factors: primary education, secondary education, post-secondary education, the political climate of the country, and affective attributes all contribute to the underrepresentation of specific groups.[3,7–11] Recent analyses from NSF indicate that in their freshman year, students from all races and ethnicities express similar intents to major in a STEM discipline.[12] This data aligns with other studies that show minority students are equally represented, and even close to that of their White peers, in STEM majors during their first semesters at university. However, these same studies show URM representation plummets among degrees awarded in these fields.[7,13,14] In addition to the aforementioned factors contributing to the inadequacy of diversity and equity in STEM, course level issues, curriculum, degree requirements, socio-affective issues, and individual differences also play a role.[11,15–19]

While prior research has highlighted the importance of sense of belonging, motivation, interest, and engagement to persist in the sciences, scholars have not fully explored how these affective traits (1) play a role in the decision-making process to leave a discipline or (2) explain the differences between those that pass a course compared to those that fail. Furthermore, at the national level, the broad categories of “physical” and “biological” sciences are unequal in their representation of URM students. These numbers give an inexact and incomplete description of individual disciplines. There is no research on individual disciplines compared to others. This dissertation seeks to fill those gaps. The overall goal of this dissertation is to provide a

comprehensive comparison of three STEM sciences (chemistry, biology, and physics) at a minority-serving institution and their individual roles in the exclusion or inclusion of marginalized students, specifically Black/African American and Hispanic/Latinx female and male students.

Purpose

The purpose of this dissertation is to understand why marginalized students leave the sciences. As previously eluded to, the answer is not one-sided. Thus, in this dissertation, I present two sides of the persistence (or lack of) story: the institution and the student. Study 1 focuses on the institution and the three science disciplines under study, chemistry, biology, and physics. Study 2 and 3 follow up by focusing on the students, their attitudes towards science and themselves, and their perspective on the state of diversity and inclusion in the sciences.

For Study 1, I use an experimental design to compare the representation and retention of different racial/ethnic and gender groups in three science disciplines. Two research aims are addressed in Study 1. The first aim is to attain a comprehensive comparison of chemistry, biology, and physics and their respective representation and retention of URM students. Data from students in each of these disciplines describe the overall state of diversity and how the disciplines differ from one another. The second aim is to investigate three time points at which equitable representation of URM students is essential to diversifying the disciplines. Looking at three time points in a discipline reveals either continued or interrupted commitments to equitable diversification and retention.

Study 2 and Study 3 turn to the students for developing a detailed description of their attitudes, beliefs, and experiences in science through affective surveys and one-on-one interviews to understand the other side of persisting. The aim of Study 2 is to characterize how

student's view themselves, academics, and science in order to understand why some students fail a course where others succeed. The use of clustering students of shared affective traits and exploring their differences in various demographics link how a student's affect is associated to their course outcome. Study 3 then uses the findings of Study 2 to inform one-on-one interviews that seek to understand student's experiences in the science classroom and major. The aim of Study 3 is to understand the URM student experience of not persisting in the sciences.

Theoretical Approach

Group membership and persistence

I chose to study the issue of persistence of marginalized peoples in the context of STEM because of my own personal background in STEM and because of the position STEM has in society. First, coming from a background in chemistry and experiencing several STEM disciplines as an undergraduate, I observed (and experienced to a much lesser extent than others) the inequities in place for people from historically marginalized backgrounds at my predominately White undergraduate institution. This made me wonder how experiences of marginalized people are affected at universities of different demographics or where marginalized people are in the majority. Second, STEM careers hold a prestigious position in our society and come with social as well as economic capital. If those careers are being held predominately by White professionals due to racial systemic barriers (i.e. opportunity hoarding), historically marginalized groups are not gaining access to those careers most prized today. It is important to understand why marginalized peoples are not persisting in STEM because equitable opportunities in enter and persist in STEM are essential to advancing society.

In this dissertation, I focus on two racial/ethnic groups and their persistence in science: Black/African American and Hispanic/Latinx students. I chose these groups for several reasons.

First, the institution at which this dissertation was conducted is racially/ethnically diverse as described above. Over one third of the undergraduate population identifies as Hispanic/Latinx and eight percent identify as Black/African American. Studying these groups at an institution that is situated in a diverse city bring a context to the research that is not typically seen at other institutions that are primarily White. Second, while I had access to the registrar's complete database with students of all races/ethnicities, these groups are the most compelling to analyze given they had adequate population sizes to meet statistical assumptions. American Indian/Alaska Native (AIAN) and Native Hawaiian/Pacific Islander (NHPI) are two groups that do not receive much attention in persistence literature but are difficult to study at this institution because they make up a relatively small percentage of the student body. Further, the inclusion of Asian students as a "minority group" is controversial in this field. While some argue they are overrepresented in STEM, others argue that "Asian" encompasses many groups that are not all represented equitably. In the context of this institution, Asian students are represented just as much, if not more, than White students in STEM. Thus, the reference groups could be either White students or Asian students. In this dissertation, I treat White students as the reference group because of their prevalence in the literature as the standard reference group. This allows for better interpretation and comparison between my research and existing studies.

The intersectionality component to of this research allows for comparison of racial/ethnic and gender groups simultaneously. For example, if NSF only considered women when considering representation among physics degree recipients, they would report that in 2016 almost 20% of all bachelor's degrees went to women.[6] While that number is low for women in general, it is especially low for women of color. What that statistic does not show is that only 3% of physical science degrees went to Hispanic/Latinx women and 2.5% were earned by

Black/African American women in that same year.[6] The first dataset that focused on only gender, hides the fact that Hispanic/Latinx and Black/African American women earned disproportionately less degrees than other women, mainly White and Asian. Intersectionality highlights groups that are otherwise buried in a sea of data that is attributed to only one of their identities. More and more researchers are opting for intersectionality when studying identity and its link to persistence because of the added robustness to the analysis and meaning.[7,20] I follow the same theoretical approach and analyze all data with an intersectionality lens, when applicable. Even though intersectionality is the goal, as will be seen in Chapter 3, some statistical differences seen between demographic groups can be explained by only gender or only race/ethnicity. However, when cell sizes allow for disaggregation into the intersectionality groups, I do explore the differences of women of color and men of color compared to their White peers.

Group membership is also important when considering persistence in the three disciplines. As noted above, I engage in a cross-disciplinary analysis of three science disciplines: chemistry, biology, and physics. The previously mentioned NSF data provides evidence that even the broad categories of "physical" and "biological" sciences are not equal in their URM representation when compared to each other (e.g. biological sciences representing slightly more URM students than the physical sciences)[6] and there is no data source that compares the disciplines at individual levels to establish if one discipline is carrying the lion's share of the diversity (or lack of). Thus, demographic group membership persistence in each of the disciplines offers a way to effectively compare students of shared racial/ethnic and gender identities across science.

Mixed methods approach

To consider the theoretical approaches fully, I employed a mixed methods design across three studies. A mixed methods design incorporates data and analyses of different natures, mainly quantitative and qualitative. The multitude of methods in this dissertation give way to a complex approach of analyzing a complex problem. The quantitative methods of Study 1 describe the state of diversity and equity of the institution. Study 2 uses a mixed methods approach for the inquiry into student affective traits before Study 3 concludes with a qualitative design of examining student experiences in the three science disciplines.

Research Questions

This dissertation examines both the institution and students to better understand the reasons motivating marginalized students to leave the sciences. I poised Study 1 to inspect various levels of the institution where URM representation could be affected. After a detailed characterization of the university, I sought to understand individual students (specifically, their attitudes, beliefs, behaviors, and experiences) and the factors that led them to fail, withdraw, or leave a science discipline.

To achieve the aims previously posed for Study 1, I designed a three-tier investigation into the institution that considers three time points at which representation and retention matter: when degrees are awarded, when students select a major following a switch, and when students are enrolled in introductory courses. The first inquiry of Study 1 is into the degrees attained by URM students. By using institutional data, I characterize the representation of URM students who receive a science degree over a thirteen-year period at a Hispanic-serving institution. To achieve the purposes of the inquiry of degrees awarded, three research questions are asked:

D1. *How are underrepresented minority students represented among chemistry degrees compared to biology and physics?*

D2. *What is the likelihood that underrepresented minority students attain a degree in chemistry compared to biology and physics?*

D3. *Have the levels of representation of underrepresented minority students changed over time in chemistry compared to biology and physics?*

At some point in their undergraduate career, many students switch majors whether it be within a field but different discipline (e.g. from chemistry to biology) or switch to another field altogether (e.g. from chemistry to economics). The purpose of major inquiry is to understand the various switching patterns students, specifically URM students, follow when either entering or leaving STEM fields. Thus, the research question for this analysis is:

M1. *Who switches in or out of the STEM degrees?*

Lastly, I follow up analyzing the discipline at large (between majors and degree holders) by studying the environments most commonly experienced by students, the courses. To do this, I examine introductory science courses for equitable representation and retention of URM students. Further, using chemistry as a model, I investigate the introductory sequence in detail to pinpoint when URM students leave chemistry. To achieve these purposes, two research questions are put forth to study issues within individual courses:

C1. How are underrepresented minority students represented among chemistry courses compared to physics and biology?

C2. When do underrepresented minority students drop out of chemistry?

Study 1 allows me to characterize the state of representation and retention of marginalized students, and Study 2 and 3 builds upon those findings to better understand the individual differences in students that contribute to their decision to leave the sciences. The overarching why question is driven by two research questions for Study 2 and Study 3, each taking focus of students' attitudes, beliefs, values, and experiences.

- *Why do underrepresented minority students leave the sciences?*

  S2. How do socio-affective characteristics affect persistence in chemistry, biology, and physics courses and disciplines?

  S3. What are the common personal experiences of underrepresented minority students who fail, withdraw, or leave a chemistry, biology, or physics course or major?

Considering the various research questions posed for this dissertation, I engage in a mixed-methods design of the three studies to incorporate the different perspectives of the same problem: URM persistence in the sciences.

Methodology

As previously noted, a mixed-methods design addresses the research questions for two sides of the persistence paradigm. The mixed-methods approach allows for the quantitative study

of institutional data but also the quantitative and qualitative nature of the data provided by individual students in surveys and interviews. As URM persistence in the science is a complex problem that many have tried to understand completely, a more sophisticated approach, such as mixed methods, may fill the gaps in our understanding. The methodological approaches for each of the studies is described further below. Then, I discuss the institutional context for this research. Lastly, I enumerate the various sources of data used in each study.

Study 1

Study 1 uses a between-subjects experimental design to analyze institutional registrar data to determine the representation of marginalized students in three science disciplines. The between-subjects design compares subjects of different groups. Throughout Study 1, I analyze science courses, majors, and disciplines by comparing students of different demographic groups; specifically, the intersection of gender and race/ethnicity. Moreover, White students, both female and male, are situated as reference groups (or control groups) to which I compare URM students. Because this data was collected from the university's registrar, I had access to the total population of students that met the criteria (known race/ethnicity and gender in the specified courses), not just a sample of the population. Because I am characterizing the state of representation and retention of URM students at a specific institution using the entire population and not a sample, both descriptive (i.e. measures of central tendency) and inferential (e.g. hypothesis testing and regression analysis) analyses were used to answer the research questions of Study 1. Several statistical models were used in these analyses which are described in further detail in Chapter 3.

Study 2

Study 2 uses a mixed-methods design to analyze survey responses and describes the differing affective patterns of students in a meaningful way. In this dissertation, the survey is used for descriptive and exploratory research into the affective characteristics of undergraduate science students. A survey is an effective means by which one can measure unobservable data (such as affective traits, attitudes, and beliefs) for a large population.[21] I designed a survey that measures several constructs, each of which have been previously analyzed for validity and reliability.

Survey responses are used to calculate a score for each construct subscale. Measure scores link to a construct classification which captures a student's association to that construct. I use hierarchical cluster analysis to group students based on shared affective characteristics. Cluster analysis has been used previously in discipline-based education research (DBER) to characterize students as at-risk[22], low affective towards chemistry[23], and high chemistry self-concept[24] for example, based on multiple variables, which made it a seamless fit to the analysis of the affective traits measured herein. Once the clusters are distinguished from one another, I qualitatively describe each cluster based on how each construct manifests, how each cluster is unique, and label them to match their student membership. Lastly, I refer to descriptive, quantitative analyses to examine how clusters differ from each other on various demographics and individual differences.

Study 3

Study 3 uses one-on-one semi-structured interviews to understand the student experience of persisting (or not) in a science course or major. Semi-structured interviews include pre-

decided questions for all interview participants but allows the researcher to ask follow-up questions unique to the individual being interviewed. By doing this, I capture the similarities and differences between each student experience. Moreover, I use purposeful selection of interview participants so that I interview the students of interest to this dissertation. Interviewing only Black/African American and Hispanic female and male students narrows the focus to the students of interest and their relative experiences.

Study 3, having purely qualitative methods, is dependent on my interpretation to make sense of the data I collect and not to use it for predicting or generalizing all student experiences. I use a constant comparative approach, based in grounded theory, of classifying the text of the interview transcripts to codes that have meaning to higher themes.[25,26] After the open coding phase of identifying underlying themes within the codes, I move on to axial coding where the code categories and themes identified are grouped to explain the phenomena under study.[27] This thematic analysis focuses on the shared experiences of the interview participants which provide a better understanding of their decision to persist or leave a discipline.

Institutional context

This dissertation gathers data from a large, urban university in the Midwestern United States. The results discussed herein are therefore situated within the context of this institution and its respective student body. As of Fall 2019, the university's undergraduate student population was 34% Hispanic/Latinx, 26% White, 20% Asian, 8% African American, 7% International, and 5% Other.[28] Almost forty percent of students are first-generation college students, which means the students' parents or guardians do not possess a four-year college degree. Sixty percent of undergraduate students here are eligible for a Pell Grant[28]; a federal

education grant that is awarded to students whose family makes less than $60,000 income annually and are thus considered low-income.[29] A quarter of all undergraduate students are STEM majors,[28] defined at this institution as majors in chemistry, biology, physics, earth and environmental science, neuroscience, computer science, engineering, and math.

This institution is fairly unique in its characteristics, which is fully considered when interpreting results. Because of its diverse population, this institution is considered a minority-serving institution (MSI), which means this institution serves high enrollments of racial and ethnic minority and low-income students.[30] More specifically, this institution also carries the designation of a Hispanic-serving institution (HSI), because at least 25% of its enrollment is full-time undergraduate students who identify as Hispanic/Latinx.[31] These distinctions are important because extant research shows that MSIs produce disproportionately large numbers of college graduates and STEM degrees for racially/ethnically marginalized students compared to those same groups at predominately White institutions.[6,32,33] Thus, issues of diversity, equity, and inclusion (DEI) at this university should be different than those reported in the literature that are based at predominately White institutions. Interestingly, there is little research existing on DEI issues at MSIs, so this work will contribute to the growing interest and understanding of specific practices and attributes MSIs have that cultivate high numbers of marginalized STEM graduates.[34,35]

Data sources

To address the aims of this dissertation and answer the research questions, three sources are used to collect the necessary data. For simplicity, I describe how each data source is used in their respective studies.

For Study 1, I use registrar data obtained from this institution. The data includes anonymized student records of their demographic groups, course enrollment, final grades, and major declaration by academic year. Three databases were formed from the registrar data to tailor to each of the three aims of Study 1. The entire data set for the interest demographic groups and disciplines or courses serve as the population for the quantitative methods used herein this study.

In Study 2, I collect student self-report information via an online survey. This data includes demographic information, self-reported academic measures, list of social influences, and responses to five reliable and valid affective instruments. The combination of the demographic and self-report measures along with student responses to the affective instruments provide sufficient data to examine the relationship between affective characteristics and other individual differences students possess.

For Study 3, the primary source of data comes from the transcripts of semi-structured one-on-one interviews. Four of the five interviews were recorded (either audio, video, or both) and transcripts were written from the recorded interviews. Technical issues with the recording for one interview led to the loss of that data. However, my detailed notes from the interview serve as the data for that participant. The data from each participant serves as the basis for the analytic process by which I describe the experiences of marginalized students in science.

Organization of the dissertation

This dissertation is organized by first reviewing the extant literature, then introducing and presenting the results of Study 1, 2, and 3 and concluding with a general discussion and implications for this research.

In Chapter II, I begin by describing the current state of inequity in STEM. I then enumerate the inadequacies of existing explanations of attrition, namely the flawed "leaky pipeline" metaphor and lack of intersectionality in the literature. Next, I describe the various factors that have been used to explain persistence, particularly student affect and contextual differences. Lastly, I explain how existing literature influenced each of my three studies to investigate the representation, retention, and persistence of marginalized students in the sciences.

In Chapter III, I introduce Study 1. I begin by defining the large registrar databases used to address my research aims and answer the research questions. I then detail the three-tier analysis which describes the state of the chemistry, biology, and physics disciplines at the degree-level, major-level, and course-level. I establish clear differences in representation and retention of students at every level between and within the science disciplines.

In Chapter IV, I introduce Study 2 by illustrating how various affective constructs in extant literature come together to form an instrument I designed to measure students' science identity, attitude towards science, growth mindset, self-doubt, and self-worth. I use the responses to group students of similar affective traits. I demonstrate how affective cluster memberships are related to demographic groups (intersection of gender and race/ethnicity) and individual differences (midterm grade, income level, social influences, and discipline).

In Chapter V, I introduce Study 3 by presenting five interview participants whose experiences in science courses contribute to the understanding of persistence of marginalized students in STEM. I detail several emergent themes shared by the students that contributed, in some way, to their persistence or decision to leave a chemistry, biology, or physics discipline or major.

Finally, in Chapter VI, I conclude this dissertation with a synthesis of the findings from the three studies and the global contributions my dissertation makes to the research community. I end with possible future directions of this research and a call to action for the scientific community to continue the pursuit of equitable representation and persistence of students of color.

Racially motivated systemic barriers have prevented marginalized students from being equitably represented and retained in the sciences. Despite exhausted efforts from researchers and policymakers to combat these inequities, the gap in degree attainment continues. This three-study dissertation uses a mixed-methods approach, guided by the science persistence literature, to investigate the unique contributions chemistry, biology, and physics each make to the representation, retention, and persistence of marginalized students at a Minority-serving institution.

CHAPTER II: LITERATURE REVIEW

As discussed in Chapter I, many studies (including those using national data) show little difference, if any, between White and non-White students intent to pursue a STEM major at the start of college.[7,13,14,36] However, the persistence gap widens after the first year and reaches severe disproportions of representation at degree attainment.[7,13,14] This would be an example of a "juncture" where students "leak" from the "pipeline". The "leaky pipeline" metaphor describes the pathway, or "pipeline", of students interested in STEM that begin in primary school, progress through secondary school and post-secondary education, and finally flow into the workforce. What makes this pipeline leaky is that some students leave this pathway at certain timepoints before entering the STEM workforce. The gaps in degree attainment show that racial/ethnic minority students and women "leak" from the pipeline more frequently than White and male students.

Gender differences in science interest and plans to pursue start at an early age with perpetuating stereotypes of who belongs in various science disciplines that carry on well into high school and beyond.[37–41] If one were to only consider gender, the greatest disparities exist in physics, where few women hold degrees or pursue the discipline; whereas chemistry and biology, for example, are nearly equal to one another and have half or more of their respective degrees being awarded to women.[6] However, there are also racial/ethnic disparities at play in the sciences. Also briefly noted in Chapter I, URM students are not as represented in the sciences as they are across the country[6] despite equal interest shown when entering college.[7,13,14] Moreover, STEM does standout in racial disparities when compared to non-STEM disciplines. For example, Riegle-Crumb, King, and Irizarry used national data to investigate whether Black and Latinx STEM students are more likely to switch majors or leave college altogether compared to their

White peers and also compared all students to non-STEM fields.[42] Descriptive statistics showed there were no overall differences between races/ethnicities in terms of initial majors (in or outside of STEM). However, in STEM, significantly higher percentages of White students persisted in their initial major than both Black and Latinx students. Further, higher percentages of Black and Latinx students switched majors or left college compared to their White peers and the gap between Black and White students persisted even after controlling for high school academic preparation and individual and institutional characteristics. This study also found that across all major types and across various high school academic measures, there are significantly larger differences between Black and White students than between Latinx and White students. Taken together, STEM has a representation and inequity issue that other disciplines do not exhibit.

Moreover, the problem of degree attainment inequity in STEM is a long-standing problem. Systemic barriers based in racism and misogyny prevented women and people of color to have equal access to power, opportunities, and resources that prevented their continuation in education, particularly in STEM, until well into the last half of the 20th century. Though national data does not reach as far back to the 1980s or before, there is data as of the 1990s in STEM degree attainment (Figure 2.1).[6] While this data on bachelor's degrees awarded to racial/ethnic groups only shows twenty years of degree attainment, it does show the relatively small proportion of degrees each group represented (less than 10%) in the late 1990s. Representation would only be less for these groups earlier in the timeline. Further, it is clear that some marginalized groups are making gains (Hispanic/Latinx) where others are remaining steady or becoming less represented over time (Black/African American) in some fields.

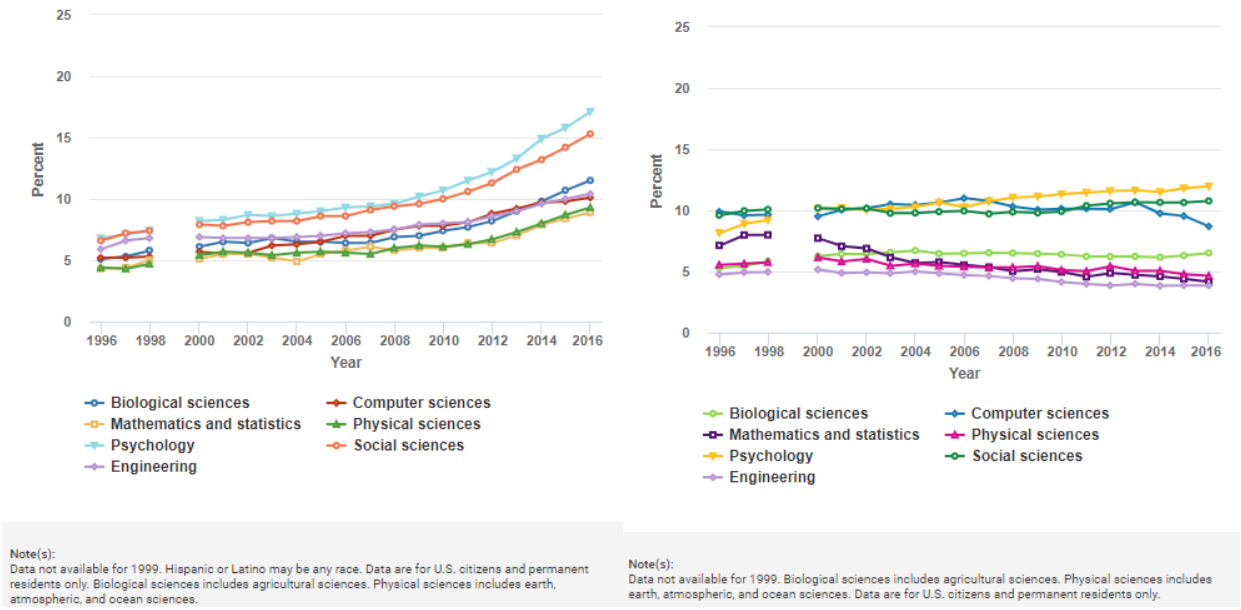

Figure 2.1 Science and engineering bachelor's degrees earned by Hispanic/Latinx (left) and Black/African American (right) as a percentage of degree by field between 1996-2016. Taken from NSF and NCES.[6]

As discussed before, STEM is a broad term and encompasses many different disciplines. It should not be assumed that all STEM disciplines exhibit the same representation and inequity issues equally. In fact, the NSF data shows that STEM disciplines are unique in this area (see Figure 2.1). Moreover, too frequently has "STEM" been used to lump together all discipline and treated as if they do share the same problems. Singling out individual disciplines is a much more effective way to investigate inequities that could be specific to a discipline. Thus, this dissertation focuses on three science disciplines: chemistry, biology, and physics. These disciplines represent most of the sciences included in STEM and are among the highest enrollment science disciplines. It is very likely that most undergraduate students will take one or more courses in one or more of these disciplines while in college. The national statistics previously cited indicate subtle differences in representation between these three disciplines. However, no extensive research has been done of the unique characteristics each of these disciplines hold that contribute to the inequity in representation. Just as gender and race/ethnicity are identities which are unique and influential, an identity as a chemist or biologist or physicist

are also unique in how they shape the scientific community and their beliefs and practices. Extant research has shown that faculty in these three disciplines adopt different instructional practices[43] and hold different epistemological beliefs[44]. Each of the discipline-specific communities are different and view students and their abilities differently so one can assume these beliefs and practices bleed into the classroom and affect students in some way. As to whether these differences propagate racial/ethnic and gender disparities is unknown and require further study.

Inequitable representation and persistence of marginalized students in the sciences is recognized as a problem at the national level. However, steps to remediate this problem have not yielded the results of a more diverse, equitable, and inclusive scientific community. The purpose of this dissertation is to understand why marginalized students leave the sciences. This chapter details the ways in which current approaches to fix the problem of underrepresentation in science degrees have not worked, how other research methods could contribute to the persistence literature, and how this dissertation will address the overarching problem of inequitable representation and persistence of marginalized students in each study.

Inadequate explanations of attrition

As described above, the overarching problem of underrepresentation of marginalized students in STEM has been well established. However, there are inadequate methods, which yield inadequate answers, as to why some students persist where others do not. In this section, I outline the ways in which the persistence literature can be better improved to answer this question. I first discuss the leaky pipeline metaphor in more detail and the problematic assumptions associated with it. I then discuss the difference between students being pulled out

compared to those that are being pushed out. Finally, I end by discussing the need for intersectionality of identities in persistence research.

A flawed metaphor

The immensely popular metaphor of the "leaky pipeline" has been invoked in nearly every iteration of research investigating attrition of students in STEM (which is why it is worth discussing). However, this metaphor is flawed for several reasons. First, the metaphor assumes the "pipeline" is linear, which disregards the many other access points, or "junctures", groups use to enter STEM.[45] It is not necessarily the case that students interested in STEM only enter during their primary school years then proceed in an orderly fashion through the pipe and into the workforce. Studies have shown students show interest and enter the "flow" in college or even later during their careers after more exposure to STEM.[46,47] The "pipeline" also doesn't account for reentry into the "flow" at any point in time. This dismissal discounts individuals who leave the "pipeline" at any point for any reason but decide to reenter later in life. Second, the metaphor has the tendency to homogenize people, as well as disciplines and job sectors.[46,48,49] As explored earlier with NSF data, disciplines (e.g. physical sciences) or groups of people (e.g. URM vs non-URM) tend to be clustered together or aggregated in ways that are not supportive in understanding unique problems faced by individual underrepresented groups (e.g. Black/African American women) or issues within specific disciplines (e.g. chemistry). Third, and probably most problematic, is the historical assumption that views women and racial/ethnic marginalized students as "untapped sources" who are called on only to replenish the loss of White males, whose interest is dwindling. It should go without saying that marginalized groups have a place in

STEM and bring their own diverse perspectives to scientific problems and are not there to merely fill a void.

The issues pertaining to the "leaky pipeline" metaphor have been noted before and because of this, alternative metaphors have been described. One alternative, albeit still flawed, metaphor is that of a "chilly climate." This metaphor explains "leaks" due to the "chilly environment" some groups, mainly students of color and women, endure that force (or push) them out of the discipline.[50,51] The "chilly climate" metaphor places some responsibility onto departments and peers, through thinly veiled, weak attempts to retain underrepresented groups. As Pawley states[51]:

> *"Programs that attempt to stem these leaks provide metaphorical "sweaters" (survival tools for underrepresented populations to better withstand the chilly environment) or train their white, male peers on how to "turn up the thermostat" by implementing, for example, parent-friendly tenure procedures, gender-neutral hiring protocols, or the much-maligned idea of "sensitivity training."*(pg. 7)

The solution to "chilly climates" in departments or disciplines should not be to put on a "sweater" or "turn up a thermostat" in an attempt to make marginalized students and faculty slightly more comfortable. The solution should be to close the metaphorical window that is allowing the chilly air to come through by eliminating the exclusionary culture around STEM. What these metaphors fail to do is take a critical lens to the culture STEM perpetuates which excludes underrepresented groups at all points in the trajectory. To this point, Cannady and colleagues correctly point out that the "leaky pipeline" metaphor can be misleading and hide important factors for lack of retention[52]:

> *"For example, it is not a story of falling into the drain to say, 'I stopped pursuing STEM in high school, even though I took calculus, because I decided I wanted to be a musician.' But it is a story of problems in the system to say, 'I stopped pursuing STEM in high school, even though I took calculus, because my teacher told me that girls can't do*

> *science.' From the pipeline framework, these are indistinguishable; they are both simply leaks."* (pg. 457)

As Cannady notes, both examples, by the pipeline metaphor, "are both simply leaks". This framework omits the most important aspect: why do some students leave where others persist?

Pushed out or pulled out?

Seymour and Hewitt's formative work in the late 1990s opened the conversation as to why students were leaving STEM. Initially, it was thought there were two mechanisms for why students switched out of STEM majors; they were either being pushed out or pulled out.[11] A student who was *pushed out* of a major would carry the label of being poorly prepared, was unwilling to work, and lacked interest. In a sense, these students would have been "properly weeded out" of the discipline because these students would not be seen as "fit" to continue within STEM. A student who was *pulled out* left because they discovered another major or career that was of more interest. These students would not be viewed as a loss either because they had interests elsewhere and the disciplines could have done little to keep them. Both definitions remove all blame from the discipline and individuals within the discipline as to the attrition of students. Their departure is rationalized as not being able to compete or keep up with the rigor or they had another calling and were never interested in STEM. The deficit thinking about students is problematic to say the least.

Not surprisingly, Seymour and Hewitt found that neither of the aforementioned definitions were true to the switchers they interviewed. Because of this, hybrid definitions were formed: more pulled than pushed and more pushed than pulled.[11] Students who were *more pulled than pushed* out of the major had strong interest in STEM, were capable of succeeding, and would have persisted in the major had it not been for poor teaching and disengagement from the

content. These students attributed their switch to the “weed-out” process. In reality, the “weed-out” process, which attempts to remove those from the pipeline that are not “fit” to be in STEM, ended up excluding students that showed strong interest and ability in the subject. Further, these students switched to other majors that would be more fulfilling for them but had mixed feelings about leaving science altogether, with some indicating the possibility for a reentry to science later in their careers.

The other switcher type, *more pushed than pulled*, felt they had the ability to earn a STEM degree, were adequately prepared, and entered the major because of their interest in the subject. However, they were discouraged by the “weed-out” process and poor teaching. These students cited the contextual factors of the STEM discipline as their reason for leaving and not a loss of interest. They switched majors but ultimately left angry, regretful, and frustrated because they felt they could have succeeded in STEM if given the proper supports and were in a more welcoming and inclusive environment. Seymour and Hewitt found that many of the women and students of color they interviewed fit the description of being more pushed than pulled. This is consistent with the exclusionary and unwelcoming culture STEM perpetuates with those that do not fit the stereotypical mold of a STEM student.

With this new framing from Seymour and Hewitt, both types of switchers are viewed as a loss for STEM who could have been retained with changes made to the culture of the disciplines and engagement of the instructors and content taught. While there were students in the study that switched majors due to a genuine lack of interest in the field, the types of switchers highlighted here are the students that could have been retained if not for problematic experiences in the discipline. Knowing why students decide to leave the sciences is the first step to knowing what

specifically needs to change at the institution and discipline level to better retain students, particularly students of color.

Seymour and Hewitt did reserve a large portion of their study to investigating switching differences based on demographic groups. Students of color cited the following reasons for switching more frequently than White students: inappropriate reasons for choosing their STEM major, conceptual difficulty within a discipline, inadequate high school preparation and study skills, pursuit of a more appealing career option.[11] Reasons for switching also differed by gender. Female students cited their top three reasons as (1) non-STEM majors offers better education and more interest, (2) loss of STEM interest, and (3) rejection of STEM careers and lifestyles. Male students differed with their top reasons: (1) loss of STEM interest, (2) fast-pace nature and curriculum overload, and (3) poor teaching by STEM faculty.[11] While Seymour and Hewitt's pivotal research attended to gender and racial/ethnic differences in switching patterns, it did not account for any intersectionality of the students' identities. Their findings are not as informative for seeking answers for specific groups of marginalized students or at the intersection of gender and race/ethnicity.

Lack of intersectionality

While scholars have advanced the understanding of gender and racial/ethnic disparities unique to STEM, further research must be done to look at the individual disciplines and their contributions to inequity based on both gender and race/ethnicity identities. Chapter 1 briefly touched on the gender and racial/ethnic disparities that exist amongst the sciences and why it is important to carefully examine intersectionality data of individual disciplines. The multi-level

disparities discussed in that chapter and above underscore the importance for using an intersectionality lens.

Throughout the persistence literature, scholars have examined gender[16,17,53–55], race/ethnicity[18,42,55,56], as well as other identities (e.g. sexual orientation, first-generation, low-income, etc.) [57–60] as possible predictors or mediators to retention or attrition. What has not been included often is the intersection of those identities. Including intersectionality when discussing identities, particularly gender and racial/ethnic identities, in relation to persistence in STEM or the sciences has been increasingly present in more recent research but is still underdeveloped and underrepresented in the literature, especially with large-scale studies.[7,8,20,61,62]

Several qualitative studies, such as those from Carlone and Johnson[61] and Hanson[8], focus on one marginalized group using intersectionality, women of color, and their persistence in the sciences. This approach allows for a detailed study of one group and their unique experiences in the sciences and how those experiences impacted their persistence. These studies have contributed significantly to the literature in how the experiences of women of color differ from White women in the sciences. In a similar fashion, a mixed-methods study from Rainey and colleagues used intersectionality of gender and race to quantitatively analyze qualitatively coded interviews about sense of belonging in STEM.[20] They found that women of color were less likely to feel they belonged whereas White men were the most likely to feel they belonged, when compared to all other groups. Many of these authors emphasized the need to impose intersectionality in the analyses because certain groups, mainly women of color or Black/African American men, are lost when only analyzing gender or only analyzing race, especially for large-scale studies as seen with NSF data.[7,20] Because of the lack of intersectionality at a large scale, Riegle-Crumb and King employed intersectionality of race/ethnicity and gender on national data

to determine if White men still hold the advantage of being historically overrepresented in STEM.[7] They found that, as before, male students dominate the physical sciences and engineering majors. However, this representation was not exclusive to White males. Black/African American males were significantly more likely to declare a physical science or engineering major than any other group, including White males.

Including intersectionality into persistence research is imperative to understanding the disparities and experiences of individual groups. Using intersections of identities would alleviate some of the problematic assumptions of homogenizing groups of people as seen in the "leaky pipeline" metaphor and national data. As it will be discussed in the next section, no one student adopts a single identity. Each person has multiple aspects and traits to which they identify, each being unique. Investigating how multiple identities interact together will provide information on how disparities affect groups differently and targeted approaches to correcting such inequities.

Factors affecting persistence

Many factors have been attributed to persistence in college and STEM, but there is no single causal factor that explains why marginalized students leave the sciences. In fact, researchers have examined this problem from many angles. One angle is to focus on the students themselves and their beliefs, values, and attitudes. Another angle is to focus on the context in which students learn. I consider both the students and the context in which they learn and the context in which they formed their beliefs and values to investigate persistence in the sciences.

Students' attitudes, beliefs, and values

Some scholars have attributed the loss of marginalized students in STEM and the sciences to student-specific characteristics and traits. Affective characteristics (i.e. observable

feelings or emotions) such as attitudes, beliefs, identity, interest, motivation, self-efficacy, self-esteem, self-worth, values, and many others have been used to better understand how students feel when learning and how it may impact their understanding and performance.[63] Below, I detail how some affective traits have been used to explain persistence in STEM and why these traits are worth highlighting. Specifically, I highlight the following: (a) *motivation* – a general desire or willingness to succeed at something, (b) *self-worth*, which refers to how one feels about themselves overall, (c) *self-doubt*, which describes one's lack of confidence in themselves when it comes to their abilities, (d) *science identity* – one's belief of how closely science is tied to their central identity, (e) *sense of belonging* is how connected and included one feels within a specific community, and (f) *fixed vs. growth mindsets* describe how one views intelligence: either in an incremental (malleable or growth) view or in an entity (fixed) view.

Achievement motivation has been frequently cited in the persistence literature as an important factor students must possess in order to succeed. One way to look at motivation is from the perspective of expectancy-value theory. Previously, researchers have used expectancy-value theory when creating instruments to measure or theorize similar constructs in attitudes towards chemistry[64] and science identity[55,65] and combining patterns of motivation[66]. Further, expectancy-value theory has been used previously in discipline-based education research to explain persistence in STEM. For example, Anderson and Ward found that science attainment value (for Black/African American, Hispanic/Latinx and White students) and STEM utility (for Hispanic/Latinx students) was positively associated with persistence in STEM on ninth-grade high school students.[56] In a general chemistry course, students from a high affective group scored significantly higher than students in a low affective group on items measuring their learning

beliefs (expectancy) and task value.[22] Motivation through the lens of expectancy-value theory can be used to better understand why some students persist and others do not.

Expectancy-value theory posits that students form perceptions of themselves based on previous experiences and social influences which influence their social-cognitive factors, which in turn influence expectancies and values, which, finally, influence their performance and persistence (Figure 2.2).[67]

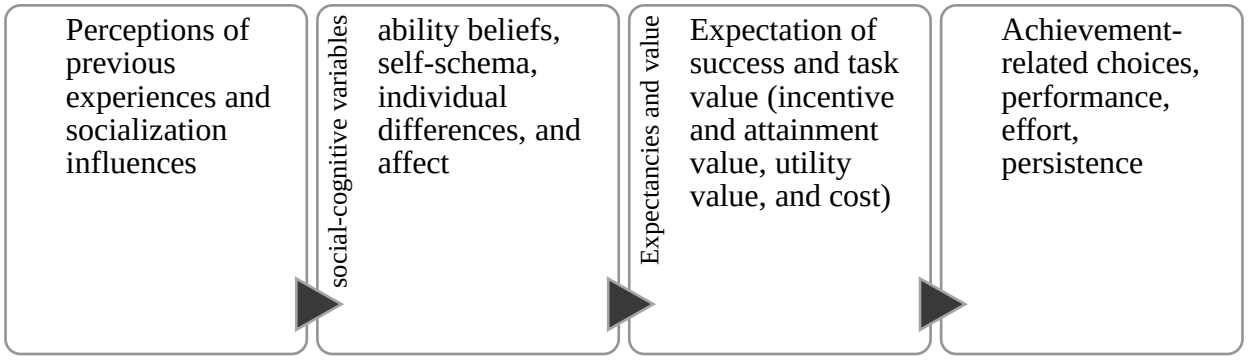

Figure 2.2 Eccles and colleagues' expectancy-value theory model of achievement motivation summarized.[67,68]

In short, how one values a task (value) and their beliefs of how well they will do (expectancies), influences their performance, effort, persistence, and subsequent choices related to their achievement. Moreover, the theory posits that social constructs like gender or racial/ethnic stereotypes, through a process, end up influencing how a student will view themselves for a task and if they will succeed and persist.[67] So while motivation and how a student values or expects to succeed at a task or course is important to achievement and persistence, their inherent beliefs are ultimately formed based on social constructs and past experiences influenced by others.

Likewise, both self-worth and self-doubt are important to students' persistence for similar reasons associated with the discussion above about expectancy-value theory since both constructs affect motivation. For example, higher self-doubt has been linked to negative affect (e.g. self-esteem and social anxiety)[69], concern about one's competence (e.g. imposter syndrome,

self-handicapping, and defensive pessimism)[69], and tendency to switch majors[15]. It is imperative to investigate how self-doubt is conceived by external or contextual factors to diminish its hold on a student's belief they can or cannot succeed in a discipline. In terms of self-worth, previous research has shown that those who switched majors were more likely to have their self-worth impacted by competition with others and academic setbacks compared to those that persisted in the major.[15] Further investigation into what mechanisms impact one's self-worth in relation to academics and the context of competing with one another in order to persist is warranted.

Turning to another affective trait linked to persistence is that of science identity. Various models of science identity have been used to explain persistence in science.[19,34,56,70] White and colleagues found science identity as an indirect effect that significantly explained academic achievement in African American students at historically Black colleges and universities (HBCUs).[34] Further, the same study found that science identity was positively associated with feelings of increased assimilation, science self-efficacy, and college science GPA. Espinosa used Carlone and Johnson's framework of science identity, along with other constructs, to quantitatively analyze persistence of undergraduate women of color in STEM.[19] One of the strongest effects they found for persistence was for science identity development through participation in an undergraduate research program, faculty interactions, value commitment, and perception of their academic self-concept and analytic, problem-solving and critical thinking skills. To that end, Chemers and colleagues found that science identity predicted commitment to a science career in the future.[70]

Various models have been developed to explain the attributes of science identity. One of the most influential models of science identity was developed by Carlone and Johnson. Carlone and Johnson created a grounded model for science identity based on successful women of

color.[61] Their model included three overlapping factors: performance (scientific practices), competence (content knowledge and understanding), and recognition (recognizing oneself and recognition from meaningful others as a "science person"; Figure 2.3).

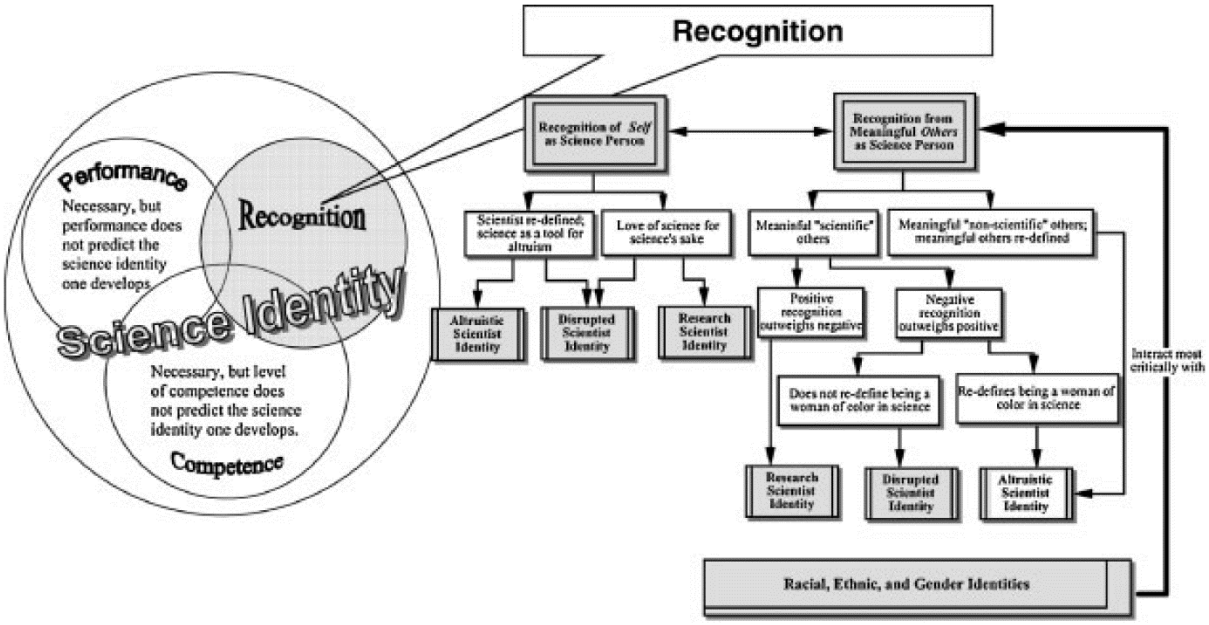

Figure 2.3 Grounded model of science identity adapted from Carlone and Johnson.[61]

While performance, competence, and recognition all contribute to the science identity of a student, both performance and competence are necessary but hold no contingencies on the type of science identity one develops. Recognition (and type of recognition) specifies how science identity is developed. Recognition of self and recognition from meaningful others (which interact with student's other identities) played the biggest role in the development of various science identities. Moreover, the type of recognition received from others, whether positive or negative, changed the way the students viewed science and themselves and if they had to redefine what it means to be a scientist in order to persist. To that end, Carlone and Johnson found three categories of science identity: altruistic scientist identity, disrupted scientist identity, and research scientist identity. The women within the *research scientist identity* described themselves

as “scientists” because they saw science as aligning with their knowledge processes, interests, and belief that science was important for the sake of science. These women worked in undergraduate research laboratories and were frequently and repeatedly recognized as valuable members of the scientific community (the only group to receive more positive interactions from “scientific meaningful others”). Women part of the *altruistic scientist identity* redefined what science meant to them and redefined whose recognition was important to them. These women saw science as a tool for altruism and as a service to humanity. Because of this view, altruistic scientists redefined “meaningful others” to reflect their altruistic beliefs and valued recognition from home community members and family. Moreover, negative interactions with “meaningful scientific others” forced these women to redefine what it meant to be a woman of color in science. Lastly, women within the *disrupted scientist identity* often felt overlooked, dismissed, or discriminated against by “meaningful scientific others” and were made to feel like spokespersons or representatives of their racial or ethnic groups. Despite the more negative experiences with the scientific community, these women shared characteristics from the other identities in that they recognized themselves as scientists early on with altruistic aspirations. While all these women persisted in the sciences and excelled in their science disciplines, interactions with the disciplines and scientific community altered their way of conceptualizing their identity in relation to science.

In addition to Carlone and Johnson’s grounded model, other models of science identity have been developed over the years. For example, Hazari and colleagues included several science disciplines in their measure to distinguish between the contextuality of science as being central to one’s identity and added interest as another factor to be considered when studying science identity.[62] As Trujillo and Tanner accurately point out, interest could be an important

aspect to consider especially in early-career undergraduate students who show an interest in science but may not have yet committed to a science identity.[71]

Further, Chemers and colleagues added a representation component to their science identity instrument with the inclusion of the following item: "Having more people with my background in my field makes me feel more like a scientist."[70–72] This instrument was used to study the efficacy of science support programs, where science identity was found to be one of the significant psychological mediators that predicted commitment to a science career.[70,72] The inclusion of the representation item links science identity to another important factor of persistence, sense of belonging. A sense of belonging in the sciences can be characterized as one feeling valued and accepted in a discipline and able to consider themselves as well-fit, legitimate members of the scientific community.[17,73] Most importantly, it has been well documented that a sense of belonging (or lack of) is directly related to persistence (or attrition) in academics.[11,16,74,75] However, many mediating factors have been found to contribute to one's sense (or lack of) belonging.

Several studies have attempted to narrow the list of factors that greatly influence sense of belonging. In an attempt to measure sense of belonging, Hoffman and colleagues determined five factors that influence sense of belonging in college students: perceived peer support, perceived family support/comfort, perceived classroom comfort, perceived isolation, and empathetic faculty understanding.[76] In a review of belonging interventions, Lewis and colleagues isolated the following factors they view as either bolstering or hindering a student's sense of belonging in STEM: quantity and quality of peers and role models, stereotypes of people who succeed in STEM, direct interventions within STEM, influences from outside academia.[17] Lastly, Rainey and colleagues found that interpersonal relationships, representation with the discipline,

perceived competence, personal interest, and science identity all contributed to a student's sense of belonging in the sciences.[20] Taken together, three overarching categories stand out as being imperative to sense of belonging: campus climate (including the discipline and instructors), peer interactions, and sense of self.

Several studies have highlighted the importance of campus climate on sense of belonging for marginalized students. Dortch and Patel detailed how microaggressions, specifically exclusion/isolation, lack of representation, and demeaning of racial heritage, significantly impacted the sense of belonging in Black women in STEM.[77] Hurtudo and Carter found that Latinx students' sense of belonging in their third year of college was positively affected by first-year experiences but negatively affected by perceptions hostile racial climates on campus.[78] Johnson found that race/ethnicity played a significant role in how women in STEM experience sense of belonging and that positive campus racial climate was linked to a more positive sense of belonging for women in STEM.[79] Regarding gender, in one study, graduate women in STEM reported they perceived they had to exert more effort to succeed in STEM compared to their peers. Further, this increase in perceived effort negatively affected their sense of belonging in STEM.[54] Similarly, Thoman and colleagues found that for women, interest in their STEM courses were tied to their sense of belonging and feelings of low sense of belonging were tied with women feeling "pushed out" of STEM.[53] Likewise, lower sense of belonging in high school girls in a computer science course was linked to lowered interest due to the lack of fit to computer science stereotypes.[80]

To that end, several scholars have turned their attention as to how to bolster students' sense of belonging. For example, an intervention aimed at increasing general sense of belonging in African American students on college campuses implemented an intervention that reframed

social adversity as common and short-lived by citing examples of upperclassmen experiencing similar feelings upon entering college then fading away over time.[81] Intervention participants were then asked to internalize the message by speaking to their own experiences similar to the ones they heard. Students in the intervention self-reported improved health and well-being. Sense of belonging is critical for students' persistence in science because of the community that is built and utilized for support when needed.

It is inevitable that college students will face failure or negative setbacks to some degree, whether in a course or their major. Thus, it is important to know how they will react and make future decisions. Dweck and colleagues found that those with an entity view are more likely to "react helplessly in the face of achievement setbacks."[82–84] However, those with an incremental view, when faced with failure, tend to blame themselves rather than others and try to correct themselves by changing practices or behaviors.[83] Moreover, extant research shows a connection between view of intelligence and academic performance and motivation. Specifically, incremental theorists were more likely to have higher grades in verbal and quantitative subjects and overall achievement[85] and an incremental view predicted upward trends in grades over two years for elementary school students[86]. Knowing this association between mindset and achievement, several researchers have implemented interventions to change the mindsets of students (towards incremental) with some positive results. In an attempt to curb stereotype threat, Aronson and colleagues devised a method to change how students view intelligence as a malleable trait. African American students who subscribed to the incrementalist theory reported greater academic enjoyment and engagement and attained higher grades than those without the intervention.[87] Blackwell and colleagues intervened on middle school students' views on intelligence and those who were taught the incremental theory saw positive change in academic

motivation.[86] While changing students' views on their intelligence does aid in their motivation, engagement, and enjoyment, it does not answer the problem of disinterest or attrition completely.

When investigating the effect of instructor's views on intelligence, Rattan and colleagues found that when instructors held an entity mindset they were (1) quicker to assume students were of low ability (compared to instructors with an incremental mindset) and (2) more likely to comfort and lighten homework load of low math ability students rather than encourage or engage the students. Students were perceptive of their instructors mindset and low expectations, which demotivated and lowered their expectations of themselves in the course.[88] Canning and colleagues found similar connections between instructor mindset (entity view) and students feeling less motivated and having more negative experiences than with instructors with a growth mindset. Furthermore, they found that instructors who held an entity view had racial achievement gaps twice as large as instructors with an incremental view on intelligence.[89] Thus, instructor's views should also be considered to better the learning environment for students.

Taken together, it is important to remember that the use of affect is to better understand students without using it to promote deficit thinking of students. While characteristics and traits detailed above are of the students themselves, external or contextual factors influenced this way of thinking. For example, Eccles and Wigfield's model of motivation begins with socialization experiences and influences. Carlone and Johnson's three science identities are contingent on how one is recognized by "meaningful scientific others" and Rattan and Canning both found that instructors views of intelligence significantly impacted students and their achievement. Thus, the context in which students learn and interact with the scientific community also shapes how they view themselves and science.

Contextual factors that impact students' persistence

Similar to affective characteristics, researchers have focused on a multitude of contextual factors that impact a student's persistence in the sciences. Such factors include previous academic measures, socio-economic status, instructor training, family background (e.g. parental or guardian education level), science capital, and systemic racial injustices. Below, I detail how some of these contextual factors have been used explain persistence in STEM and why these factors are (or are not) worth further research. Specifically, I highlight the following: previous high school academic measures (i.e. high school grades, GPA, test scores like ACT or SAT, course completed, and rank), socio-economic status (includes income, educational attainment, financial security, and social status and class[90]), science capital (science-related cultural and social capital and science-related behaviors and practices[91–93]), and system racial issues within the education system (like opportunity hoarding).

Frequently, researchers have used academic preparation measures from high school when including statistical predictors for persistence in college and STEM.[11,15,94–100] In theory, these measures can communicate how prepared an individual is for college. Also, many of these measures are used as placement mechanisms for introductory-level courses. However, these measures do not account for many, and usually, more important, and significant predictors of persistence (such as the affective factors enumerated above). Moreover, the racial/ethnic disparities found in high school academic measures stem from a much more systemic issue. Socio-economic status (SES), a big component of which is income, has been shown to be a mediator for disparities seen in academic preparation measures. SAT scores, high school grades, and rank differ as a function of income, which effectively then differ by race because of the

income inequality between Black/African American and White families.[100–103] This income inequality points to one aspect of how systemic racism effects the education system.

Considering the variance seen in academic measures between students of different backgrounds (income levels, social class, etc.), theorists have devised a new construct to explain how these differences explain the disparities in science participation that attempt to account for differing opportunities. Science capital (the collective resources one has access to that are science-related that envelop them into the scientific community) have been linked to higher science identity, positive attitudes about science, and persistence in the sciences.[91,92,104] Science capital is not a separate type of capital, but an analytic lens to focus on science-related capital to identify differences in student participation in science that otherwise only differ on a few characteristics.[92] Science capital theorists believe that by analyzing disparities in science participation through this lens, researchers can better understand differences between students of similar backgrounds who persist differently in science.

Science-related cultural capital refers to one's scientific literacy, culturally valued forms of knowledge, and view of science as being valuable and useful.[91] Scientific literacy are the skills and know-how of the scientific community and ability to use those skills in everyday life. Students who have high science literacy use the behaviors and practices commonly used in the community like possessing deductive argumentative skills, ability to see patterns in data, identify variables, and many others. Culturally valued forms of knowledge about science and its transferability to the job market is also a form of science-related cultural capital. Previous exposure to science (like advanced placement courses in high school or attendance of "elite" institutions[105]) gives students a better understanding of how science is valued in the job market and what paths to take to succeed in a science career. Lastly, one's view on science being

valuable and useful in society is a form of science cultural capital. This is important because if one's family or support system sees the utility and values science, they are more likely to be supportive of their student pursuing a science discipline.[106]

Science-related social capital is parental science qualifications, talking to others about science, and knowing someone who works in science.[91] This aspect of science capital takes into account the social influences one has that may impact their participation and retention in science. For example, having one or more relatives in the science field, say medical doctors, who can introduce you to the discipline, have informal conversations about the discipline, or who can connect you with others in the discipline is a form of science-related social capital. Engaged parental or familial figures can cultivate a student's interest or curiosity in science from a young age that later progress to career aspirations. Scholars have emphasized the importance of family on science capital and, in turn science identity, on student participation and achievement in the sciences.[104,107] Science instructors, academic advisors, and other science-related mentors or "experts" are other forms of science-related social capital.

Science-related behaviors and practices include informal science learning (outside the context of school) and consumption of science media.[91] Informal science learning can include frequent visits to science museums, participating in after school science activities, or completing at-home science experiments. These informal learning opportunities can cultivate continued interest in science. Science media includes science TV shows, books, online video series, and any other form of media that has a science or science fiction component to it. Again, this type of media is another informal learning opportunity for students to become more interested in science.

Science capital is still a relatively new analytic tool for differentiating participation based on access to science-related resources. There are concerns around the measurement of such a

construct. Moote and colleagues detailed the survey items they used to measure science capital and the relative weighing of each response.[93] For example, items related to family science skills, knowledge, and qualification weighted scores from -1 to +1, whereas items related to participation in out-of-school science learning contexts weighted scores from -2 to +2. The issues with weighting items of different dimensions are that it assumes one dimension has a stronger impact than another and generalizes this across all respondents, regardless of demographics. If previous research in STEM persistence has contributed anything, it is that students do not have equitable access to resources, but many families and institutions find creative solutions to nurture scientific curiosity in their students. While there are issues surrounding the relative strength of science capital dimensions as a measure itself, using science capital as an analytic lens is valuable and worth including in further research, if not for the simple fact that it highlights inequities in the distribution of educational and scientific resources.

One idea put forth by scholars that encompasses the differential access to education resources is the concept of opportunity hoarding. Opportunity hoarding is defined by Tilly as acquiring and maintaining access of a limited and highly-valued resource that offers continued advantages now and in the future.[108,109] Scholars have argued that education is a resource that is highly-valued in society and has become another source for opportunity hoarding where those at an advantage (typically White or Asian families) amass resources and knowledge about education to keep their advantage and (consciously or unconsciously) limit access to the same resources and knowledge of others (typically Hispanic/Latinx and Black/African American families.[110–112]

The theory of opportunity hoarding has been used in K-12 research to explain how White and Asian families have more access to high-achieving schools, tracking into highly-valued

education resources like advanced courses (AP and IB courses), and the racial segregation of cities and suburbs that highlight the advantages of White suburban schools.[113–116] Riegle-Crumb, King, and Irizarry argue that opportunity hoarding in education can be taken further when investigating racial/ethnic disparities seen specifically in undergraduate STEM.[42] STEM careers are seen as highly valued in society in terms of prestige and income and their exclusive reputation gives the appearance that STEM careers are a limited resource to a select few. Using an opportunity lens in their study, the authors expected that STEM would observe more racial/ethnic disparities in degree attainment than non-STEM fields. Indeed, several findings indicated that STEM, but not business, humanities, or social science majors, disproportionately exclude marginalized students. URM students were more likely to switch out of STEM than other majors with this gap persisting for Black/African American students even when controlling for high school preparation. Further, URM students had a higher probability than White students of leaving college altogether after entering as a STEM major, a finding not found when examining URM students in other majors.[42]

The individuals within STEM are not immune to facilitating White privilege. The reluctance to change the community and institutional norms are symptoms of keeping the majority (usually White males) in an environment that advantages them but not many others. Sustaining an environment that caters to few groups undermines the sense of belonging of other groups in the same space.[20] For example, not challenging the status quo of science or the stereotypical image of someone in science perpetuates the idea that science is only for certain individuals. The individuals within science are responsible for changing such norms and thus changing the culture.

Present study

So far, I have emphasized the need to improve the current body of persistence literature. To do this, one must include research methods incorporating intersectionality and multiple, but individual, science disciplines while investigating the whole institution and students themselves. Below, I specify how existing literature has influenced my research methods for each of the three studies included in this dissertation. Throughout the studies, I include the intersectionality of gender and race/ethnicity to expand the persistence research to include students from specific subgroups. Lastly, my research builds on the previous work of other scholars to investigate inequities at the institutional level of three science disciplines and determine how multiple affective characteristics and experiences influence marginalized students to leave the sciences.

Study 1

As discussed before, the "leaky pipeline" has several "junctures" at which students leave the sciences. However, these "junctures" in the "pipeline" have not been well established. Study 1 provides more detail on where students "leak" from the "pipeline", specific to this institution. The three "junctures" studied are the (1) introductory science courses, (2) major switches, and (3) degree attainment.

One "juncture" in the pipeline that "leaks" students during their undergraduate career is the "weed-out" course. "Weed-out" courses (also known as gateway or barrier courses[117–122]) are foundational or introductory-level courses with high student enrollment and high DFW rates (percentage of students who receive a grade of D, F, or Withdraw from the course). In STEM, these courses are supposed to serve as a filter to determine which students are scientists and which are not; a means of being "cruel to be kind" so students can leave the discipline early and

find another major.[11] Students have described these courses as heavy volume, fast-paced, too abstract or high-level for an introductory course, and having misalignment with assessments and content delivered in the course.[121] Several studies have found that "weed-out" classes disproportionately affect students of color (predominately Hispanic/Latinx and Black/African American), first-generation students, and low-income students.[119,121] Their pervasive and exclusionary nature increases student attrition in STEM majors and plays a role in predicting who graduates from college altogether.[117,119,121,123] The introductory science courses are perhaps the biggest "leak" of students from the pipeline because these courses are, for some students, their first exposure to the disciplines and negative experiences in these courses turn students off from the discipline altogether early on.[124] Investigating introductory science courses in Study 1, specifically those with high DFW rates and enrollment, detail their contributions to the removal of marginalized students in the sciences.

Another "juncture" that would "leak" students from the "pipeline" would be when students leave the major. These would be students who previously declared a science major but for a multitude of reasons (previously discussed above) decided to leave the major. Seymour and Hewitt highlighted the various reasons why students leave the science majors, one of which was the "weed-out" courses.[11] An analysis as to who is leaving the majors (demographic groups) and which majors they switch to (inside or outside of STEM) is important to understanding the degree to which marginalized students are truly "lost" from the sciences.

The last "juncture" analyzed is those that earn the degree. This "juncture" is important because it gives a baseline of those that actually earn a degree. For example, if this institution awards more degrees to Hispanic/Latinx students in chemistry than other demographic groups, it would be expected that Hispanic/Latinx students are also more represented in the courses

themselves compared to other demographic groups. This timepoint allows for context of who succeeds in this discipline and what advantages or disadvantages they were given at the two time points before that influenced their outcome.[94]

By examining three distinct time points in an academic career in, I build a more complete picture of the paths marginalized students take in the sciences and how each time point holds unique opportunities for retention. Study 1 focuses on the institution, but the subsequent studies turn to focus on the students and how their individual differences and experiences influence their persistence.

Study 2

Study 2 launches the investigation as to how individual differences between students may influence their persistence in the sciences. I begin Study 2 by exploring several affective constructs previously used in the persistence literature. I then use these constructs together to explain differences between groups of students and how the constructs collectively describe the student and their eventual outcome in a science course.

Above, I outlined why various affective constructs, including attitudes towards science, self-worth, self-doubt, science identity, and view of intelligence, have been used to explain persistence in the sciences. These constructs were chosen to be included in my research because of the known influences they pose individually to achievement and persistence in the sciences. One's attitudes towards science, specifically if they find science emotionally satisfying and intellectually accessible, is how one views science as a discipline and will influence how they interact with the community and tasks of that discipline.[64,125] If a student views science and not emotionally satisfying then according to expectancy-value theory they will not have high

achievement in that discipline. Further, how one views science impacts their development of a science identity, which has been linked to persistence in science.[55,61,70] Self-worth and self-doubt impacts motivation which then impacts performance and persistence in the sciences.[15,69] Lastly, a student's view of intelligence predicts how they will react to academic setbacks[82–84], which are bound to happen in the sciences. How one reacts to failure will have some influence on their decision to remain or leave a discipline. These affective constructs are central, I believe, to understanding persistence in the sciences. Because these constructs have been cited in previous literature, I look to how those studies could have been improved to fully detail how affect effects persistence.

Extant research on affect and persistence does include examining more than one affective characteristic. When studying persistence in the sciences or STEM, researchers who focus on affect have investigated sense of belonging and interest[53], self-esteem and self-worth[126], interest and family's proximity and attitudes towards science[99], competency beliefs and science identity[55], interest and motivation[35], and the list goes on and on. While this research is indeed adding to the understanding of persistence (or not) in the sciences, it is limiting to only two or three affective characteristics of students. As previously discussed, students have many things about them that influence their decision to persist and exploring a handful of affective traits is not enough. Work from Shedlosky-Shoemaker and Fautch came the closest to what I am trying to achieve. They incorporated perceptions of ability and performance, motivation, identity, and self-worth and compared how students' scored on these measures differed for those that persisted, switched, or left their major.[15] What resulted was how those that persisted scored on, for example, self-worth items compared to those that switched scored on the same measure. While Shedlosky-Shoemaker and Fautch were able to analyze many different affective

characteristics and compare them across groups, there is little discussion as to how these traits interact with each other for groups of students and how they influence persistence in some but not others.

There is no existing literature that has attempted to use multiple affective constructs collectively to help explain persistence in the sciences and how the collective affect influences persistence. My research makes a significant contribution to the persistence literature by collectively giving a more complete picture of the student. One way to analyze this data is by using cluster analysis. Cluster analysis is the technique of grouping objects together based on shared characteristics more so than the objects in another group, or cluster. In this dissertation, the students are the objects that are being grouped together based on shared affective characteristics then the clusters are used to analyze differences in course outcome and other individual differences. Cluster analysis has been used before in education research to identify "low affect" students[22,23], "low chemistry and high math" self-concept students[24], and "high familiarity" faculty with assessments[127]. This method yields promising results of relating several factors together to better explain an outcome, such as persistence.

One limitation of survey research into the affective domain is that survey responses on a Likert scale only provide so much information. What they are unable to do is make the direct connection between a feeling or characteristic and a decision to persist or leave a discipline. Therefore, Study 2 is followed by interviews that capture the student experience and relate them to their decision to leave a major or why they failed a science course in Study 3.

Study 3

Finally, Study 3 provides students' views on why they chose to not persist in a science course or major. This study is important because while Study 1 and 2 provide essential information as to how the institution and the students' affect play a role in persistence, they do not answer the ultimate why question: Why do marginalized students not persist in STEM? Studies 1 and 2 provide associations of various factors that affect persistence but do not provide the explicit, direct, causal link. Interviewing students does answer the why of it all and how the scientific community and institutions can best mitigate corrections to the inequities students face.

A handful of researchers have used student experiences to inform their research and contribute to the community's understanding of persistence of marginalized students. For example, Carlone and Johnson used the experiences of women of color who persisted in science to develop a grounded model for science identity.[61] Their methods for collecting and analyzing student data led them to differences students of the same marginalized group experience and how that impacts their continuation in the sciences and their view of themselves as scientists. Additionally, White and colleagues used student experiences (captured via interviews) to corroborate their quantitative findings and to examine how HBCUs facilitate the development of science identity and science self-efficacy beliefs in conjunction with racial identity.[34] Capturing student experiences is a significant part in understanding what events or interactions lead marginalized students to leave the sciences.

Through the three studies described above, this dissertation attempts to understand why inequitable disparities in representation, retention, and persistence exist for marginalized students between three science disciplines at a minority-serving institution in order to directly inform the

improvement of curriculum, instruction, recruitment, and retention of the chemistry, biology, and physics departments and disciplines. Because this dissertation examines both the institution's role and the role of student affect on persistence, my research contributes to the growing body of information needed in order to make the sciences a more diverse, equitable, and inclusive environment for students.

CHAPTER III: STUDY 1 – Representation and Retention by the Numbers

Introduction

As discussed earlier, problems of representation of historically marginalized groups in STEM have been the subject of many discussions, including but not limited to pertaining to the economic impact and global competitiveness of the United States in scientific and technology fields.[1,2,4] Even though the issue of equitable representation has become more visible, recent studies and national reports show the persistence gap of underrepresented minority (URM) students in STEM has not made much movement or any gains made are not seen across all marginalized groups.[36,42,128,129] Moreover, URM students are not experiencing underrepresentation to the same magnitude in all STEM fields. Comparing individual disciplines may lead to better insight of shortcomings or gains other disciplines made to lift up their students. Thus, the first goal of this Study is to achieve a comprehensive comparison of three STEM sciences (chemistry, biology, and physics) and their representation and retention of URM students.

Further, other representation or persistence studies typically focus on one time point in a student's undergraduate studies.[15,42] While these studies provide invaluable information on URM representation, they only consider one juncture in college, when in reality URM students can leave STEM at many points throughout college. This study is not a longitudinal study in the traditional sense, but it does investigate three points at which equitable representation of URM students is essential, which is the second goal of this Study. The three time points that will be studied are the time of degree attainment (degree-level), the time at which students switch majors (major-level), and, finally, the time during which a student is enrolled in a 100- or 200-level introductory science course (course-level).

The purpose of the degree-level analysis is to (a) characterize the representation of URM students of all who attain a degree, (b) determine the likelihood a student from a URM group to attain a degree in one field versus another, and (c) ascertain if representation of URM in degrees awarded has improved over time. To achieve the purposes of the degree-level analysis, three research questions are asked:

D1. *How are underrepresented minority students represented among chemistry degrees compared to biology and physics?*

D2. *What is the likelihood that underrepresented minority students attain a degree in chemistry compared to biology and physics?*

D3. *Have the levels of representation of underrepresented minority students changed over time in chemistry compared to biology and physics?*

Next, at some point in their collegiate studies, many students switch majors whether it be within a field but different discipline (like from physics to chemistry) or switch to another field altogether (like from physics to business). The purpose of major-level analysis is to understand the various switching patterns students, specifically URM students, follow when either entering or leaving STEM fields. Thus, the only research question for the major level analysis is:

M1. *Who switches in or out of the STEM degrees?*

Lastly, students will not be able to attain STEM degrees if they are unable to overcome the barriers put in place by many introductory courses, or “weed out” courses.[124,130] The purpose

of the course-level analysis is to examine the grade distribution of popular 100- and 200-level introductory courses in the three disciplines to determine if URM students are disproportionately failing these courses. Further, using chemistry as a model, I will investigate the introductory sequence in detail to pinpoint when URM students leave chemistry. To achieve these purposes, two research questions are put forth:

C1. How are underrepresented minority students represented among chemistry courses compared to physics and biology?

C2. When do underrepresented minority students drop out of chemistry?

No specific hypotheses were made for each of the research questions since similar studies typically utilize national data sets (which are different in kind to the diverse make up of this institution). However, because I am using institutional registrar data to complete these analyses from an institution that is considered an Hispanic-serving Institution (HSI), I do hypothesize that Hispanic students will not be as underrepresented as other URM students in the three disciplines. This institution has been a federally recognized minority-serving institution (MSI) since 2010 and in 2016 received a multi-million-dollar grant to increase Hispanic representation in STEM degrees, specifically.[30] Considering the efforts needed to warrant HSI distinction and federal grants supporting them, Hispanic students should have more representation in the three science disciplines compared to other URM groups.

Methods

Demographic groups of interest

While the Registrar data allows for nine categories of race/ethnicity to be analysed, I decided to study only two URM groups: Hispanic students and Black/African American students[1]. As discussed in Chapter 1, I chose these groups because, while the institution has a diverse undergraduate population, I wanted to study the challenges of representation and persistence of two of the most disenfranchised groups in a diverse environment.

Moreover, as previously stated, it is not sufficient to only consider race/ethnicity in these analyses. Gender differences, in STEM have been widely researched. However, there is a lack of comparisons on gender within and between various racial groups. Thus, I made the choice to use the intersectionality of race/ethnicity and gender to be the focus of the analyses of this research. The following groups will be considered throughout the analyses of representation and persistence: Hispanic female and male students and Black/African American female and male students. White female and male students are included in several analyses to serve as a comparison, or reference group.

Registrar data

Data used in this research was collected from the institutional registrar. Three databases were constructed to answer the research questions: (1) data for the degree-level analysis, (2) data for the course-level analysis, and (3) data for the major-level analysis.

Degree-level. In order to answer the degree-level research questions (*D1 – D3*), the data included the records of any student who was awarded a BS or BA degree in chemistry, biology,

[1] White students were included in analyses to serve as a reference group.

or physics for the time the data was available (2005 – 2017).[2] Anonymous student records included the student's gender[3], race/ethnicity[4], degree conferred, and the academic year the degree was conferred. Cases were eliminated (< 2%) if there was no information on a student's gender or race/ethnicity (e.g. unreported or 'Unknown').

Course-level. The course-level data included records of any student who was enrolled in a 100- or 200-level chemistry, biology, or physics course for the time the data was available (2004 – 2017). The 100- and 200-level courses were chosen because the data would encompass the introductory sequences in the disciplines. These introductory sequences see the largest enrollments in the respective departments and would include students of various major backgrounds. Anonymous student records included the student's gender, race/ethnicity, course, final grade in the course, and the term and academic year in which the course was taken. Again, cases were eliminated (1.8%) if there was no information on a student's gender or race/ethnicity. While the institution gives many different course grades, only grades of A, B, C, D, F, and W (withdraw) were considered in the analyses because they are the most common at the university and within the literature base. Furthermore, at the institution, a grade of a C or higher is needed to proceed through a course sequence, so for all intents and purposes, a grade of a D, F, or W would be considered failing.

The course-level database included records for over 50 courses across the three disciplines. A reduction in the data was needed to effectively describe the issue of representation and retention in the courses. Thus, the analysis was limited to those courses with the highest

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[2] The institution under study houses the biochemistry department within the chemistry department so biochemistry degrees were given the 'Chemistry' label for these analyses.
[3] Institutional registrar data had two categories for gender: female and male.
[4] Institutional registrar data had nine categories for race/ethnicity: White, Hispanic, Asian, Black/African American, International, American Indian/Alaskan Native, Native Hawaiian/Pacific Islander, Multi-race, and Unknown.

failure rates because these are, arguably, the most difficult courses in the departments. Further, I wanted to determine if these courses were difficult for all students or if certain groups of students (i.e. URM students) were receiving the majority share of the failing grades. I decided to focus on the four lecture-based (non-lab) courses from each discipline that had the highest percentage of final grades given to students that were a D, F, or W (withdraw). Lab courses were not included since the requirements for labs vary across disciplines. In addition, only courses that had an average student enrollment over 200 were included to ensure a large enough sample size (N) for statistical power. Thus, the focus of the course-level analysis became the courses with the highest DFW rates. A DFW rate is the proportion of grades that are a D, F, or W. Table 3.1 shows the courses with the highest DFW rate for their discipline, their mean DFW rate (%) over the 14 years of data available, and the standard deviation.

Table 3.1 Date reduction to the 12 courses with the highest average DFW rates in the three disciplines. These courses will be the focus of the course-level analysis.

Department	*Courses*	*Mean DFW Rate (%)*	*SD*
Chemistry *N = 64605*	Organic Chemistry II	36.56	4.86
	Organic Chemistry I	30.74	5.03
	General Chemistry I	29.69	4.03
	Preparatory Chemistry	29.28	4.32
Physics *N = 27704*	General Physics I – Mechanics	30.74	5.75
	Introductory Physics I	30.72	5.40
	General Physics II – Electricity and Magnetism	24.18	7.72
	Introductory Physics II	19.26	4.37
Biology *N = 41616*	Ecology and Evolution	20.70	4.78
	Mendelian and Molecular Genetics	18.80	2.95
	Cell Biology	17.47	3.78
	Cells and Organisms	15.32	2.57

The courses included from the chemistry department were Preparatory Chemistry, General Chemistry I, Organic Chemistry I, and Organic Chemistry II. Preparatory Chemistry is a course that is taken by students who generally have not taken a chemistry course prior to their

undergraduate career and/or who failed the chemistry placement exam as an incoming first year student. Preparatory Chemistry focuses on dimensional analysis, units, chemical nomenclature, and stoichiometry. General Chemistry I is the first course in the General Chemistry sequence and is a course generally taken by a student in their first year. General Chemistry I covers stoichiometry, reactions, gases, solutions, equilibrium, and acid-base chemistry. This course is a prerequisite for all other chemistry courses at the institution. Organic Chemistry I is the first course in the Organic sequence and covers structure, reactivity, and synthesis of organic molecules. Organic Chemistry I is a prerequisite for Organic Chemistry II. Organic Chemistry II is the last introductory sequence course and covers reactivity, synthesis, spectroscopy, reaction mechanisms, and biochemical reactions.[131]

The courses included from the physics department are two mutually exclusive sequences: (1) Introductory Physics I and II and (2) General Physics I and II. Introductory Physics I and II are non-calculus-based physics courses, while General Physics I and II are calculus-based physics courses. Introductory Physics I covers kinematics, Newton's laws, work and energy, momentum, oscillations, waves, and special relativity. Introductory Physics II includes electrostatics, electric current, magnetism, Faraday's law, Maxwell's relations, introduction to quantum mechanics, nuclear physics, and particle physics. General Physics I covers kinematics, vectors, Newton's laws, momentum, work and energy, and static equilibrium. General Physics II includes electrostatics, electric current, reflection and refraction, waves, and Maxwell's equations.[132]

The courses included from the biology department are Cells and Organisms, Mendelian and Molecular Genetics, Cell Biology, and Ecology and Evolution. Cells and Organisms is a course recommended for science majors and completion of General Chemistry I is encouraged.

The Cells and Organisms course covers cell structure, respiration, photosynthesis, molecular genetics and development, and physiology of plants and animals. Cells and Organisms serves as a prerequisite for Mendelian and Molecular Genetics and Cell Biology. Mendelian and Molecular Genetics focuses on basic molecular genetics, principles of heredity and variation, gene regulation, and DNA replication, transcription, and translation. Mendelian and Molecular Genetics also suggests concurrent or previous enrollment in Organic Chemistry I. Cell Biology covers organelle biogenesis, cell transport, cell signaling, and the relation of cell structure and function. Cell Biology requires the General Chemistry sequence to be completed and suggests completion of Organic Chemistry I. Finally, Ecology and Evolution covers concepts and models of population growth, interactions of species, community ecology, and energy and nutrient flow in ecosystems.[133]

Major-level. The major-level data is a subset of the course-level dataset which included the records of any student who switched majors while enrolled in a 100- or 200-level chemistry, biology, or physics course for the time the data was available (2004 – 2017). Anonymous student records included the student's gender, race/ethnicity, major they were leaving, and major they were entering. Six major categories were analyzed: Chemistry, Biology, Physics, Other STEM (as defined by the institution[5]), Non-STEM, and Undeclared. Chemistry, Biology, and Physics were chosen because they are the disciplines of interest throughout this research. Other STEM, Non-STEM, and Undeclared were included to investigate the switching patterns of students into or out of STEM and, more specifically, STEM sciences.

[5] Other STEM majors include Computer Science, Earth and Environmental Science, Engineering, Math, and Neuroscience.

Results

Degree-level analysis: Examining diversity of graduates

D1. How are URM students represented among chemistry degrees compared to biology and physics? To first establish the state of students completing their STEM science undergraduate education, I collected registrar data on degrees conferred between 2005 – 2017 to study the representation of URM students in three disciplines: chemistry (N = 1159), biology (N = 4398), and physics (N = 117). Table 3.2 shows the representational make-up of degrees by the racial/gender demographic intersections of interest in this research: Hispanic female, Hispanic male, Black/African American female, Black/African American male, White female, and White male. For further comparisons, campus-wide data was included for all undergraduate degrees conferred between 2011 – 2018[6].[134]

As seen in Table 3.2, Hispanic and Black/African American students constitute a smaller percentage of the degrees awarded in each field. Hispanic and Black/African American students, both female and male, comprise 14.4% of all chemistry degrees, 15.7% of all biology degrees, and 8.6% of all physics degrees. Meanwhile, White students hold 36.6%, 36.5%, and 70.9% of chemistry, biology, and physics degrees, respectively.

Table 3.2 Representation of various demographic groups for degrees awarded in chemistry, biology, and physics (2005 - 2017) compared to overall campus representation for the population of undergraduate degrees conferred (2011 - 2018) by only race/ethnicity. Groups in the 'Other' category include Asian, American Indian/Alaskan Native, Native Hawaiian/Pacific Islander, Multi-Race, and International.

	Chemistry *(N = 1159)*	*Biology* *(N = 4398)*	*Physics* *(N = 117)*	*Undergrad Population*
Hispanic Female	4.4%	6.3%	1.7%	15.2%
Hispanic Male	4.9%	4.4%	6.0%	
Black/African American Female	2.8%	3.3%	0%	6.7%
Black/African American Male	2.3%	1.7%	0.9%	
White Female	18.4%	21.4%	12.8%	44.4%
White Male	18.2%	15.1%	58.1%	
Other	48.9%	47.7%	20.7%	33.7%

[6] This was the data publicly available at the time of the analysis. Campus data for the same time period as registrar-collected data was not available.

Further, there is a large disparity between URM representation in chemistry, biology, and physics and overall campus degrees. For instance, Hispanic students, both female and male, represent 9.3% of all chemistry degrees, 10.7% of all biology degrees, and 7.7% of all physics degrees awarded over 14 years. Conversely, the same racial group constitutes more than 15% of all undergraduate degrees awarded on campus over an eight-year period. Similar disparities exist for Black/African American students: these students represent 5.1% of all chemistry degrees, 5% of all biology degrees, and less than 1% of physics degrees, but represent 6.7% of degrees awarded across the campus.

D2. What is the likelihood that URM students attain a degree in chemistry compared to biology and physics? When comparing the sample sizes across disciplines (Table 3.2), physics had a low N (N = 117) relative to chemistry and biology, which makes statistical comparisons across all three disciplines at the degree-level not feasible. Thus, the likelihood of degree attainment analysis will be between chemistry and biology, only.

I employed binary logistic regression to investigate if demographic group is associated with the likelihood of attaining a degree in chemistry or biology. The outcome, or dependent variable, was the degree attained, *chemistry* = 0 and *biology* = 1 (*chemistry* being the reference category). The categorical independent variables, or predictors, of gender and race/ethnicity were dummy coded for ease of interpretation: *whether female* (no = 0, yes = 1), *whether Hispanic* (no = 0, yes = 1), and *whether Black/African American* (no = 0, yes = 1), with male and White as the reference groups. I also included two interaction terms to the model: *whether Hispanic female* (no = 0, yes = 1) and *whether Black/African American female* (no = 0, yes = 1). The predictors were included in a stepwise regression to first account for main effects, then account for interactions in the second step.

The binary logistic regression model was statistically significant at Step 1, $X^2(3) = 14.836$, $p = .002$, -2LL = 1653.612. However, Step 2, which introduced interactions, was not significant, $X^2(2) = 1.070$, $p = .586$, and was not considered for the overall model. Table 3.3 includes the Wald Chi-squares and betas for predictors included in the significant model. The only significant predictor for the regression model was *whether female*. This means that female students are more likely to attain a degree in biology rather than chemistry.

Table 3.3 Wald Chi-square tests and betas of predictors for the binary logistic regression to determine if demographic group is associated to likelihood of a student attaining a degree in biology, compared to chemistry, N = 1628.

			Wald Chi-			*Exp (B) or*	*95% CI for Exp(B)*	
	B	*SE*	*Square*	*df*	*p*	*Odds Ratio*	***Lower***	***Upper***
Whether female	.434	.123	12.497	1	<.001	1.544	1.213	1.964
Whether Hispanic	.040	.148	.074	1	.785	1.041	.779	1.391
Whether Black/AA	-.337	.204	2.725	1	.099	.714	.479	1.065
Constant	1.123	.097	132.862	1	<.001	3.074		

Figure 3.1 shows the relative odds ratios of each predictor included in the significant model for attaining a degree in biology vs a degree in chemistry. As seen in the figure, female students are significantly more likely to attain a degree in biology, rather than chemistry, when compared to their male peers, holding race/ethnicity constant. However, Black/African American and Hispanic students are just as likely (no statistical difference) to attain a degree in biology as in chemistry, when compared to White students, while holding gender constant.

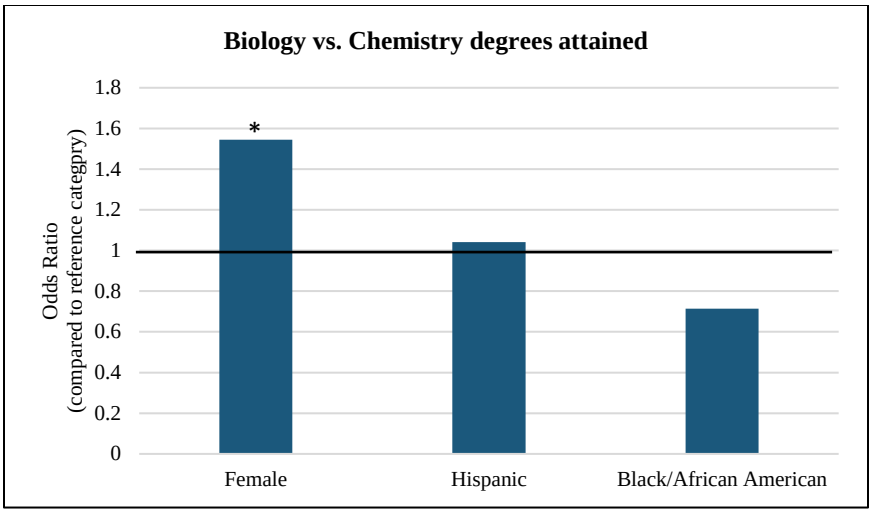

Figure 3.1 Odds ratios, compared to respective reference categories, for attaining a degree in biology relative to chemistry. The reference line at y = 1.0 is the odds ratio for the reference categories, male and White. Asterisk indicates statistically significant differences from the reference group.

D3. Have the levels of representation of URM students changed over time in chemistry compared to biology and physics? Since there were clear differences in representation between degree programs, I wanted to investigate if the proportion of degrees awarded to URM students changed as a function of time. Figures 3.2-3.4 show the relative proportions of degrees awarded for each discipline among all bachelor's degrees over the 13-year period of data. Unfortunately, due to small cell sizes and low power[135], a statistical analysis examining the change in degrees awarded over time was not possible. However, because this data contained the whole population from the institution, I could consider descriptive statistics (Table 3.4) and the trends observed in Figures 3.2-3.4 as a form of analyzing the changes of degree attainment that occurred over time.

Table 3.4 Mean percent (and standard deviation) of degrees awarded among all bachelor's degrees by demographic group in chemistry, biology, and physics between 2005 – 2017.

	Chemistry	*Biology*	*Physics*
Hispanic Female	1.02% (0.58)	5.84% (1.80)	0.03% (0.07)
Hispanic Male	1.55% (0.90)	5.37% (1.74)	0.24% (0.33)
Black/African American Female	1.58% (1.15)	7.15% (2.56)	0.00% (0.00)
Black/African American Male	2.39% (1.36)	6.86% (3.17)	0.11% (0.39)
White Female	1.93% (0.47)	8.60% (1.84)	0.14% (0.12)
White Male	2.04% (0.69)	6.44% (1.02)	0.66% (0.21)

Before exploring the trends of each demographic group with the three disciplines, it is important to understand what the trends were seen across campus, similar to the comparisons in

research question D1. As seen in the table above, biology makes up a larger percentage of all bachelor's degrees compared to chemistry or physics, though all are still relatively small within each demographic group. Within a racial/ethnic group, female students have a higher mean percentage of biology degrees than their male peers. The opposite is true for chemistry degrees, with males earning more degrees on average within the same racial/ethnic group.

Figure 3.2 shows the relative proportions of chemistry degrees awarded among all bachelor's degrees across campus each year for each demographic group of interest. Overall, each of the demographic groups steadily increase in their proportion of chemistry degrees over time. However, White students (blue lines) were retained in chemistry degrees more consistently than their peers. Black/African American (yellow lines) and Hispanic (red lines) students were more susceptible to ebbs and flows in their representation in chemistry as seen by the sharp increases and declines in the graph below.

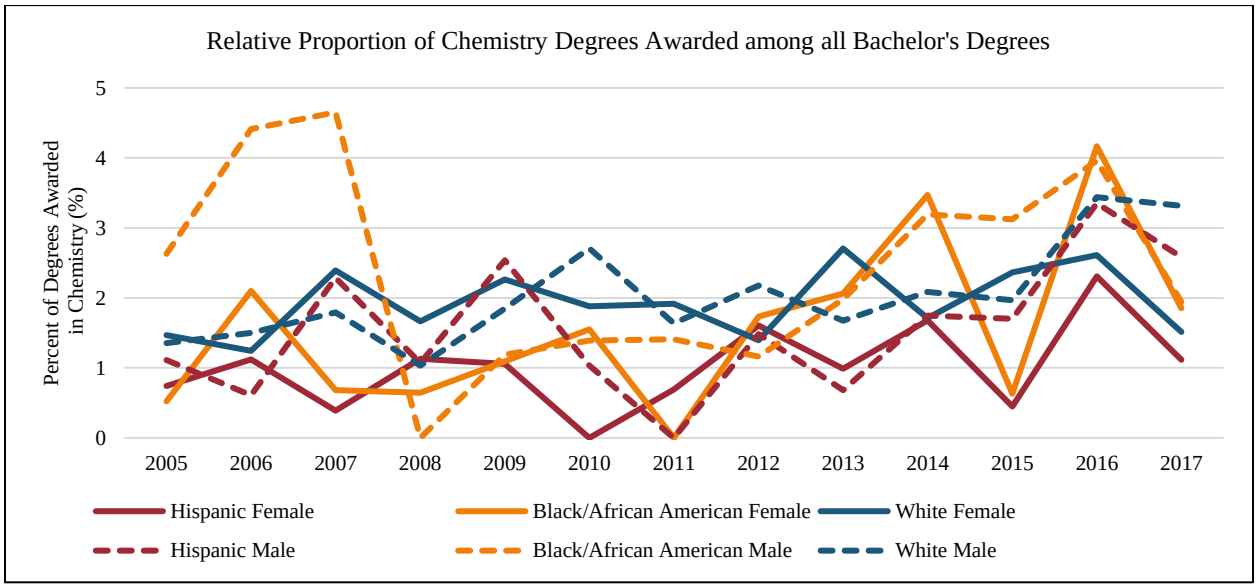

Figure 3.2 Relative proportion of chemistry degrees among all bachelor's degrees across campus each year. Each line representing a demographic group.

Similar to chemistry, each demographic group increased over the thirteen-year time period in biology representation among all bachelor's degrees (Figure 3.3). Additionally, White students were more consistent over these years of biology degrees whereas biology degrees for Hispanic and Black/African American students vary wildly in their proportion of all degrees.

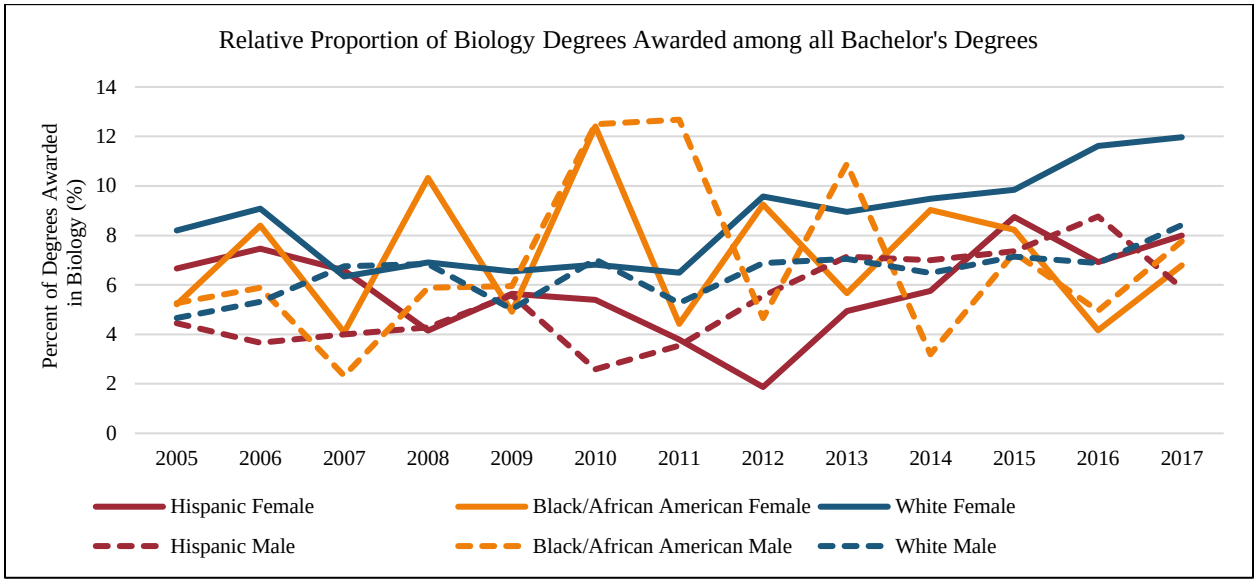

Figure 3.3 Relative proportion of biology degrees among all bachelor's degrees across campus each year. Each line representing a demographic group.

As previously mentioned, physics had a much lower N relative to chemistry and biology. For any given year within the data set, physics made up no more than 1.5% of all bachelor's degrees for any demographic group. To this point, relatively small proportions of female students earned physics degrees over the thirteen years, with no Black/African American female students earned a physics degree within this time frame. Similar to the other science disciplines, marginalized students who did earn physics degrees fluctuated year to year, while representation of White male students was more consistent.

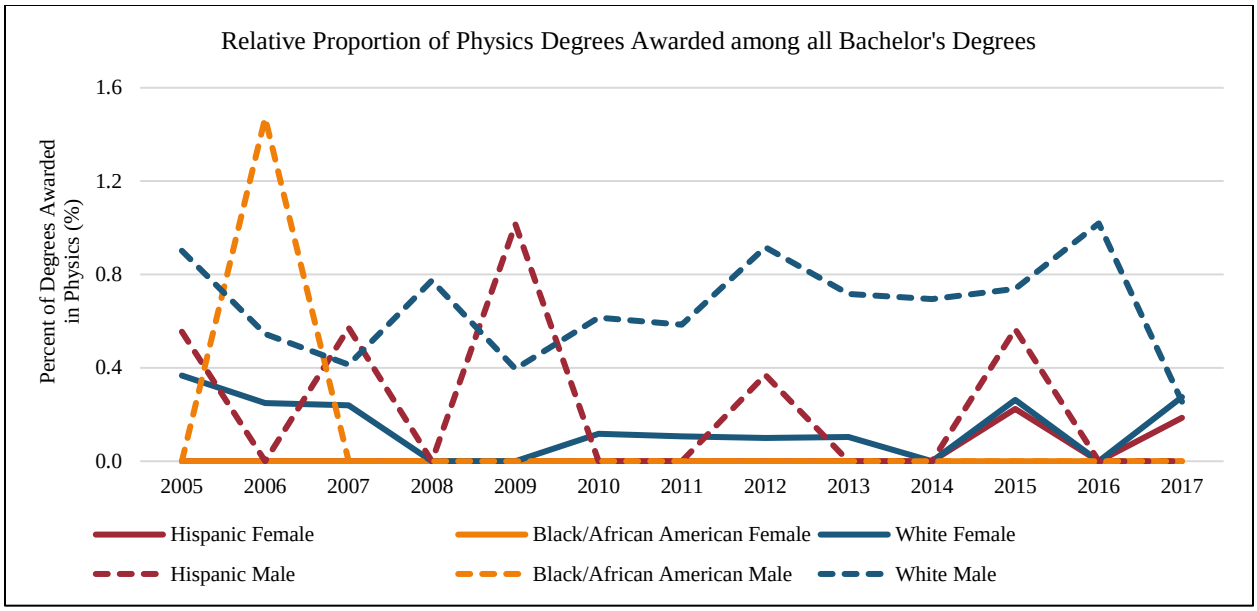

Figure 3.4 Relative proportion of chemistry physics degrees among all bachelor's degrees across campus each year. Each line representing a demographic group.

Major-level analysis: Entering or leaving?

M1. Who switches in or out of the STEM degrees? Having examined the representation and likelihood of degrees awarded to students in chemistry, biology, and physics and seeing the varying Ns between departments, it's worth trying to understand if there are large movements of students due to switching majors. A Sankey diagram (pictured below) is a representation that can be used to show the flow between a source and a target. The width of the link between the source and target changes with amount of flow (i.e. the wider the link, the higher the number of students that took that path). In the context of this analyses, we can think of the source as the major before a switch occurred and the target as the major after a switch. Further the flow will indicate the number of students who made the same kind of switch between majors.

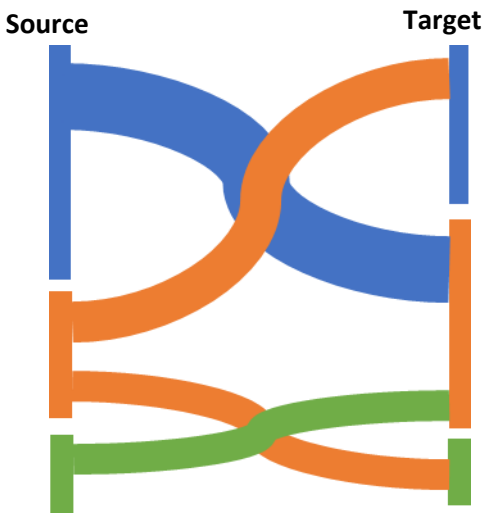

Figure 3.5 Generic Sankey diagram

To examine the flow of students between majors, Sankey diagrams were created for each of the demographic groups. From the individual Sankey diagrams, I clustered demographic groups together based on their shared net changes of switchers for each major category. As seen in Table 3.5, among the six demographic groups, three common groupings emerged: (1) a loss for chemistry, biology, and physics (CBP), (2) a loss for chemistry, and (3) a loss for physical sciences.

Table 3.5 The change in percent of representation in each major per demographic of those that switched. Negative values (in red cells) indicate fewer students remain in a particular major after the switches occurred. Positive values (in green cells) indicate more students remain in a particular major after the switches occurred.

	Δ Chemistry	**Δ Biological Sciences**	**Δ Physics**	**Δ Other STEM[7]**	**Δ Non-STEM**	**Δ Undeclared**
Black/African American female	-12.2%	-6.4%	-0.3%	+1.4%	+14.8%	+2.8%
Hispanic female	-11.6%	-4.7%	-0.7%	+2.2%	+14.1%	+0.9%
White female	-11.5%	+8.0%	+0.1%	+2.4%	+7.6%	-6.7%
Hispanic male	-5.1%	+4.5%	+0.2%	+2.1%	+6.9%	-8.8%
White male	-7.6%	+7.4%	+0.9%	+3.1%	+6.5%	-10.3%
Black/African American male	-8.5%	+5.0%	-0.5%	+5.0%	+5.0%	-6.0%

[7] As defined by the university, Other STEM includes earth and environmental science, neuroscience, computer science, engineering, and math

A loss for CBP. The first trend was shared between Black/African American female students and Hispanic female students (Figures 3.6 and 3.7). This trend shows there is a net decrease for Chemistry, Biological Sciences, and Physics and a net increase for Other STEM, Non-STEM, and Undeclared. This means that more Black/African American female students and Hispanic female students are switching out of CBP majors than switching into those same majors. For both these groups of students, Biology is the largest contributor of switchers. Additionally, Biology and Non-STEM are the largest beneficiaries from these students switching. Finally, Chemistry sees the largest proportional descreases than with all other majors for these students.

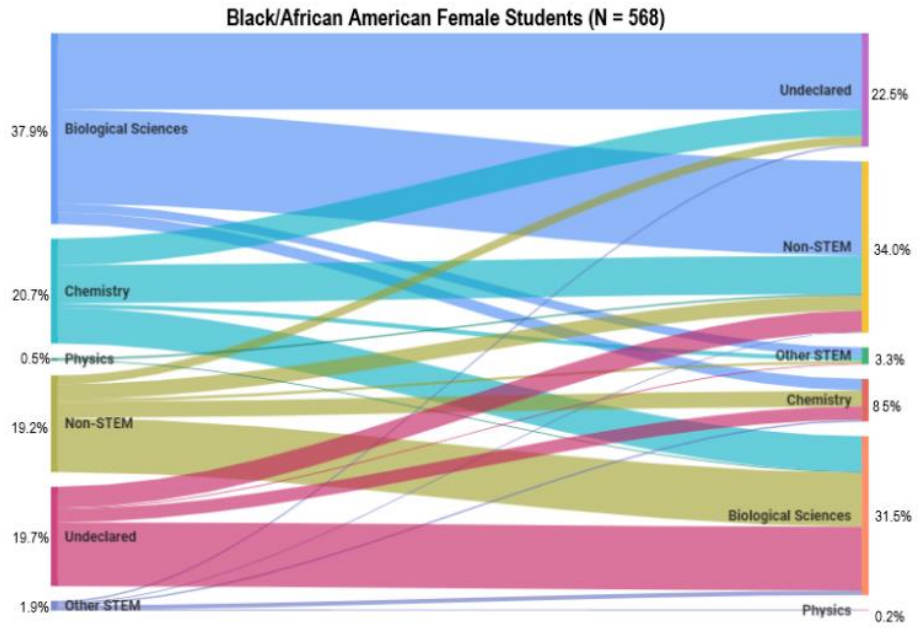

Figure 3.6 Sankey diagram of Black/African American female students who switched majors. Percentages indicate how many students were within each major before and after the switch.

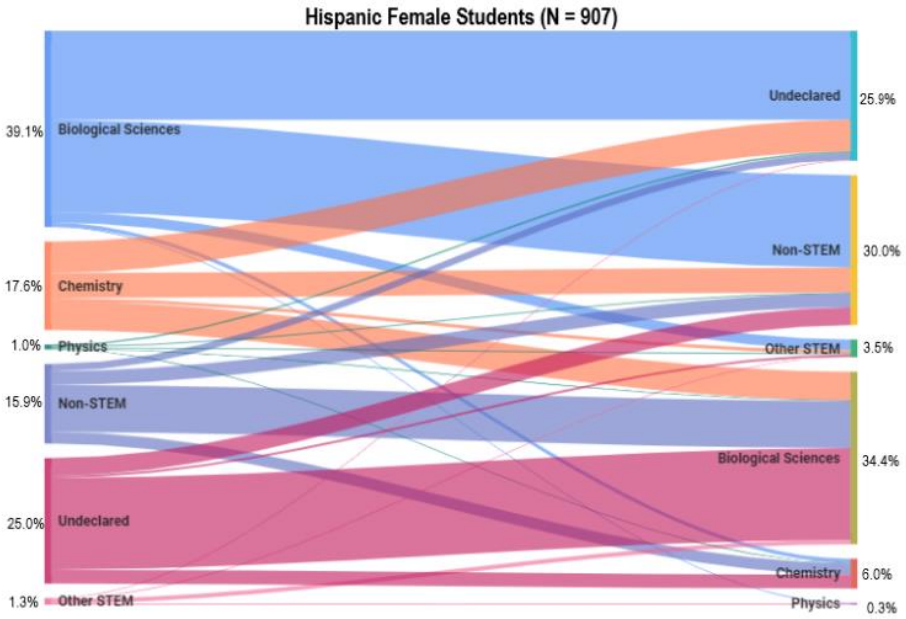

Figure 3.7 Sankey diagram of Hispanic female students who switched majors. Percentages indicate how many students were within each major before and after the switch.

A loss for physical sciences. The second trend that emerged was seen only for Black/African American male students (Figure 3.8). Here, we see negative net changes for Chemistry, Physics, and Undeclared and positive net changes for Biological Sciences, Other STEM, and Non-STEM. The negative net changes for Undeclared is not necessarily a bad thing, since having less students be Undeclared means students are deciding on a major. In the case of Black/African American male students, they are overwhelmingly choosing Biological Sciences over other majors. Additionally, Chemistry sees a decrease in students from switching and not a single student decides to switch into Physics.

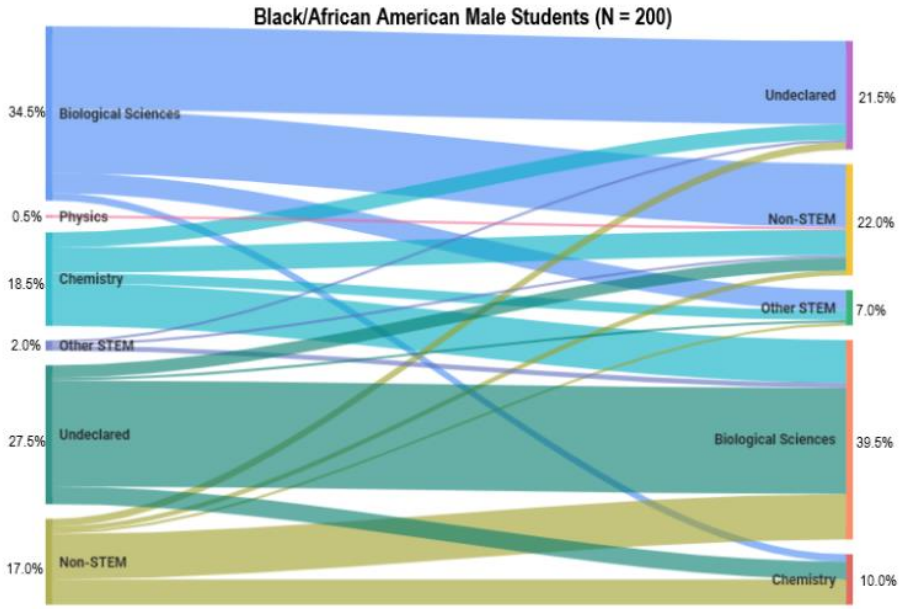

Figure 3.8 Sankey diagram of Black/African American male students who switched majors. Percentages indicate how many students were within each major before and after the switch.

A loss for chemistry. The second trend was shared between Hispanic male students and White students, both female and male (Figures 3.9-3.11). Here, only two major categories see negative net changes: Chemistry and Undeclared. As mentioned in the second trend, a negative net change for Undeclared means students are deciding to declare majors. For all three of these demographic groups, all students who were Undeclared before the switch had chosen a major, either Chemistry, Biological Sciences, Physics, Non-STEM, or Other STEM, after the switch occurred. Unfortunately, this leaves Chemistry as the only major with losses of students after switching for these demographic groups, ranging in losses between 5.1-11.5% of students. On the positive side, Biological Sciences is the largest inheritor of switchers in these three demographic groups, with more than 35% of students choosing this major post-switch.

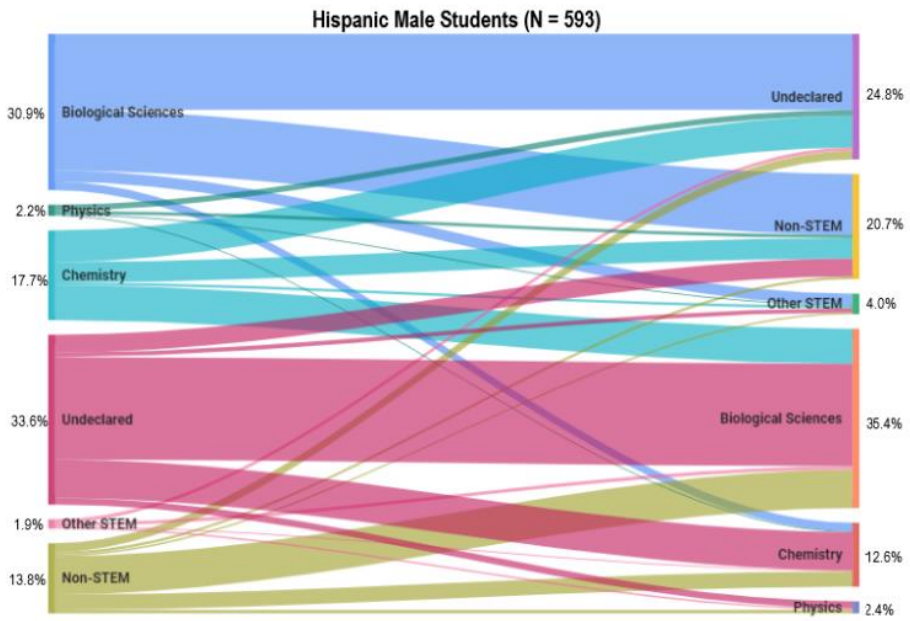

Figure 3.9 Sankey diagram of Hispanic male students who switched majors. Percentages indicate how many students were within each major before and after the switch.

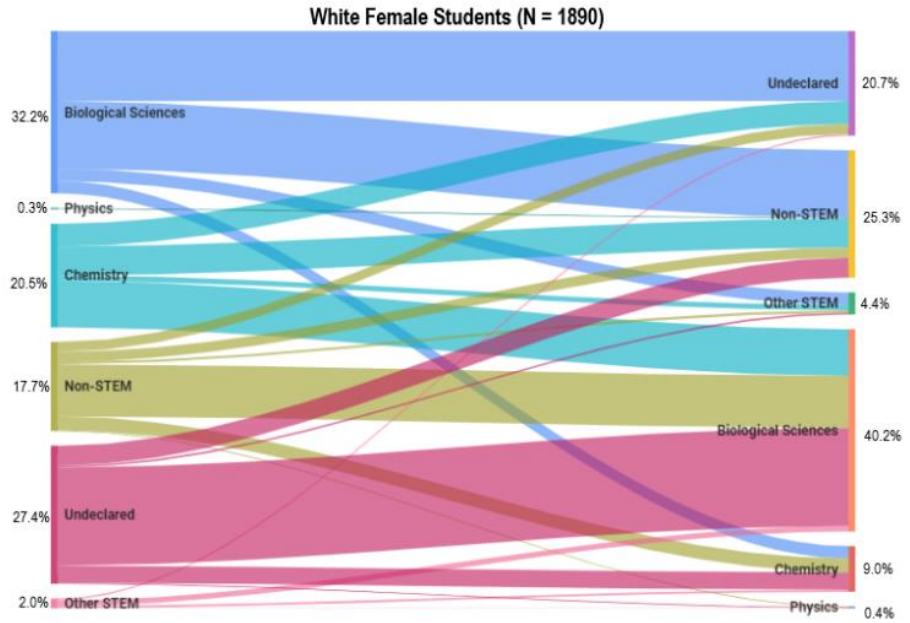

Figure 3.10 Sankey diagram of White female students who switched majors. Percentages indicate how many students were within each major before and after the switch.

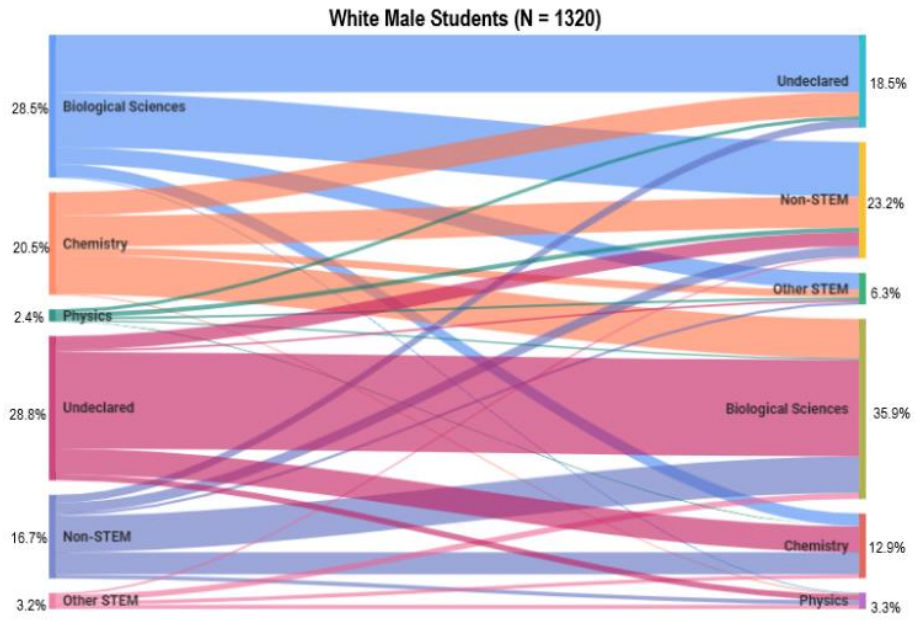

Figure 3.11 Sankey diagram of White male students who switched majors. Percentages indicate how many students were within each major before and after the switch.

Across all six demographic groups, more students leave the Chemistry major than enter and more students enter Other STEM and Non-STEM majors than leave. Further, Black/African American female students and Hispanic female students are leaving chemistry in larger proportions than any other demographic groups. When considering trends on a gender basis, more female students from each demographic group (i.e. Black/African American female, Hispanic female, and White female) switch into Non-STEM majors than leave Non-STEM majors, while more male students (i.e. Black/African American male, Hispanic male, and White male) leave Non-STEM majors than switch into Non-STEM majors.

Table 3.6 Percentage of all students who switched from and to each major. Cells are shaded by quartiles to show more popular switching patterns (darker shades) and less popular patterns (lighter shades): Q1: ≤ 0.25%, Q2: 0.26-0.49%, Q3:0.50-3.51%, Q4: ≥3.52%.

		Switched to…					
		Chemistry	**Biological Sciences**	**Physics**	**Other STEM**	**Non-STEM**	**Undeclared**
Switched from…	**Chemistry**	--	7.81%	0.04%	1.06%	5.70%	5.08%
	Biological Sciences	2.05%	--	0.07%	2.59%	13.98%	14.28%
	Physics	0.06%	0.13%	--	0.16%	0.44%	0.37%
	Other STEM	0.38%	1.02%	0.31%	0.02%	0.15%	0.26%
	Non-STEM	3.23%	9.13%	0.33%	0.40%	2.05%	1.72%
	Undeclared	4.11%	18.66%	0.49%	0.42%	3.52%	0.02%

Overall, more than half of all students who switched majors took one of four paths: (1) from Undeclared to Biological Sciences, (2) from Biological Sciences to Undeclared, (3) from Biological Sciences to Non-STEM, or (4) from Non-STEM to Biological Sciences (Table 3.6).

Course-level analysis: DFW rates and Chemistry drop-out analysis

C1. How are URM students represented among chemistry courses compared to physics and biology? Because the degree-level and the major-level analysis revealed disparities among URM students who completed the degree program and those who chose to leave the degree program, it is important to drill down to the course-level to determine if disparities exist there as well. To answer the research question, I first examined the DFW rates of various groups of students. Again, we look at DFW rates because these grades prevent students from advancing in the introductory sequences. Tables 3.7-3.9 include the DFW rates for female vs. male students, Black/African American vs. Hispanic vs. White students, and the demographic groups with the intersection of race/ethnicity and gender, respectively.

When considering only gender, we can see that the four biology courses have little difference in DFW rates and overall, have relatively low DFW rates (≤ 25%). The physics courses vary on DFW rates. However, overall, chemistry has the highest DFW rates, with female students having higher DFW rates compared to their male peers in the same course.

Table 3.7 Count and DFW rates of female and male students over the 14-year period of the data. DFW rates are shaded by quartiles ranging from the low end of bright orange to the higher end of bright red (Q1: ≤ 21%, Q2: 22-28%, Q3:29-33%, Q4: ≥34%).

Course	Female		Male	
	N	*DFW Rate*	*N*	*DFW Rate*
Preparatory Chemistry	7850	33%	4146	30%
General Chemistry I	8023	33%	6361	32%
Organic Chemistry I	4755	36%	3247	30%
Organic Chemistry II	3199	40%	2537	36%
Cells and Organisms	6461	18%	3618	17%
Genetics	2926	21%	2171	20%
Cell Biology	2675	21%	1971	15%
Ecology and Evolution	2515	25%	1660	19%
Introductory Physics I	3076	35%	2350	34%
Introductory Physics II	1984	20%	1458	22%
General Physics I	1100	35%	3492	32%
General Physics II	765	26%	2728	25%

When the DFW rates are compared by race/ethnicity, overwhelmingly, Black/African American students have higher DFW rates, with Hispanic students shortly behind, when compared to their White peers across courses of all disciplines. Finally, again, biology courses have the lowest DFW rates compared to chemistry and physics across racial groups.

Table 3.8 Count and DFW Rates of Black/African American, Hispanic, and White students over the 14-year period of the data. DFW Rates are shaded by quartiles ranging from the low end of dark green to the higher end of dark red (Q1: ≤ 25%, Q2: 26-30%, Q3:31-41%, Q4: ≥42%).

Course	Black/AA		Hispanic		White	
	N	*DFW Rate*	*N*	*DFW Rate*	*N*	*DFW Rate*
Preparatory Chemistry	1952	42%	5202	37%	4842	23%
General Chemistry I	1715	42%	4678	37%	7991	28%
Organic Chemistry I	908	44%	2069	40%	5025	29%
Organic Chemistry II	592	45%	1331	44%	3813	35%
Cells and Organisms	1319	28%	3086	23%	5673	12%
Genetics	551	28%	1194	28%	3352	17%
Cell Biology	549	26%	1175	23%	2922	15%
Ecology and Evolution	462	35%	1107	30%	2606	17%
Introductory Physics I	642	48%	1270	43%	3514	29%
Introductory Physics II	367	32%	728	26%	2347	17%
General Physics I	399	50%	1231	42%	2962	27%
General Physics II	261	31%	858	34%	2374	22%

Since there are seemingly large differences between gender and race/ethnicity for DFW rates, I also examined the DFW rates for the intersection of race/ethnicity and gender (Table 3.9). Not only do the trends seen in the gender and race/ethnicity comparison remain, but they are

exacerbated for some groups. A clear difference in DFW rates can be seen when comparing White students, both female and male, to their URM peers. Black/African American female students have DFW rates in most chemistry and physics courses above 40%. However, White students, both female and male, have DFW rates all below 36% and as low as under 20% in the majority of the courses.

Table 3.9 DFW Rates of Black/African American, Hispanic, and White female and male students over the 14-year period of the data. DFW Rates are shaded by quartiles ranging from the low end of dark green to the higher end of dark red (Q1: ≤ 25%, Q2: 26-29%, Q3:30-39%, Q4: ≥40%).[8]

Course	Female Black/AA DFW Rate	Female Hispanic DFW Rate	Female White DFW Rate	Male Black/AA DFW Rate	Male Hispanic DFW Rate	Male White DFW Rate
Preparatory Chemistry	44%	39%	22%	34%	35%	24%
General Chemistry I	41%	38%	26%	43%	36%	29%
Organic Chemistry I	47%	43%	30%	36%	37%	26%
Organic Chemistry II	47%	48%	36%	40%	40%	33%
Cells and Organisms	29%	23%	11%	25%	21%	13%
Genetics	29%	27%	16%	25%	28%	17%
Cell Biology	27%	27%	17%	26%	17%	13%
Ecology and Evolution	36%	34%	19%	31%	25%	15%
Introductory Physics I	47%	43%	30%	50%	43%	28%
Introductory Physics II	32%	25%	16%	33%	27%	19%
General Physics I	52%	42%	28%	49%	42%	27%
General Physics II	28%	39%	21%	34%	32%	22%

To examine how DFW grades are distributed in courses and if the differences above are statistically significant, I applied a binary logistic regression to investigate if a student's demographic group is associated with their likelihood of passing or failing a given course. The outcome, or dependent variable, was the *final grade*, with DFW = 0 and pass = 1 (*pass* being the reference category). The predictors, or independent variables, were gender and race/ethnicity. The categorical independent variables were dummy coded for ease of interpretation: *whether female* (no = 0, yes = 1), *whether Hispanic* (no = 0, yes = 1), and *whether Black/African American* (no = 0, yes = 1), with male and White were the reference groups. I also included two interaction terms to the model: *whether Hispanic female* (no = 0, yes = 1) and *whether*

[8] A table of the N for each racial/gender demographic group per course can be found in Appendix A.

Black/African American female (no = 0, yes = 1). The predictors were included in a stepwise regression to first account for main effects of gender and race/ethnicity, then introduce interactions in the second step. Models were constructed for each of the twelve courses.

Overall, all models were statistically significant (Table 3.10). However, some courses had significant models only at Step 1 (when main effects were entered), while other courses had significant models when main effects and interactions were included (Step 2 was significant). Wald Chi-squares and betas for all predictors in the significant model are included in Appendix A.

Table 3.10. Results of each binary logistic regression model to determine if gender, race/ethnicity, and academic year is associated with a student passing or failing a given course.

Course	-2LL	Chi-square	df	p	Last Sig Step in Model
Preparatory Chemistry	14694.706	385.987	5	<.001	Step 2
General Chemistry I	17921.922	210.144	5	<.001	Step 2
Organic Chemistry I	10029.397	162.451	3	<.001	Step 1
Organic Chemistry II	7552.724	60.822	3	<.001	Step 1
Cells and Organisms	9019.591	285.201	5	<.001	Step 2
Genetics	5086.714	81.857	3	<.001	Step 1
Cell Biology	4351.463	79.026	3	<.001	Step 1
Ecology and Evolution	4336.840	13.859	3	<.001	Step 1
Introductory Physics I	6856.762	136.462	3	<.001	Step 1
Introductory Physics II	3455.617	56.270	3	<.001	Step 1
General Physics I	5697.216	137.844	3	<.001	Step 1
General Physics II	3907.011	51.386	3	<.001	Step 1

Using Preparatory Chemistry as an example, Equation 1 shows the logit expression for the model, where p'(Y) is the probability (here, the probability of passing the course), the *significant* predictor variables and their coefficients: *whether female* (female), *whether Hispanic* (Hispanic), *whether Black/African American* (Black), *whether Hispanic female* (HispanicF), *whether Black/African American female* (BlackF), and the constant.

$$logit = ln\frac{p'(Y)}{1-p'(Y)} = 1.157 - .556 * Hispanic - .510 * Black - .256 * HispanicF - .538 * BlackF \quad (1)$$

Table 3.11 includes the logit expressions for all twelve courses under study. Within the twelve courses, two large groupings were found to have similar significant coefficients, and three courses stand alone with unique significant predictors.

Table 3.11 Logit expressions of all models for the binary logistic regression to determine if gender and race/ethnicity is associated with the likelihood of a student passing or failing a given course. Only significant predictors are included in the logit expressions.

Course	Logit Expressions
Preparatory Chemistry	$logit = 1.157 - .556 * Hispanic - .510 * Black - .695 * HispanicF - .931 * BlackF$
General Chemistry I	$logit = .886 + .147 * female - .293 * Hispanic - .619 * Black - .417 * HispanicF - .513 * BlackF$
Organic Chemistry I	$logit = 1.050 - .230 * female - .523 * Hispanic - .641 * Black$
Organic Chemistry II	$logit = .724 - .163 * female - .406 * Hispanic - .399 * Black$
Cells and Organisms	$logit = 1.890 + .178 * female - .582 * Hispanic - .807 * Black - .703 * HispanicF - 1.001 * BlackF$
Genetics	$logit = 1.593 - .642 * Hispanic - .651 * Black$
Cell Biology	$logit = 1.931 - .338 * female - .514 * Hispanic - .671 * Black$
Ecology and Evolution	$logit = 1.773 - .346 * female - .724 * Hispanic - .888 * Black$
Introductory Physics I	$logit = .914 - .607 * Hispanic - .815 * Black$
Introductory Physics II	$logit = 1.490 - .503 * Hispanic - .825 * Black$
General Physics I	$logit = .990 - .647 * Hispanic - .987 * Black$
General Physics II	$logit = 1.284 - .604 * Hispanic - .499 * Black$

Group 1. Genetics and all four physics courses, Introductory Physics I and II and General Physics I and II, had only main effects included in the model and had two significant negative predictors in their logit expression: *whether Hispanic* and *whether Black/African American*. For these five courses, identifying as Hispanic or Black/African American lower the probabilities of passing the course, when compared to their White peers.

Figure 3.12 shows the odds ratios, relative to the respective reference categories, of passing the given course. Female students were just as likely to pass each of these courses when compared to their male peers (no statistical differences). However, Hispanic and Black/African

American students were significantly less likely to pass these courses when compared to their White peers.

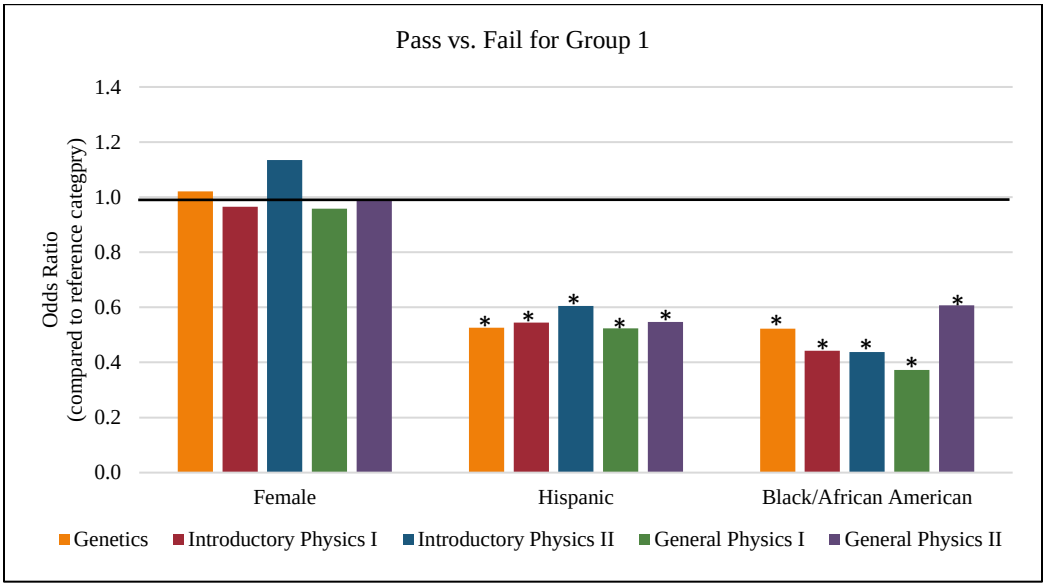

Figure 3.12 Odds ratios, compared to respective reference categories, for passing a course. The reference line at y = 1.0 is the odds ratio for the reference categories, male and White. Asterisks indicate statistically significant differences from the reference group.

Group 2. Organic Chemistry I and II, Cell Biology, and Ecology and Evolution also had significant models with only main effects included. These courses had models with all significant main effects, with negative coefficients. Female students were significantly less likely to pass each of these courses when compared to their male peers. Similarly, Hispanic and Black/African American students were significantly less likely to pass these courses when compared to their White peers (see Figure 3.13).

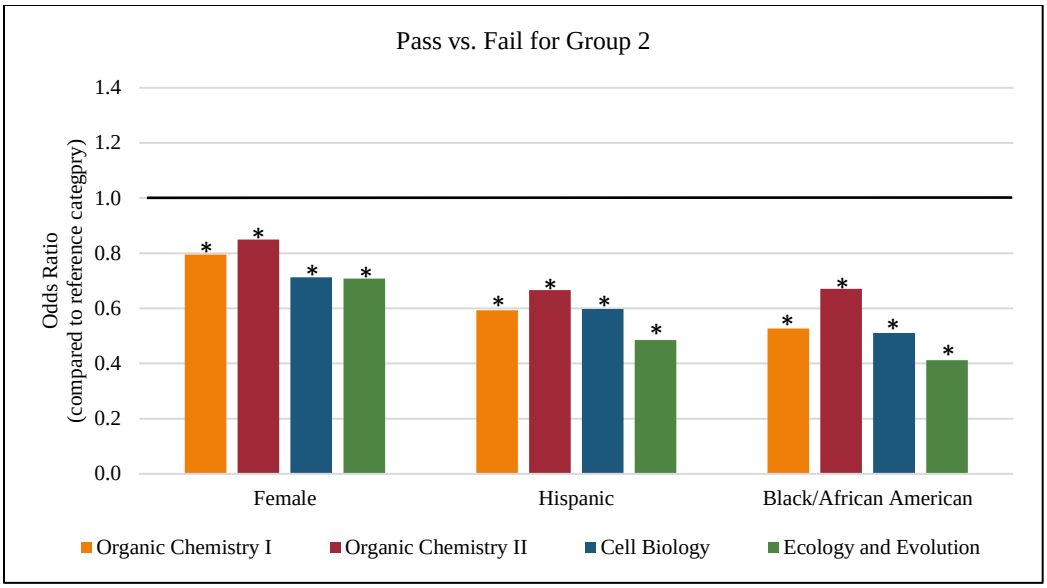

Figure 3.13 Odds ratios, compared to respective reference categories, for passing a course. The reference line at y = 1.0 is the odds ratio for the reference categories, male and White. Asterisks indicate statistically significant differences from the reference group.

Group 3. Because of how the predictors were dummy coded, follow-up calculations were needed for the models that were significant when the interaction terms were included (Preparatory Chemistry, General Chemistry I, and Cells and Organisms). From the binary logistic regression, the beta coefficients for Hispanic female students and Black/African American female students had to be calculated from the other beta terms. Using Hispanic female students as an example in Preparatory Chemistry (Table 3.12), the *whether Hispanic female* interaction term produced a unique term that compared the grand mean to the entire population. To correctly compare Hispanic female students to the reference group (White male) and not the entire population, one needs to sum the beta coefficients for the *whether female*, *whether Hispanic*, and *whether Hispanic female*.

Table 3.12 Calculated beta coefficient terms for Hispanic female and Black/African American female students.

Course	*Hispanic female*	*Black/African American female*
Preparatory Chemistry	-0.695	-0.931
General Chemistry I	-0.417	-0.513
Cells and Organisms	-0.703	-1.001

However, these calculations of the betas do not give information on the significance of odds ratios. Therefore, another analysis was done to account for Hispanic female and Black/African American female students' likelihood of passing the courses. I applied a binary logistic regression to investigate if racial group is associated with whether a female student is likely to pass these three courses. White female students were used as the reference group. Again, a model was constructed for each of the courses. All models were significant (Table 3.13). Wald Chi-squares and betas for all predictors in the significant model are included in Appendix A.

Table 3.13 Results of each binary logistic regression model to determine if gender, race/ethnicity, and academic year is associated with a student passing or failing a given course.

Course	-2LL	Chi-square	df	p
Preparatory Chemistry	9679.967	310.993	2	<.001
General Chemistry I	9969.730	155.176	2	<.001
Cells and Organisms	5811.655	230.961	2	<.001

Figure 3.14 shows the odds ratios, relative to the respective reference categories, of passing a given course. When compared to White female students, Hispanic female and Black/African American female students were significantly less likely of passing each of the three courses. White female students had significantly higher odds of passing General Chemistry I and Cells and Organisms but just as likely to pass Preparatory Chemistry, when compared to their White male peers. Finally, Hispanic male and Black/African American male students showed significantly lower odds of passing each of the three courses when compared to their White male peers.

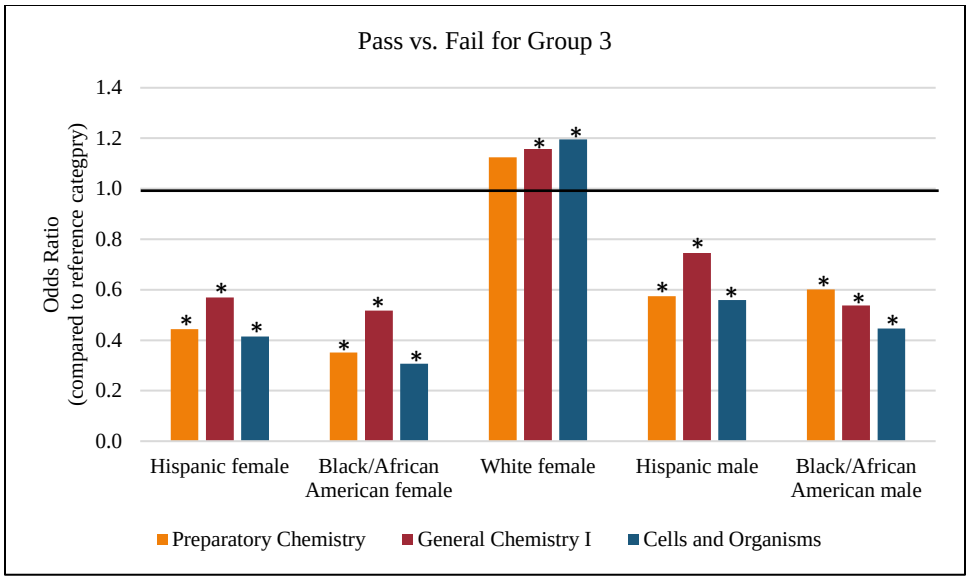

Figure 3.14 Odds ratios, compared to respective reference categories, for passing a course. The reference line at y = 1.0 is the odds ratio for the reference categories, male and White. Asterisks indicate statistically significant differences from the reference group.

C2. When do URM students drop out of chemistry? Because the results of the drop-out analysis above showed URM students were at higher risk of receiving a DFW in the majority of the courses, a subset of the course-level data was used to study at what point in a sequence do URM students drop out of a single discipline. Here, only chemistry was studied. In previous analyses, chemistry has been a significant source of disparity for URM students. In the major-level analysis, Black/African American female students and Hispanic female students left chemistry in larger proportions than any other demographic groups. Further, in the couse-level DFW analysis above, URM students showed significantly higher risks of receiving a DFW across all four chemistry courses analyzed.

The subset of the data includes students in the demographic groups of interest (Hispanic female and male, Black/African American female and male, and White female and male students) who began in one of two chemistry tracks (N = 16959). In the chemistry department at this institution, there are multiple tracks a student can follow based on their performance on the chemistry entrance exam prior to their first year. Two tracks were studied here (Figure 3.15): (1)

a student begins in Preparatory Chemistry, progresses through the General Chemistry sequence, and moves on to the Organic Chemistry sequence or (2) a student begins in the General Chemistry sequence and then onto the Organic chemistry sequence. These tracks were chosen because they are the most common at the institution. Moreover, a student being placed in Track 1 could delay them a semester or more behind a student placed in Track 2 (if the objective is to complete the full introductory sequence).

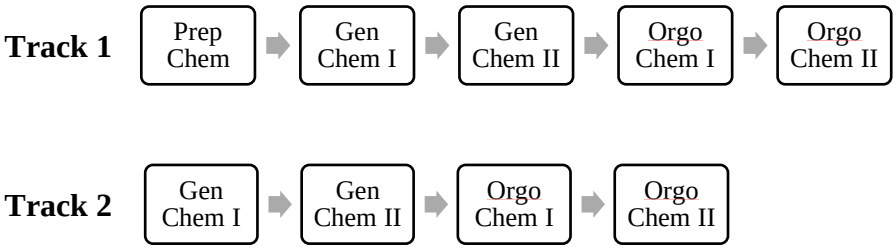

Figure 3.15 The two tracks under study to determine at what point are URM students dropping out of the chemistry discipline.

Further, when representation of students in the first course of each track were compared, Hispanic and Black/African American students collectively comprised 58% of the original student population of Track 1 and only 35% of the original student population of Track 2.

Track 1. A Pearson Chi-square test revealed that demographic group and course retention were significantly correlated ($X^2(20) = 207.37$, $p < .05$). To examine each course along the sequence, a two-proportion Z-test (with Bonferroni corrections) was carried out to determine if demographic groups had different retention rates. Table 3.14 shows the proportion of students retained for each demographic group by course and the statistically significant Z-test statistics at $p < .003$. Z-test statistics not shown mean the two proportions were not statistically different. All comparisons were made between demographic groups, but only White female and male students showed statistical differences for Track 1.

Table 3.14 Proportion of students retained when entering each course in Track 1 by demographic group. Z-test statistics shown were statistically significant at p < .003 (using a Bonferroni correction), meaning the two proportions (vs. White female students and vs. White male students) are statistically different.

	General Chemistry I			General Chemistry II			Organic Chemistry I			Organic Chemistry II		
	P	**Z-test** vs. White female	**Z-test** vs. White male	**P**	**Z-test** vs. White female	**Z-test** vs. White male	**P**	**Z-test** vs. White female	**Z-test** vs. White male	**P**	**Z-test** vs. White female	**Z-test** vs. White male
Black/AA female	.50	-8.27	-6.91	.21	-6.45	-3.66	.13	-6.19	-3.72	.08	-5.09	-4.35
Hispanic female	.54	-7.51	-5.79	.21	-8.49	-4.59	.13	-8.66	-5.08	.08	-7.09	-5.80
White female	.64	--	--	.31	--	--	.21	--	--	.13	--	--
Black/AA male	.50	--	--	.24	-3.00	--	.15	--	--	.10	--	--
Hispanic male	.51	-8.25	-6.75	.19	-9.04	-5.81	.12	-7.63	-4.82	.08	-5.62	-4.73
White male	.63	--	--	.27	--	--	.18	--	--	.13	--	--

In all four courses, a significantly higher proportion of White female and male students were retained than Black/African American female students and Hispanic students, both female and male. Black/African American male students were retained significantly less than White female students in General Chemistry II. Figure 3.16 graphically represents the retention of students over the course of the Track 1 sequence.

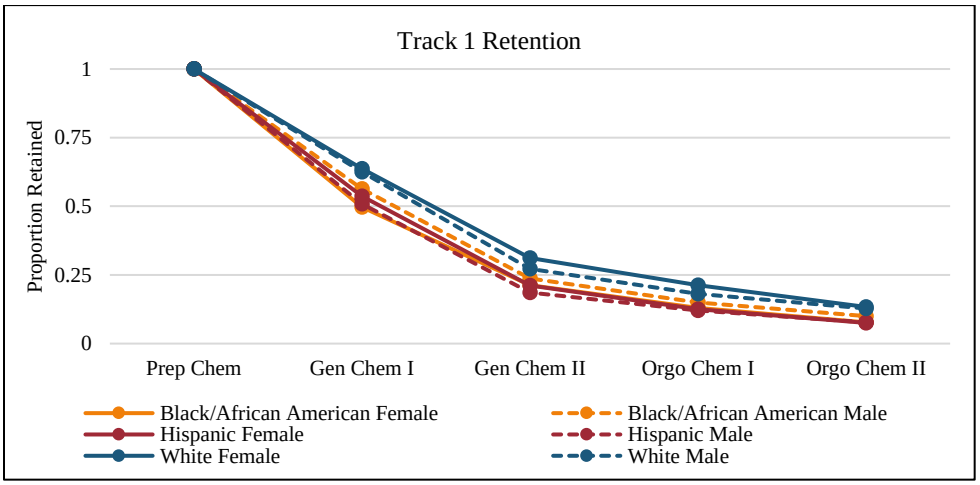

Figure 3.16 Track 1 retention of Black/African American, Hispanic, and White students (reference).

Track 2. A Pearson Chi-square test revealed demographic group and course retention were significantly correlated ($X^2(15) = 130.59$, $p < .05$). To examine each course along the

sequence, a two-proportion Z-test (with Bonferroni corrections) was run to determine if demographic groups had different retention rates. Table 3.15 shows the proportion of students retained of each demographic group by course and the statistically significant Z-test statistics at $p < .003$. Z-test statistics not shown mean the two proportions were not statistically different. All comparisons were made between demographic groups, but only White female students and Black/African American female students showed statistical differences for Track 2.

Table 3.15 Proportion of students retained when entering each course in Track 2 by demographic group. Z-test statistics shown were statistically significant at $p < .003$ (using a Bonferroni correction), meaning the two proportions (vs. White female students and vs. Black/African American female students) are statistically different.

	General Chemistry II			**Organic Chemistry I**			**Organic Chemistry II**	
	P	**Z-test** vs. White female	**Z-test** vs. Black/AA female	**P**	**Z-test** vs. White female	**Z-test** vs. Black/AA female	**P**	**Z-test** vs. White female
Black/AA female	.47	--	--	.34	--	--	.19	--
Hispanic female	.41	-5.49	--	.28	-4.94	--	.17	-4.69
White female	.53	--	--	.38	--	--	.26	--
Black/AA male	.37	-4.27	--	.26	-3.43	--	.20	--
Hispanic male	.36	-8.20	3.73	.24	-7.01	3.45	.17	-5.11
White male	.41	7.64	--	.27	7.42	--	.20	4.13

Across Track 2, White female students had significantly higher proportion of students retained than Hispanic students, both female and male, and White male students. In General Chemistry II and Organic Chemistry I, White female students had significantly higher proportion of students retained than Black/African American male students. In those same courses, Black/African American female students had a significantly higher proportion of students retained than Hispanic male students. Figure 3.17 graphically represents the retention of students over time in the sequence.

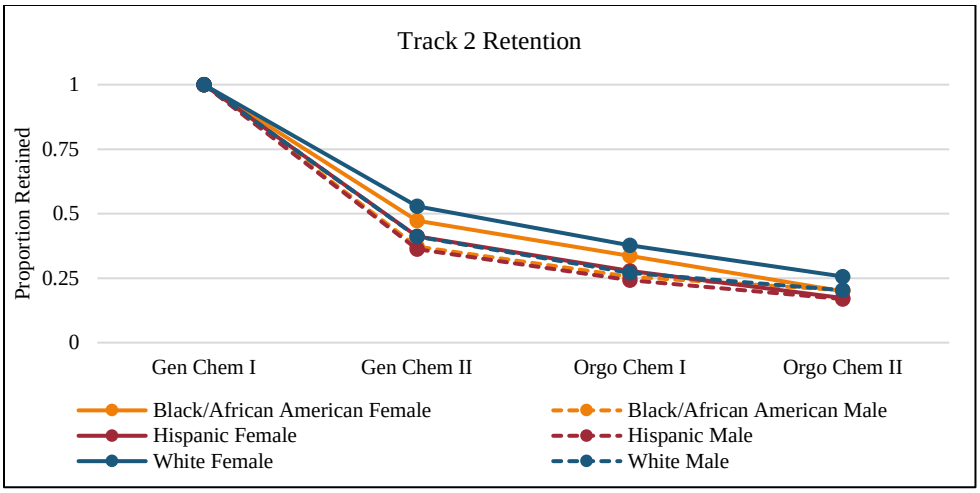

Figure 3.17 Track 2 retention of Black/African American, Hispanic, and White students (reference).

Discussion

Degree-level analysis: STEM sciences miss mark on equitable representation

The goal of the degree-level analysis is to answer three research questions: (1) *how are URM students represented among chemistry degrees compared to biology and physics*, (2) *what is the likelihood that URM students attain a degree in chemistry compared to biology and physics*, and (3) *have the levels of representation of URM students changed over time in chemistry compared to biology and physics*?

How are URM students represented among chemistry degrees compared to biology and physics? To answer the first research question, I explored the descriptive statistics of degrees awarded for the three disciplines. First, when comparing degrees conferred to those of White students, Hispanic and Black/African American students are seen to be overwhelmingly underrepresented, with URM students holding less than 16% of degrees collectively in each of the disciplines. Unfortunately, this is not dissimilar to national data. NSF reported that Hispanic students are awarded 8% and 10% and Black/African American students are awarded 5% and 6% of physical science and biological science degrees, respectively.[36]

Within the same analysis, we see representation is not equitable in CBP when compared to overall campus degree attainment within a demographic group. Both Hispanic and Black/African American students are not being awarded degrees at an equitable rate as they are across the campus. Students are more inclined to pursue a degree other than chemistry, biology, or physics. There are several common explanations as to why these racial/ethnic disparities exist in science. However, just because they are common in the literature, does not mean they explain what is happening at this institution. The first explanation could be that science, in general, has a reputation of difficulty and exclusivity. The idea that much of science, particularly chemistry and parts of physics, is abstract and cannot be experienced by our senses presents issues of conceptual understanding for students and barriers on instruction for teachers.[136,137] The second explanation could be science concepts are built upon in subsequent courses, which is not a reality of non-STEM coursework, making non-STEM degrees more accessible and flexible. Further, science concepts are usually accompanied by breaking down past misunderstandings or misconceptions from real-world phenomena and force students to rebuild complex models or theories every time new information is given.[136,138] However, these two common explanations would explain why science may be difficult for *anyone*. They do not explain why some students identifying as Black/African American or Hispanic are disadvantaged in a course where others, mainly those that are White, excel. Lastly, many institutions, including the institution of this dissertation, burden students with higher tuition for science-related degrees (usually due to lab costs). While this explanation could explain some disparities on racial/ethnic lines (if we take into account the systemic racial divides in income inequity), higher tuition costs associated with science majors have not been widely studied to understand the importance of them when choosing to leave a major. To explain the wide-spread disparities that URM students face in the

sciences, one has to look at systemic racism in our education structures, which includes but is not limited to inequitable access to educational resources and funding, racial/ethnic bias from instructors and administrators, inequitable school policies or practices, and biased or inequitable curricula or assessments.[139–141] Interview analyses in Chapter 5 will explore some of these systemic problems to better understand their effect on individual students at this institution.

What is the likelihood that URM students attain a degree in chemistry compared to biology and physics? Now that the first research question provided insight to the descriptives of the degrees, the second research question analyzed the likelihood of a student attaining a degree in one discipline vs. another, in this case chemistry vs. biology. Female students, regardless of race/ethnicity, were more likely to attain a degree in biology rather than chemistry when compared to their male peers. This finding is consistent with the findings from Riegle-Crumb and King who reported females of each racial group had significantly lower odds of declaring physical science and engineering majors, even when factoring SES, confidence and affect, and academic preparation.[7] Moreover, national data show women are awarded 58% of biological sciences degrees but only 39.7% of the physical sciences degrees.[36] Race/ethnicity was not a significant predictor in my analysis, which means that one racial group is not more likely than another to attain a degree in biology or chemistry; they are just as likely between these disciplines. To this point, NSF data also shows representation of Hispanic and Black/African American students do not differ between physical or biological sciences.[36]

For this research question, one discipline, physics, was analyzed but had to be removed from the comparative analysis with chemistry and biology due to a low N. As shown in Figure 3.5, over the thirteen years of data, physics only produced 117 degrees, a small fraction of the degrees awarded in biology and chemistry. Further, of the 117 degrees, less than nine percent of

physics degree recipients identified as Black/African American or Hispanic, with absolutely no Black/African American female degree holders. Unfortunately, due to this low N for physics, an analytic comparison was not possible across all three disciplines, which is a limitation for this analysis.

Have the levels of representation of URM students changed over time in chemistry compared to biology and physics? The third research question allowed for a temporal analysis of the degrees awarded in each discipline. Chemistry and biology had similar trends in their degrees awarded over time (Figures 3.2 and 3.3, respectively). While all demographic groups showed a general upwards trend of increasing science representation of all bachelor's degrees for their demographic group, representation of White students in chemistry and biology were more consistent than their marginalized peers. Representation of Hispanic and Black/African American students fluctuated from year to year in chemistry and biology. In other words, retention of marginalized students in the sciences was inconsistent across disciplines at this institution despite more recent efforts to increase persistence of URM students in science.

In recent years, the institution has seen an increase in Hispanic students on campus (making it an HSI) with female students entering at a higher rate than males. These changes in student demographics were accompanied by programs to increase representation and persistence of marginalized students in the sciences. Several programs and initiatives on campus, are dedicated to improving Latinx student retention in STEM programs. The Latin American Recruitment and Educational Services Program (LARES) provides academic advising, financial aid assistance, tutoring to Latinx students who are pursuing higher education.[142] The Hispanic Center of Excellence, based in the College of Medicine, introduces Latinx students to medical professions through a scholars program with its own curriculum, summer research programs, and

a summer enrichment program.[143] PAP STEM is a mentoring network that offers research experience, seminars, networking, and academic support to students majoring in STEM fields.[144] Another initiative at this institution, aimed at URM male students, was the Minority Male STEM Initiative, which aimed at bringing URM male students from the city community colleges to this institution to pursue biology, chemistry, and physics.[145] The pilot phase, between 2012-2013, would select about 25 male students. Successfulness of this program would lead to a slight tick up in URM male students attaining degrees in 2014 and beyond, which is seen in my results for Hispanic male students in biology and chemistry. Further investigation into how these programs impact student representation and retention is warranted.

The physics degrees awarded over time were also analyzed. Low production of degrees, no more than twelve in any given year, and considering the degrees that are awarded are largely to White male students, representation of URM students is severely lacking. Similar to chemistry and biology, representation of White male students was consistent over time whereas representation of all other demographic groups varied each year. The largest point of concern is that over the thirteen years of data, not a single degree was awarded to a Black/African American female student and not many more degrees were awarded to Black/African American male or Hispanic students. However, a lack of diversity in physics is not unfamiliar. DeWitt and colleagues found that the choice to pursue physics was largely gendered. In fact, their survey found that female students, when compared to their male peers, were significantly more likely to pursue science without physics than science with physics. The same disparities in racial groups are also well documented. The American Institute of Physics, using national data, reported that even though the total number of degrees awarded to Black/African American students is increasing, it had held stagnant between 2005 and 2015.[129] Whereas a similar report by AIP

between 2002 and 2012 reported physics degrees earned by Hispanic students doubled and were growing at a rate more than the overall bachelor's degree population.[128] Unfortunately, the national rates seen for marginalized students in physics are not reflected at this institution.

A limitation of this analysis is the low N when the population is disaggregated into the racial/gender demographic groups that inhibited the use of examining any statistical differences in the proportion of students awarded degrees over time.

To summarize, when analyzing degree attainment in chemistry, biology, and physics, disparities exist between groups of students as well as between disciplines. Again, this analysis was on those who survived and completed the degree. Having representational issues at the end stage could mean that there is an issue with initial recruitment of students or students are entering but opting to leave the degree path at some point. Further investigation into those students who opt for other degrees was clearly warranted and thus, the major-level analysis.

Major-level analysis: Larger leaks in physical science

Who switches in or out of the STEM degrees? The degree-level analysis, while telling, only conveys a story for those that completed the degree program. It does not tell us anything about the students who entered but chose to leave a STEM science major or its courses. The goal of the major-level analysis was to answer one research question: who switches in or out of the STEM degrees? Withstanding personal experiences of the students (which will be discussed in Chapter 4), the major-level analysis quantitatively described the pathways of students who switched majors while enrolled in a 100- or 200-level chemistry, biology, or physics course.

Previous studies that compared switchers vs. non-switchers (or persisters) found URM students switching at higher rates than their White peers and found that this problem is unique to

STEM and one that is not found in non-STEM disciplines.[42] The objective of this analysis was not to replicate analyses of switching vs. persisting rates of URM students, but to study the switching patterns within STEM of those that do switch. Because this dissertation's focus is a comprehensive comparison of three STEM science disciplines, it is important to understand if switching patterns are different between disciplines within STEM and how those patterns may be different for various demographic groups.

When examining the Sankey diagrams, we observed three distinct groupings of students that had unique switching patterns among the six categories of majors: (1) Black/African American female students and Hispanic female students leave the CBP majors at a rate higher than entering but enter Other STEM and Non-STEM at a higher rate than leaving, (2) Black/African American male students leave the physical science majors at a rate higher than entering but enter Biological Sciences, Other STEM, and Non-STEM at a higher rate than leaving, and (3) Hispanic male students and White students, both female and male, enter all other majors at a higher rate than leaving with the exception of chemistry.

While it is common for students to switch majors within the first two years of college, we did see disproportionate switching out of CBP majors by URM students. One major, chemistry, showed higher proportions of URM students switching out of than into the major. Physics followed shortly behind with three out of four URM groups switching out more than entering. We already established in the degree-level analysis that Black/African American and Hispanic students, both female and male, are underrepresented in these majors when compared to their White peers and when compared to overall campus representation. Combining previous findings of this dissertation with the results of major-level analysis, Black/African American and Hispanic female students are systemically turning away from the CBP majors even after

declaring one of the disciplines as a major. The reason why students leave the CBP majors at this institution is unknown from this data. Proposing inferences or hypotheses as to why certain groups of students leave STEM majors ignores the student perspective and experience. Reasons for leaving a chemistry, biology, or physics major (or course) will be explored further in the student interviews section of Chapter 4.

One limitation of this analysis is that the data was limited to 100- and 200-level courses. By limiting the courses within the dataset, I could not explore any switches, or reentries for that matter, that happen after this time point. Students could wait to switch majors for various reasons, including deferring for financial reasons, completing general education requirements as a priority, or simply have not yet decided. Another limitation from this analysis would be the lack of more student-level information, such as their GPAs before and after a major switch, that may uncover a common reason why these students chose to leave the major. A low GPA before a major switch would indicate that low grades were the cause of leaving. Chapter 5 will address the specific reasons why students left their major in more detail.

The results from the major-level analysis indicate that URM students are leaving the STEM science majors more than entering while enrolled in 100- and 200-level courses. The next step to understanding the disparities that are trickling up into the majors, and ultimately the degrees, is to unpack the disparities seen in the courses.

Course-level analysis: High DFW rates and attrition for URMs

The goals of the course-level analysis were twofold. First, I wanted to determine if the DFW distribution in each target course was equitable across all demographic groups. The second goal was to focus on one discipline (chemistry) and determine at which point in an introductory

sequence do students drop out. To accomplish these goals, two research questions were asked: (1) *how are URM students represented among chemistry courses compared to physics and biology* and (2) *when do URM students drop out of chemistry*?

How are URM students represented among chemistry courses compared to physics and biology? To answer the first research question, I employed a binary logistic regression to determine if demographic group is associated with a student's outcome in the course (pass vs. DFW). Based on the results of this analysis, the twelve courses were organized into three groups due to their similarities in significant predictors, and ultimately their logit expressions.

The first grouping included five courses: Genetics and all four physics courses (General Physics I and II and Introductory Physics I and II). In these courses, Hispanic students and Black/African American students had significantly lower odds of passing the course when compared to their White peers. As discussed previously, as a discipline, physics has low degree turnout but more so with URM students.[128,129] This analysis reveals that the problem is prevalent at the course-level as well. While Hispanic and Black/African American students are enrolling in these physics courses at a much lower rate compared to their White peers, 38% of the URM students, on average, still received a failing grade. For physics, it is clear that not only does the discipline face difficulty in recruiting URM students, but it also has a significant problem retaining the students that do pursue physics. As for Genetics, a 28% DFW rate is not among the worst rates for URM students, but it is still significantly higher than the 17% of White students who received the same grade.

The second group, which included four courses (Organic Chemistry I and II, Cell Biology, and Ecology and Evolution), saw differences between gender and race/ethnicity in their odds for passing. Across the four courses, female students were less likely to pass compared to

their male peers. In the Organic Chemistry sequence, the DFW rate was high for both groups of students (≥30%) but statistically higher for female students. On the other hand, rates for Cell Biology and Ecology and Evolution are among the lowest (≤ 25%) but, again, female students were still significantly higher than their male peers. As for race/ethnicity, Hispanic and Black/African American students were significantly less likely to pass each of the four courses. The high DFW rates for URM students in the Organic Chemistry sequence are of particular concern. These are the last courses of the introductory sequence. Whether students are taking these courses as chemistry majors or fulfilling requirements for other STEM majors, high probability of not passing the last introductory courses could mean a delay or complete loss of these students from their desired programs.

The last grouping consisted of three courses (Preparatory Chemistry, General Chemistry I, and Cells and Organisms) that had unique characteristics of their significant predictors. In all three courses, Hispanic female and Black/African American female students were less likely to pass, compared to White female students, and Hispanic male and Black/African American male students were less likely to pass, when compared to White male students. Coincidentally, these three courses serve as required pre-requisites for many courses within the scope of this dissertation and many others not studied here. So, failure in these courses will set students behind in continuing their studies, furthering the disenfranchisement of URM students in STEM.

A limitation of this analysis was the inability to include other measures in the model that could also explain the likelihood of passing (i.e. SAT scores, high school preparation, SES, etc.). Many other studies show inclusion of these factors do have a significant effect on the likelihood of a student passing or persisting in STEM courses.[7,11,42,47] Unfortunately, this data was not available to me when creating the registrar databases that were the source of the analysis.

When do URM students drop out of chemistry? To answer the second research question, two introductory chemistry sequences were analyzed to determine at what point do students drop out of the sequence. Firstly, when comparing the two tracks, Hispanic and Black/African American students represented a larger proportion of those enrolled in Track 1 than in Track 2. It is important to note that of the two tracks, being placed in Track 1 has clear disadvantages. First and foremost, Track 1 has more courses, five as opposed to four courses in Track 2. Being placed in Track 1 automatically places a student at least one semester behind any student placed in Track 2. Further, it is likely that students placed in Track 1 have additional courses to take in other disciplines to "correct" other "deficiencies" noted in their placement exam. Failure of the placement exam would indicate that those students are less ready for a chemistry major. However, the chemistry placement exam at this institution is, in large, a math test with chemistry sprinkled throughout. There is a heavy emphasis on the quantitative approach to chemistry on this exam that would make it difficult for anyone with lower math skills to pass. Thus, it is often the case that students placed in Track 1 also have a remedial level math course to complete before beginning to fulfill any math requirements. Math ability upon college entrance surely has unforeseen consequences (to the student) on time-to-degree.

The results for Track 1 revealed significant differences in retention between URM and White students. Hispanic students, both female and male, and Black/African American female students were retained significantly less than their White peers throughout the track. Roughly half of all Hispanic students and Black/African American female students proceed to General Chemistry I after Preparatory Chemistry. Considering the fact that Preparatory Chemistry is required to continue through the Track 1 sequence and Preparatory Chemistry does not fill the general education requirement of Natural Science with a Lab, it is probable that the students not

retained after Preparatory Chemistry leave the discipline indefinitely. For the students that do move on, another steep decline in retention is seen between General Chemistry I and General Chemistry II. However, attrition of students at this juncture is expected since General Chemistry I does fulfill the Natural Science with a Lab general education requirement. However, URM students continue to be poorly retained through the remainder of the sequence. At the outset of Organic Chemistry II, only 8% of Black/African American female students remain from the original population who started in Preparatory Chemistry. The same is true for Hispanic female and Hispanic male students.

Track 2 results are different in nature. First, Black/African American female students are among those that showed significantly higher retention. In fact, throughout the sequence, female students were retained more than their male peers within the same racial group. However, Hispanic students, both female and male, and Black/African American male students are retained significantly less than their White female peers. While we see declines in retention at each juncture of the sequence and less retention of the majority of URM students, overall, students in Track 2 are better retained than students at Track 1 at the same time points regardless of their demographic group. For instance, at the outset of Organic Chemistry II in Track 2, 17% of the original population of Hispanic female students were retained compared to only 8% retained at the same time point in Track 1.

Because I studied two chemistry sequences with four and five courses each, it is worth noting when a natural reduction in course retention occurs due to the degree requirements of various STEM majors. Beginning at the start of the sequence (for Track 1), completing Preparatory Chemistry does not fulfil any requirements for STEM majors. So, for Track 1, the steep drop in retention going into General Chemistry I, especially for marginalized students,

cannot be explained by degree requirements of any kind, and thus further highlights the disparities they face in chemistry. Progressing through the remaining of the sequence, I refer to the major requirements of several STEM majors (Table 3.16). All thirteen STEM majors require General Chemistry I and II. Thus, any drops in retention for students before entering Organic Chemistry are not due to the degree requirements of these majors. However, considering non-STEM majors, General Chemistry I or II would fulfill the General Education requirement of a natural science with a lab. It is possible that the decrease in retention for either track after General Chemistry I is influenced by non-STEM majors. Lastly, not all STEM majors require Organic Chemistry, so some of the drops in retention entering Organic Chemistry I and, even more so for Organic Chemistry II, can be due to degree requirements being fulfilled. The attrition rates moving into the Organic portion of the sequence were not as severe as the decreases seen earlier in the sequence but nevertheless can be explained better by fewer students needing to complete Organic Chemistry courses.

Table 3.16 Chemistry course requirements for eleven STEM majors.

Major	***General Chemistry I***	***General Chemistry II***	***Organic Chemistry I***	***Organic Chemistry II***
Chemistry	X	X	X	X
Chemical engineering	X	X	X	X
Pre-Pharmacy	X	X	X	X
Biological sciences	X	X	X	
Neurology	X	X	X	
Kinesiology	X	X	X	
Nutrition	X	X	X	
Pre-Medicine	X	X	X	
Earth and Environmental Sciences	X	X		
Integrated Health Sciences	X	X		
Bioengineering	X	X		
Nursing	X	X		
Physics	X	X		

At this institution, the introductory chemistry courses are undoubtedly acting as barriers rather than gateway courses for URM students. Unfortunately, this is not an uncommon problem for the discipline. To fix the exclusionary reputation that chemistry owns, the American

Chemical Society (ACS) Symposia in recent years has addressed the problem of retention in chemistry. There were several reoccurring themes throughout the research offered: reconceptualizing or reconfiguring courses[146–150], student- and instrument-driven labs[151,152], and using TAs or experienced undergrads to support instruction[59,153], and changing instructor attitudes to be less "negative"[154]. While these efforts may help some URM students for the simple fact they are in the same classroom that is being reconfigured for maximizing general student retention, focused changes are what have shown to improve retention of URM students in science. In a separate ACS Symposium specifically for increasing URM retention in chemistry and STEM, Cessna and colleagues outlined three aspects of the research that point to why retention interventions worked for URM students. The three aspects institutions should pay attention to were: (1) filling the gap to ensure adequate academic preparation and college readiness, (2) cultivating a student's science identity and self-efficacy, and (3) ensuring cultural congruence with the institution and department.[155] Now, none of these aspects are easy elements to incorporate in a chemistry classroom. These changes require commitment on every level of the institution and department to make chemistry a more equitable field. Further, it is on the institution, department, and individual instructors to ensure URM students are not systemically being pushed out due to faculty attitudes, ineffective teaching strategies, or inequitable practices and policies.

There were several limitations of the sequence analysis. First, due to lack of data, it was not possible to track in which year of their studies (e.g. first year, second year, etc.) students dropped out of the chemistry sequences. While many students complete these courses within their first two years, it is not known if this was the case for all students or if student spread out their chemistry coursework over several years. This data would give insight as to the enrollment

patterns students take and how it affects or lengthens their time-to-degree or program completion. Along this same line, another limitation of this analysis was the removal of repeats of courses. This analysis did not consider those students that repeated courses in the sequence, and only those that completed the sequences straight through. This would be an interesting follow-up analysis as it may provide insight on additional students that do complete the sequence but after repeated attempts of one or more courses.

The course-level analysis completed the three-tier research plan of describing the representation and retention of URM students in chemistry, biology, and physics. At each level, it is evident that disparities exist at this institution that prevent URM students from pursuing STEM and achieving STEM degrees. The next study of this dissertation will collect survey data from students enrolled in the twelve target courses to determine if affective characteristics and individual differences play a role in the persistence of URM students in chemistry, biology, and physics.

CHAPTER IV: STUDY 2 – Affective Characteristics of Undergraduate Science Students

Introduction

Study 1 detailed the ways in which URM students are not retained in the sciences. While that study presented a clear and descriptive picture, it does explain why these students are failing or leaving the fields. One of the ways to understand why students, particularly students of color, leave the sciences is to look at their affective traits when it comes to general academics and science.[15,18,20,61,65] Students who intrinsically value science and have high motivation for science do well in science courses and persist in the field.[55,65,68] If I consider persistence through an affective lens, there are two main possibilities for why students of color do not have equitable representation in the sciences. One of the possibilities is that these students have low science identity and motivation and therefore do not want to continue in the science. This could be due to either genuine lack of interest or it could be that they once had interest but then it faded or was diminished due to a myriad of circumstances (e.g. lack of exposure, resources, support, etc.). Another possibility is that these students do have a high science identity and motivation but systemic and structural barriers in the education system keep them out. Study 2 examines these possibilities with the research question:

S2. How do socio-affective characteristics affect persistence in chemistry, biology, and physics courses and disciplines?

To answer this research question, I first need to identify how students view themselves, academics, and science. In Study 2, I utilize a survey that measures various affective

characteristics (e.g. science identity, self-esteem, attitudes towards science), social influences, socio-economic status, and self-reported academic measures that have been used in prior literature to understand persistence. Each of these constructs measure how a student views themselves, academics, and science which, in turn, will lead to a better understanding of why one would leave the sciences. The six constructs explored further in this chapter are: attitudes towards science, science identity, view of intelligence, self-worth, and self-doubt. While each of these constructs have been investigated in prior research, they have not been taken together to explore the multiple facets of a student's affect. Each of the constructs are briefly described below as they have been previously defined in the literature.

Attitudes towards a subject also greatly affect how one will perform in a course. I will be analyzing a student's attitude toward science; specifically, their perceived level of science as being intellectually accessible and emotionally satisfying. Whether a student finds science as something they intrinsically value, find emotionally satisfying, or inherently difficult to comprehend will determine how they interact with the material and if they persist.[64,68]

Science identity is one's belief of how closely science is tied to their central identity. This could be developed in their youth or during their undergraduate experiences. In either case, a student's science identity has been linked to achievement and success in the sciences.[34,55,65] Including this construct in this study lays the groundwork to explore work how science identity could be leveraged to retain more students of color in the sciences.

Fixed vs growth mindsets describe how one views intelligence: either in an incremental (malleable or growth) view or in an entity (fixed) view. Dweck and colleagues found that those with an entity view are more likely to "react helplessly in the face of achievement setbacks."[82–84] However, those that subscribe to an incremental view, when faced with failure, tend to blame

themselves and try to correct what they see as their failures by trying harder or changing study habits or strategies.[83] Measuring a student's view on their intelligence will allow me to understand how they view their "failure" in a course and what their response will be to a negative setback.

Self-worth refers to how one feels about themselves overall. In this study, I will be measuring how three aspects could threaten a science student's self-esteem: other's approval, competition with others, and academic competence. College students' self-esteem is tied closely to their academic competence[126], or how well they are performing at school, which impacts their decision to persist. Further, competing with others (as may be the case in so-called "weed-out" courses) and seeking others' approval[126,156,157], whether that be academic persons or family members, all influence their decision to persist or leave a field.

Self-doubt describes one's lack of confidence in themselves when it comes to their abilities. Confidence, or lack thereof, plays a role in how one views their abilities, their sense of motivation, and ultimately their decision to pursue a field.[68] To analyze all affective constructs together, I employed cluster analysis methods as a secondary analysis. Cluster analysis is the technique of grouping objects (in this case students) together based on shared characteristics more so than the objects in another group, or cluster. Cluster analysis is used when one wishes to classify large data sets of multiple variables to more easily and effectively understand and describe patterns of similarities and differences between subjects.[158] Moreover, cluster analysis is used as an exploratory tool to determine if several variables can be meaningfully summarized by the description of one cluster compared to another.[158] Analyzing my survey data via cluster analysis as opposed to factor analysis or logistic regression allows for the classification of several affective variables into collective and more descriptive variables that may give better

insight to how multi-faceted affect play a role in persistence. Cluster analysis has been employed successfully in other discipline-based education research (DBER) studies with various assessments and surveys.[22–24,127] Results from these studies have yielded promising results of how to characterize students and further inform interventions or change in instruction. For example, Chan and Bauer used cluster analysis on survey responses measuring attitude, self-concept, and motivation among General Chemistry students to identify low, medium, or high affect students and determine differences on exam performance and beliefs between groups.[22] The authors also pursued the predictive validity of their cluster solution for future use. Nielsen and Yezierski used cluster analysis as an alternative to academic tracking to understand differences in student self-concept in chemistry and mathematics.[24] The precedent set by researchers' use of cluster analysis gives way for its use in the context of this research. In this study, I attempt to cluster students based on their responses to the survey measures and group them based on shared affective attributes with the hope that these clusters can provide insight into the characteristics of students that persist in STEM.

Cluster membership was then analyzed against five different individual differences: self-reported midterm grade, race/ethnicity and gender, social influences, income level, and science discipline. Comparing cluster membership and midterm grades will yield how certain affective characteristics are associated with either passing or failing a science course. Such an analysis can later inform interventions that aim to positively change student attitudes in cases were specific cluster membership is associated with success in a course. Analysis of cluster membership and income level could shed light on how closely income inequality affect one's views on their abilities and science. Social influences such as family, friends, high school teachers, college professors, and many others have an effect on a student's choice to declare a major or withdraw

from a course. Role models, mentors, or other forms of support either elevate or hinder a student from continuing in a course or major.[15,58,156,157] Finally, the focus of this dissertation is on the differences of race/ethnicity and gender in three science disciplines. Analyzing cluster membership on these aspects will tell me more about the disparities on minoritized groups in chemistry, biology, and physics but at the affective level.

Similar to Study 1, no specific hypotheses were made for Study 2 since the surveys were compiled in a way not yet explored in the literature and a priori relationships could not be predicted.

Methods

Participants

Survey participants were recruited from the courses used in the Study 1 course-level analysis. These were the courses with the highest DFW rates in their respective disciplines and my data analyses showed these courses were highly problematic for URM students. Specifically, Black/African American and Hispanic students had a lower probability of passing the majority of the courses when compared to their White URM students. Thus, collecting survey data from the same courses could help develop a more complete picture of the status of URM attrition. Specifically, the surveys can provide information on the student level that, when analyzed, lead to a better understanding of individual differences in self-esteem, confidence, and science identity, for example, and how these individual differences may or may not be connected to persistence. Table 4.1 shows the courses from which students were recruited to complete the survey. The survey was distributed in two semesters: Spring 2019 for the pilot and Fall 2019 for the full implementation.

Table 4.1 Courses from which students were recruited to participate in the survey.

Department	***Courses***	***Semester(s) survey distributed***
Chemistry	Preparatory Chemistry	Fall 2019
	General Chemistry I Lecture	Fall 2019
	Organic Chemistry I	Fall 2019
	Organic Chemistry II	Spring 2019, Fall 2019
Physics	Introductory Physics I Lecture	--
	Introductory Physics II Lecture	Fall 2019
	General Physics I – Mechanics	Fall 2019
	General Physics II – Electricity and Magnetism	Spring 2019, Fall 2019
Biology	Biology of Cells and Organisms	Fall 2019
	Mendelian and Molecular Genetics	Fall 2019
	Cell Biology	Fall 2019
	Ecology and Evolution	Spring 2019, Fall 2019

A pilot was warranted since the survey measures, while individually reliable and previously validated (discussed below), have not been aggregated in this way before. Further, it was important to know how long it took participants to answer the 60-item survey to ensure fatigue would not be an issue in the full implementation In Spring of 2019, the pilot survey was distributed to three courses (one from each discipline): Organic Chemistry II, General Physics II, and Ecology and Evolution. These courses were chosen for the pilot because they are typically taken by students later in their studies. I did this to ensure there would be a lower chance of double-sampling students when the full implementation of the survey was released the following semester. Items performed as expected and there were no issues found within the survey itself, so all pilot responses were included with the full implementation survey responses to be analyzed together.

Between the pilot and full implementation of the survey, only one item was changed. In Spring of 2019, respondents were only able to select one course from the list asking in which course they were enrolled. I thought in the full implementation, it was likely that many students would be enrolled in more than one course that were listed since the list is comprised of all introductory courses in three science disciplines and I wanted to capture that information. Thus,

in the full implementation of the survey in Fall of 2019, this item allowed for more than one answer (check boxes).[9] No other changes were made to the survey between distributions.

For the full implementation of the survey in the following Fall 2019 semester, only eleven of the original twelve targeted courses were included in the recruitment. Introductory Physics I was not offered as a course in Fall 2019. All students in the eleven other courses were invited to participate in the survey via email.

The survey was distributed via Qualtrics™. Compensation in the form of a lottery entry was given to students upon completion of all survey items. One participant was chosen at random to receive an iPad tablet, valued at $250.

Survey measures

The 60-item survey included five sections: consent, demographics, socio-economic status, academic self-report information, and six previously validated survey measures. Table 4.2 shows the five sections of the survey, the information captured from each, and the numbered items associated with the section. The full survey is in Appendix B.

[9] It was later found that this change complicated matters for students who did check more than one box. I was unable to link the course they were referencing when completing the survey since they listed more than one. Those students whose course could not be determined were dropped from any analyses.

Table 4.2 Information captured within each section of the survey.

Survey section	Information captured	Item Number
Consent	• Participation • Student record access • Contact for follow-up interview • Viewing of de-identified video	1-8
Demographics	• Natal sex • Gender identity • Race • First semester status	9-12
Socio-economic status	• Head of household • Number of people in household • Estimated household yearly income • Job status • Number of jobs	13-18
Academic self-report information	• Name of enrolled course(s) • Self-report midterm grade • Self-report GPA • Declared/undeclared major	19-24
Survey measures	• Social influences • ASCIv2 • Science identity • CSWS • ITI • Self-doubt	25-60

IRB-approved informed consent documents were provided in Section 1. Participants answered four items to indicate their consent.

Demographics such as natal sex, gender identity, race, and first semester status were collected in the second section of the survey. The survey was my opportunity to open the gender variable to include a wide array of identities (e.g. transgender, gender non-conforming, etc.), which could not be captured in Study 1 using registrar data, which treated gender as a binary variable.

Data was collected to determine, at a broad level, the socio-economic status of respondents. A student's socio-economic status could heavily influence their success in undergraduate studies, particularly students from low-income communities, which is disproportionately more likely for Black/African American and Hispanic/Latinx students.

Financial stress, or lack thereof, may factor into a student's decision to persist or leave a discipline.

Academic self-report information, such as midterm grade, GPA, course, and declared or undeclared major, was collected in the fourth section of the survey. Final grades were collected from the Registrar office if students consented to allow access. I collected this information to include in the analysis of survey responses to determine if academic measures and individual differences are connected.

The final section of the survey included six survey measures that have been previously published or validated. Each are described in detail below.

For the first measure, I collected data on the social influences in a participant's life. People like family, friends, instructors, advisors, and others who have some kind of influence over a student are considered their social influences or people of influence. Social influences may have an effect on a student's choice to declare a major or withdraw from a course or major. A list adapted from Shedlosky-Shoemaker and Fautch[15], was included in the survey that allowed students to select types of people that influenced them to pursue their major. In my survey, three groups of people were added (mentors, TAs, and Other with write-in option) to the list Shedlosky-Shoemaker and Fautch created in order to allow for a wider array of answers. In the form of check boxes, respondents were able to check as many categories they would describe as social influences regarding their major.

The Attitudes towards the Subject of Chemistry version 2 (ASCIv2) scale measures a students' attitude towards chemistry on two latent factors: emotional satisfaction and intellectual accessibility.[125] I adapted the ASCIv2 to measure on "science" in general, rather than chemistry specifically since the survey was distributed to three science disciplines. The ASCIv2 is an 8-

item measure that has the respondent rate on a 7-point bipolar scale how much they agree with two descriptive words, for example chaotic and organized. Individual responses were averaged to get a subscale score. Based on the subscale score, a profile of low (score < 4), neutral (score = 4), or high (score > 4) intellectual accessibility and emotional satisfaction, respectively, was assigned.

Measure 3 collects information on a respondent's science identity. Science identity measures one's belief of how closely science is tied to their identity. Science identity is measured with four items on a 5-point Likert scale.[55] Two items measure science identity (e.g. "I consider myself a good science person") and two items measure attainment value (e.g. "Being good in science is an important part of who I am"). One of two possible science identity profiles are assigned based on a respondent's average score from the four items. A score of 2.5 or higher was assigned a "high" science identity and an average score of less than 2.5 was assigned "low" science identity.

The Contingencies of Self-Worth Scale (CSWS) measures seven factors that affect one's self-worth and self-esteem.[159] In this survey, I used three of the subscales: academic competence (e.g. "I feel bad about myself whenever my academic performance is lacking"), competition (e.g. "My self-worth is affected by how well I do when I am competing with others"), and others' approval (e.g. "My self-esteem depends on the opinions others hold of me"). Each subscale is five items on a 7-point Likert scale. Individual items were averaged to get a subscale score. Subscale scores were used to assign a profile of low (score < 4), neutral (score = 4), or high (score > 4) contingency on academic competence, competition, and others' approval, respectively.

The Implicit Theory of Intelligence (ITI) measures if one's view of intelligence is an entity (fixed) view or incremental (malleable) view.[83] An example of an item reads "You have a certain amount of intelligence and you really can't do much to change it". Three items on a 6-point Likert scale measured respondent's implicit theory of intelligence. Again, individual items were averaged to get a score for this subscale. A score of 3 or higher was assigned as an entity view and a score less than 3 was assigned as an incremental view of intelligence.

The Self-Doubt subscale of the Subjective Overachievement Scale measures one's self-doubt, or lack of confidence, in their abilities (e.g. "I sometimes find myself wondering if I have the ability to succeed at important activities").[69] Eight items on a 6-point Likert scale measured self-doubt. Scores for each item were averaged for a composite score. A composite score of 4 or higher was assigned high self-doubt, whereas a score less than 4 was assigned low self-doubt.

For all reliability and factor analyses, only complete survey responses (N = 377) were used.

Pre-analysis

Before proceeding with the analysis of the survey responses, several parameters needed to be calculated to ensure reliability of subscales and that all items were loaded onto the proper subscales, via confirmatory factor analysis. The following Pre-analysis section reports on these results. While optimizing reliability and factor loading are not integral parts of this dissertation, it is important to report these statistics for this specific population and for further use of these survey subscales.

Reliability

To ensure the measure subscales were reliable under the population of this study, Cronbach's α were calculated for each subscale and compared to their literature values (Table 4.3). Each of the subscales had a Cronbach's α value within 10% of the cited values, with the exception of the CSWS Academic Competence subscale ($\alpha_{lit} = 0.82$ vs $\alpha = .71$). Though the difference between the α values is more than 10% difference, the α value calculated for this study is an acceptable value for reliability.[160]

Table 4.3 Reliability measures for each of the survey subscales (literature values and recalculated values from current use).

Measure	Subscale	Survey Items	Cronbach's α	Literature Cronbach's α
ASCIv2	Intellectual Accessibility	26.4, 26.5, 26.7, 26.8	0.78	0.82[125]
ASCIv2	Emotional Satisfaction	26.1, 26.2, 26.3, 26.6	0.79	0.79[125]
Science Identity	Science Identity	28-31	0.86	.83-.90[55]
Contingencies of Self-Worth	Academic Competence	33, 35, 37, 38, 41	0.71	0.82[159]
Contingencies of Self-Worth	Competition	34, 36, 39, 43, 45	0.87	0.87[159]
Contingencies of Self-Worth	Others' Approval	40, 42, 44, 46, 47	0.82	0.82[159]
Implicit Theory of Intelligence	Implicit Theory of Intelligence	49-51	0.92	.94-.98[83]
Self-doubt	Self-doubt	53-60	0.81	.82-.83[69]

Because this dissertation focuses on racial/ethnic and gender identities and, for this study, how affect may differ as a function of identity, I also analyzed if the individual subscales were reliability for each demographic group. Table 4.4 below includes the Cronbach alpha values for each of the eight subscale measures for each demographic group of interest.

Table 4.4 Reliability measures (Cronbach's α) for each of the survey subscales by demographic group.

	Black/AA Female (N = 26)	**Black/AA Male (N = 5)**	**Hispanic Female (N = 52)**	**Hispanic Male (N = 22)**	**White Female (N = 58)**	**White Male (N = 32)**
Intellectual Accessibility	0.69	--	0.75	0.75	0.81	0.70
Emotional Satisfaction	0.68	--	0.81	0.83	0.82	0.57
Science Identity	0.82	--	0.87	0.90	0.87	0.88
Academic Competence	0.61	--	0.61	0.72	0.76	0.65
Competition	0.90	--	0.85	0.91	0.90	0.86
Others' Approval	0.90	--	0.79	0.78	0.83	0.73
ITI	0.94	--	0.92	0.90	0.90	0.96
Self-doubt	0.86	--	0.80	0.87	0.79	0.71

As seen in the table, several demographic groups differ in their alpha values compared to the literature values. Most notably, four demographic groups (Black/African American female and male, Hispanic female, and White male) differed more than 10% from the literature values of the Academic Competence subscale of the Contingencies of Self-Worth Scale. White male students also differed by more than 10% from the literature value of the Emotional Satisfaction subscale. These differences show that these subscales may not function similarly across different demographic groups and should be studied further. Lastly, Black/African American males differed on the Science Identity subscale. However, the Cronbach's α values for Black/African American males could not be calculated due to the low sample size. This demographic group has a considerably lower N (N = 5) compared to the rest of the demographic groups of interest and is prone to extreme responses or outliers for reliability and viability measures.

Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) was completed on each of the subscales to compare correlations among latent variable, or factor loadings, with those reported in the literature. For all CFAs, a maximum likelihood estimation was used. Further, for each factor analysis that was completed, the regression weight of one item in each subscale was set to 1. Several fit indices were considered when assessing which model had the best fit. Though the Chi-square is included in all factor analyses, it is highly sensitive to sample size and non-normality, so I relied on other fit indices to determine best fit. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are comparative measures. The AIC and BIC are used when comparing different models, with lower values indicating better fits. The Comparative Fit Index (CFI) measure was included as a means of comparing fits with those in the literature. A CFI value greater than .90, or .95 being more conservative, is considered to be of good fit.

Attitudes towards the Subject of Chemistry Inventory, version 2. Eight items (items 26.1 – 26.8) make up the ASCIv2 with two subscales: intellectual accessibility (items 26.4, 26.5, 26.7, 26.8) and emotional satisfaction (items 26.1, 26.2, 26.3, 26.6). Table 4.5 has the model fit indices for the one-factor model and two-factor model for this survey and the models reported in Xu and Lewis.[125]

Table 4.5 Model fit indices for the one- and two-factor models for confirmatory factor analysis for the ASCIv2 items compared to their literature values.

Model	Chi-square	AIC	BIC	CFI
One-factor	$X^2(20) = 478.493$, $p < .001$	510.493	573.409	.557
Two-factor	$X^2(19) = 180.597$, $p < .001$	214.597	281.445	.844
Two-factor, 1 item removed	$X^2(13) = 106.369$, $p < .001$	136.369	195.353	.891
Xu & Lewis, one-factor model	$X^2(20) = 156.1$, $p = 0.00$	--	--	.89
Xu & Lewis, two-factor model	$X^2(19) = 77.0$, $p = 0.00$	--	--	.95

For this population and in Xu and Lewis (N = 354), the two-factor model had the better fit than the one-factor model. However, my two-factor model (CFI = .844) did not meet the CFI

of Xu and Lewis (CFI = .95).[125] Though this may indicate a poor model fit, the purpose of this CFA is to determine if it is appropriate to use the survey measure in further analyses.

Factor loading comparisons were used to further determine the appropriateness of the measure. Table 4.6 reports the factor loadings for each item and the percent difference between studies (M = 9.1, SD = 10.8). Only one item from the *Intellectual Accessibility* subscale (item 26.7, Clear : Confusing) fell outside two standard deviations from the mean. With this item removed, the CFI, AIC, and BIC improved significantly for this population, as shown above. However, my calculated Cronbach's alpha lowered from α = 0.78 to α = 0.75, which was still less than a 10% difference from Xu and Lewis (α = .82). Because the removal of this item improved the model fit for this population, this item was removed for all future analyses.

Table 4.6 CFA standardized factor loadings for the two subscales for this survey compared to those reported in Xu and Lewis. (Note: Items that were reverse coded are marked with an asterisk.)

Subscale	Item	Factor Loadings	Factor Loadings Xu & Lewis[125]	Percent Difference (%)
Emotional satisfaction	Organized : Chaotic*	.49	.48	2.1
	Satisfying : Frustrating	.77	.77	0.0
	Comfortable : Uncomfortable	.76	.74	2.7
	Pleasant : Unpleasant	.79	.83	4.9
Intellectual accessibility	Easy : Hard	.61	.68	10.9
	Simple : Complicated*	.80	.80	0.0
	Clear : Confusing*	.59	.82	32.6
	Not challenging : Challenging*	.74	.61	19.3

Because the best fitting model for the pooled CFA was the two-factor model with one item (item 26.7) removed, the same model was used to determine model fit of each demographic group (Table 4.7). The model fits reasonably well for some demographic groups, but not all. Due to low cell size, a CFA for Black/African American males could not be done. The CFI for White males was also much lower than other groups or the pooled sample (see above).

Table 4.7 Model fit indices for the two-factor one item removed model for confirmatory factor analysis for ASCIv2 items for each demographic group.

Demographic Group	N	Chi-square	CFI	RMSEA
Black/African American female	26	$X^2(13) = 21.122$, $p = .071$	.784	.158
Black/African American male	5	--	--	--
Hispanic female	52	$X^2(13) = 26.407$, $p = .015$	.900	.142
Hispanic male	22	$X^2(13) = 24.611$, $p = .026$	.850	.206
White female	58	$X^2(13) = 15.855$, $p = .257$	.980	.062
White male	32	$X^2(13) = 21.944$, $p = .056$	.580	.149

Factor loadings for demographic groups vary wildly for several items (Table 4.8). Because of the differences, these subscales require further investigation of their performance for various demographic groups, though not the focus of this dissertation. Forthcoming results stemming from the Emotional Satisfaction and Intellectual Accessibility subscales should be taken conservatively.

Table 4.8 Factor loadings of the two-factor one item removed model for the ASCIv2 items for each demographic group.

Subscale	Item	Black/AA Female	Black/AA Male	Hispanic Female	Hispanic Male	White Female	White Male
Emotional satisfaction	Organized : Chaotic*	.20	--	.42	.40	.69	.56
	Satisfying : Frustrating	.64	--	.74	.92	.72	.34
	Comfortable : Uncomfortable	.90	--	.60	.86	.96	.74
	Pleasant : Unpleasant	.64	--	1.08	.92	.62	.29
Intellectual accessibility	Easy : Hard	.40	--	.28	1.09	.82	.39
	Simple : Complicated*	.95	--	.52	.55	.65	1.07
	Not challenging : Challenging*	.59	--	1.16	.57	.66	.25

Science Identity. The four items (items 28-31) that measure science identity in the survey come from Robinson and colleagues.[55] The authors adapted this scale from two other scales: science identity[161] (items 28 and 31) and attainment value[66] (items 29 and 30). While the reported and calculated Cronbach's α were within a good range, these items were not previously subjected to factor analysis as an item set. Below are the model fit indices (Table 4.9) and the factor loadings (Figure 4.1) of my CFA for two models for the science identity items.

Table 4.9 Model fit indices for the one- and two-factor models for confirmatory factor analysis for science identity items.

Model	Chi-square	AIC	BIC	CFI
One-factor	$X^2(2) = 22.205$, $p < .001$	38.205	69.663	.970
Two-factor	$X^2(1) = .092$, $p = .762$	18.092	53.482	1.00

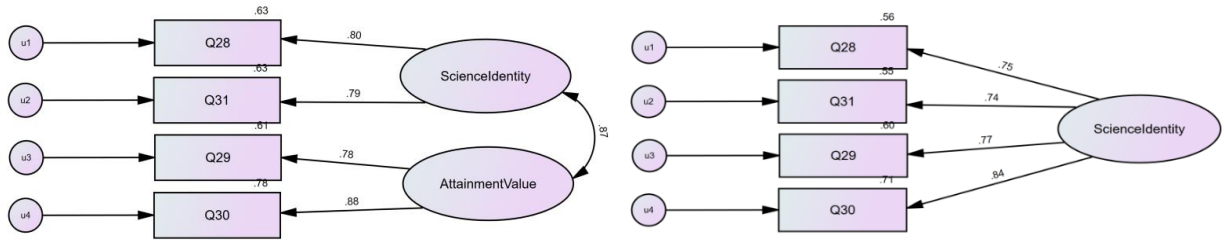

Figure 4.1 Factor loadings of the two-factor model (left) and the one-factor model (right) for the science identity items.

The two-factor model that separates the items by their original scales fits better than the one-factor model. Both the AIC and the BIC are lower for the two-factor model and the CFI is higher, at 1.00, for the two-factor model. Considering model fit and acceptable factor loadings, all items of science identity were kept for further analyses.

I also compared the subscale against the various populations of interest to my research. Since the two-factor model was the best fit for the pooled respondent sample, the same model was kept when completing CFAs for each demographic group for the Science Identity subscale. As seen in Table 4.10, the two-factor model fits reasonably well for all demographic populations, with the exception for Black/African American males. This subgroup had a low N which made a CFA impossible.

Table 4.10 Model fit indices for the two-factor model for confirmatory factor analysis for science identity items for each demographic group.

Demographic Group	N	Chi-square	CFI	RMSEA
Black/African American female	26	$X^2(1) = 4.521$, $p = .033$	.914	.375
Black/African American male	5	--	--	--
Hispanic female	52	$X^2(1) = .641$, $p = .423$	1.00	.000
Hispanic male	22	$X^2(1) = 4.819$, $p = .028$	.935	.426
White female	58	$X^2(1) = 3.612$, $p = .057$	.979	.214
White male	32	$X^2(1) = 2.461$, $p = .117$	.977	.217

Overall, most of the items performed similarly across demographic populations (Table 4.11). Item 29 on the Attainment Value subscale ("Being someone who is good at science is important

to me") had a factor loading of .46 for Black/African American female students, which is much lower than the other demographic groups. The difference in factor loadings lends to the possibility this item did not perform as intended for one subgroup and should be studied further.

Table 4.11 Factor loadings of the two-factor model for the science identity items for each demographic group.

Subscale	Item	Black/AA Female	Black/AA Male	Hispanic Female	Hispanic Male	White Female	White Male
Science Identity	Being involved in science is a key part of who I am.	.96	--	.70	.87	.91	.86
	I consider myself a science person.	.76	--	.91	.87	.76	.87
Attainment Value	Being someone who is good at science is important to me.	.46	--	.72	.77	.90	.80
	Being good in science is an important part of who I am.	.97	--	.97	1.01	.88	.86

Contingencies of Self-worth Scale. I included three subscales of the CSWS[159] in this survey: academic competence (items 33, 35, 37, 38, 41), competition (items 34, 36, 39, 43, 45), and others' approval (items 40, 42, 44, 46, 47). Because the original measure from Crocker et al. had seven total subscales, I cannot effectively compare my model fit indices to theirs. Table 4.12 shows the overall model fit and fit indices for the factor analyses.

Table 4.12 Model fit indices for the one- and three-factor models for confirmatory factor analysis for the CSWS items.

Model	Chi-square	AIC	BIC	CFI
One-factor	$X^2(90) = 1350.095, p < .001$	1410.095	1528.063	.522
Three-factor	$X^2(87) = 429.887, p < .001$	495.887	625.651	.870
Three-factor, 1 item removed	$X^2(74) = 367.268, p < .001$	429.268	551.168	.885

Here, the chi-square test is significant, so I considered fit indices to determine which model is best. The AIC and BIC values were lower for the three-factor model. The CFI was closer to 1 for the three-factor model (though not above the .90 threshold for good fit). So, the three-factor model had the better fit of the two models. Though I cannot compare overall models and fit indices to those of Crocker et al., I can compare the standardized factor loadings of items within each of the subscales (Table 4.13). Percent differences (M = 11.8, SD = 12.3) between the

two studies' factor loadings show an overall similarity to one another across the populations. One item from the *Others' Approval* subscale, "I can't respect myself if others don't respect me", lies beyond two standard deviations from the percent difference mean. The model fit improved with this item removed: the AIC and BIC were lower than the three-factor model with all items and the CFI increased, though not at the acceptable level of good model fit. The Cronbach's alpha increased for the subscale from 0.82 to 0.87. Because the removal of this item improved the model fit for this population, this item was removed for all future analyses.

Table 4.13 CFA standardized factor loadings for the three-factor model for this survey compared to those reported in Crocker et al. (Note: Items that were reverse coded are marked with an asterisk.)

Subscale	Item	Factor Loadings	Factor Loadings Crocker et al.[159]	Percent Difference (%)
Academic competence	My self-esteem is influenced by my academic performance.	.62	.82	27.8
	I feel better about myself when I know I'm doing well academically.	.75	.78	3.9
	Doing well in school gives me a sense of self-respect.	.75	.75	0.0
	I feel bad about myself whenever my academic performance is lacking.	.64	.66	3.1
	My opinion about myself isn't tied to how well I do in school.*	.45	.56	21.8
Competition	Doing better than others gives me a sense of self-respect.	.83	.82	1.2
	Knowing that I am better than others on a task raises my self-esteem.	.75	.79	5.2
	My self-worth is affected by how well I do when I am competing with others.	.68	.77	12.4
	My self-worth is influenced by how well I do on competitive tasks.	.74	.76	2.7
	I feel worthwhile when I perform better than others on a task or skill.	.81	.71	13.2
Others' approval	I don't care what other people think of me.*	.92	.79	15.2
	What others think of me has no effect on what I think about myself.*	.79	.78	1.3
	I don't care if other people have a negative opinion about me.*	.82	.75	8.9
	My self-esteem depends on the opinions others hold of me.	.64	.73	13.1
	I can't respect myself if others don't respect me.	.29	.47	47.4

Using the three-factor model with one item removed as above, I completed CFAs for each demographic group for the Contingencies of Self-Worth Scales. Due to low cell size, a CFA for Black/African American males could not be done. As seen in the table below (Table 4.14), the model fit reasonably well for Hispanic and White students. Further investigation is warranted for Black/African American female students.

Table 4.14 Model fit indices for the one-factor model with item-item correlation for confirmatory factor analysis for the three contingencies of self-worth items for each demographic group.

Demographic Group	N	Chi-square	CFI	RMSEA
Black/African American female	26	$X^2(74) = 162.315, p < .001$	.680	.218
Black/African American male	5	--	--	--
Hispanic female	52	$X^2(74) = 122.542, p < .001$	.819	.113
Hispanic male	22	$X^2(74) = 109.222, p = .005$	.804	.151
White female	58	$X^2(74) = 144.857, p < .001$	.858	.130
White male	32	$X^2(74) = 129.261, p < .001$	.800	.155

In the Academic Competence subscale, factor loadings for Black/African American females were outside the range of other demographic groups for four of the five items. For the item “My opinion about myself isn’t tied to how well I do in school”, factor loadings for Hispanic females and White males were much lower than the other demographic groups. For the Competition and Others’ Approval subscales, items performed similarly overall across demographic groups.

Table 4.15 Factor loadings of the one-factor model with item-item correlation model for the self-doubt items for each demographic group.

Subscale	Item	BlackAA Female	BlackAA Male	Hispanic Female	Hispanic Male	White Female	White Male
Academic competence	My self-esteem is influenced by my academic performance.	.35	--	.53	.71	.65	.72
	I feel better about myself when I know I’m doing well academically.	.60	--	.73	.78	.76	.87
	Doing well in school gives me a sense of self-respect.	.41	--	.77	.81	.83	.97
	I feel bad about myself whenever my academic performance is lacking.	.94	--	.35	.47	.66	.42
	My opinion about myself isn’t tied to how well I do in school.*	.55	--	.25	.53	.66	.09

Competition	Doing better than others gives me a sense of self-respect.	.97	--	.79	.73	.88	.85
	Knowing that I am better than others on a task raises my self-esteem.	.71	--	.54	.74	.84	.78
	My self-worth is affected by how well I do when I am competing with others.	.81	--	.74	.83	.72	.50
	My self-worth is influenced by how well I do on competitive tasks.	.78	--	.66	.79	.69	.75
	I feel worthwhile when I perform better than others on a task or skill.	.77	--	.93	.97	.89	.80
Others' approval	I don't care what other people think of me.*	.92	--	.82	.86	.89	1.04
	What others think of me has no effect on what I think about myself.*	.94	--	.72	.96	.90	.65
	I don't care if other people have a negative opinion about me.*	.70	--	.81	.70	.66	.87
	My self-esteem depends on the opinions others hold of me.	.85	--	.66	.60	.73	.56

Implicit Theory of Intelligence. Dweck and colleagues' subscale on implicit theory of intelligence was used in this survey (items 49-51). Dweck et al. did not assess their model via factor analysis, so it was not possible to compare models between populations. Further, the model for this population was just-identified. This means the number of distinct sample moments and the number of distinct parameters to be estimated are equal, with zero degrees of freedom. Thus, a chi-square test and p-value cannot be calculated. Just-identified models are able to reproduce the data. Further, since I am not comparing models, AIC or BIC were not relevant.

Table 4.16 shows the factor loadings for the ITI subscale for this survey and a range of loadings from Dweck and colleagues, which were from five study populations.[83] The factor loadings of this study and literature values were compared and percent differences were calculated (M = 5.2, SD = 4.2). All three items fell within two standard deviations of the percent

difference mean. Considering there was good reliability (α = .92) and similar factor loadings, all items of the ITI were kept for future analyses.

Table 4.16 CFA factor loadings for the ITI subscale for this survey compared to those reported in Dweck et al. (Note: the decimal points on Dweck et al. factor loadings were added because they were omitted from their original manuscript.)

Item	Factor Loadings	Factor Loadings Dweck et al.[83]	Percent Difference (%)
You have a certain amount of intelligence and you really can't do much to change it.	.95	.94-.96	0.0
Your intelligence is something about you that you can't change very much.	.90	.94-.96	5.4
You can learn new things, but you can't really change your basic intelligence.	.84	.91-.95	10.2

Keeping all the items in the just-identified model, I ran CFAs for each demographic group (except for Black/African American males due to low cell size). Factor loadings for each group (Table 4.17) were all of acceptable magnitude and quite close to literature values from Dweck and colleagues, meaning the items performed similarly across all demographic groups.

Table 4.17 Factor loadings of the just-identified model for the ITI items for each demographic group.

Item	Black/AA Female	Black/AA Male	Hispanic Female	Hispanic Male	White Female	White Male
You have a certain amount of intelligence and you really can't do much to change it.	.87	--	.96	1.06	.87	.98
Your intelligence is something about you that you can't change very much.	.95	--	.93	.76	.93	.97
You can learn new things, but you can't really change your basic intelligence.	.92	--	.80	.88	.80	.88

Self-doubt. One of two Oleson and colleagues' subscales, self-doubt, were used in this survey (items 53-60). Two models were assessed to for this subscale. Both models loaded onto one factor, but the second model was run with an item-item correlation between two items: "As I begin an important activity, I usually feel confident in my ability" and "As I begin an important activity, I usually feel confident in the likely outcome". This was done because the modification indices for Model 1 indicated a large residual covariance for this pair and the model could fit better if it were modified to allow for a correlation between these items. As seen in Table 4.18,

the model significantly improved with the item-item correlation, with the AIC and BIC significantly lower and an improved CFI value. This is not surprising as these items are worded similarly and Oleson and colleagues also reported a similar overall model with these two items correlated.[69]

Table 4.18 Model fit indices for the one-factor model with and without item-item correlations for confirmatory factor analysis for the self-doubt items.

Model	Chi-square	AIC	BIC	CFI
One-factor	$X^2(20) = 235.134$, $p < .001$	267.134	330.050	.795
One-factor w/ item-item correlation	$X^2(19) = 46.029$, $p < .001$	80.029	146.877	.974

Table 4.19 reports the comparison of the factor loadings for the self-doubt subscale for this survey and that seen in the Oleson et al. study. Even with the modified model, one item did not have comparable factor loadings ("As I begin an important activity, I usually feel confident in the likely outcome"). However, this item, though showing a high percent difference, was within two standard deviations of the mean percent difference (M = 18.7, SD = 11.6) and was kept for future analyses.

Table 4.19 CFA standardized factor loadings for the self-doubt subscale for this survey (model with modified correlations) compared to those reported in Oleson et al. (Note: Items that were reverse coded are marked with an asterisk. These are also the items that were correlated to modify the model.)

Item	Factor Loadings	Factor Loadings Oleson et al.[69]	Percent Difference (%)
When engaged in an important task, most of my thoughts turn to bad things that might happen (e.g., failing) than to good.	.78	.70	10.8
For me, avoiding failure has a greater emotional impact (e.g., sense of relief) than the emotional impact of achieving success (e.g., joy, pride).	.40	.49	20.2
More often than not I feel unsure of my abilities.	.88	.82	7.1
I sometimes find myself wondering if I have the ability to succeed at important activities.	.60	.76	23.5
I often wish that I felt more certain of my strengths and weaknesses.	.60	.68	12.5
As I begin an important activity, I usually feel confident in my ability.*	.49	.67	31.0
Sometimes I feel that I don't know why I have succeeded at something.	.49	.47	4.2
As I begin an important activity, I usually feel confident in the likely outcome.*	.46	.69	40.0

Because the model that fit the Self-doubt subscale best included one factor with one item-item correlation (#54 and #57, see above), the same model was employed for the CFAs of each demographic group. Due to low cell size, a CFA for Black/African American males could not be done. As seen in the table below, the model fit well for some demographic groups, namely Black/African American females and White females. The other demographic groups had models that did not fit as well.

Table 4.20 Model fit indices for the one-factor model with item-item correlation for confirmatory factor analysis for self-doubt items for each demographic group.

Demographic Group	N	Chi-square	CFI	RMSEA
Black/African American female	26	$X^2(19) = 23.099$, $p = .233$	.957	.093
Black/African American male	5	--	--	--
Hispanic female	52	$X^2(19) = 37.518$, $p = .007$	.877	.138
Hispanic male	22	$X^2(19) = 39.293$, $p = .004$	.793	.226
White female	58	$X^2(19) = 26.661$, $p = .113$	.945	.084
White male	32	$X^2(19) = 38.280$, $p = .005$	.765	.181

In terms of factor loadings (Table 4.21), several items performed differently between demographic groups. Specifically, “I often wish that I felt more certain of my strengths and weaknesses” performed with a higher factor loading with Black/African American female students than compared with the other demographic groups. Additionally, two items (“As I begin an important activity, I usually feel confident in my ability” and “Sometimes I feel that I don’t know why I have succeeded at something”) had a wide variation of factor loadings across demographic groups, with ranges of .39 and 0.32, respectively.

Table 4.21 Factor loadings of the one-factor model with item-item correlation model for the self-doubt items for each demographic group.

Item	Black/AA Female	Black/AA Male	Hispanic Female	Hispanic Male	White Female	White Male
When engaged in an important task, most of my thoughts turn to bad things that might happen (e.g., failing) than to good.	.82	--	.82	.70	.77	.77
For me, avoiding failure has a greater emotional impact (e.g., sense of relief) than the emotional impact of achieving success (e.g., joy, pride).	.48	--	.48	.46	.39	.11

More often than not I feel unsure of my abilities.	.96	--	.79	.98	.81	.88
I sometimes find myself wondering if I have the ability to succeed at important activities.	.65	--	.53	.57	.69	.64
I often wish that I felt more certain of my strengths and weaknesses.	.81	--	.65	.61	.51	.63
As I begin an important activity, I usually feel confident in my ability.*	.44	--	.55	.67	.48	.28
Sometimes I feel that I don't know why I have succeeded at something.	.66	--	.45	.77	.54	.45
As I begin an important activity, I usually feel confident in the likely outcome.*	.42	--	.33	.55	.38	.27

The findings of the above factor analyses by demographic group for each subscale should be considered when interpreting further analyses of this survey as conservative. While not the focus of this dissertation, further study should be done to determine how these subscales perform among demographic groups with a larger population.

Results

The aim of the analyses for this chapter are to understand the various affective characteristics of students and how they may affect their outcome in a course. The primary analysis for this study was to describe each of the survey subscales across course outcome and demographic group to determine if affect differs as a function of these variables.

As a secondary analysis, I used cluster analysis to group students of similar affective traits together. Then, using demographic information from students, such as self-reported midterm grade, race/ethnicity and gender, income level, and science department, analyses were run to see if clusters differ for these other demographic groups. Ultimately, this analysis will show how different affective characteristics correlate with passing or failing grades. Before the results of the clusters analyses, this section briefly reports on the descriptive statistics of the survey responses over the two semesters it was implemented.

Descriptive statistics

Though the survey was distributed over two semesters (one being a pilot), responses were aggregated to analyze since there were no significant differences in the items or implementation. Table 4.22 has the number of complete responses for each implementation and their respective response rates.

Table 4.22 Response counts and response rates for each implementation of the survey.

Implementation	Complete Responses	Response Rate
Pilot – Spring 2019	69	9.8%
Full – Fall 2019	308	6.2%
Overall	*377*	*6.6%*

Descriptive statistics (i.e. mean, medians, range, skewness, etc.) for every survey measure can be found in Table 4.23.

Table 4.23 Descriptive statistics for each survey subscale (N = 377).

	Intellectual Accessibility	***Emotional Satisfaction***	***Science Identity***	***Academic SW***	***Competition SW***	***Others' Approval SW***	***ITI***	***Self-Doubt***
Mean	3.0	4.7	4.2	5.8	5.0	3.8	2.5	3.8
Median	3.0	4.8	4.3	6.0	5.2	4.0	2.3	3.9
Std. Deviation	1.3	1.3	.80	.82	1.3	1.5	1.2	0.9
Variance	1.6	1.6	.64	.67	1.7	2.3	1.5	.73
Skewness	.693	-.390	-1.128	-.823	-.715	.004	.747	-.132
Kurtosis	.308	-.045	1.281	.756	.425	-.727	-.125	-.268
Range of scores	1 – 7	1 – 7	1 – 5	2.4 – 7	1 – 7	1 – 7	1 – 6	1.4-6

Affective measures as a function of course grade

The primary motivation behind the surveys was to determine if affective characteristics differed in students that may lead to a different outcome in the course (pass vs. fail). To investigate this, I tested the eight affective measures as a function of the self-reported midterm grade. I employed a Mann-Whitney U test to determine if there were statistical differences in survey measure scores between the two groups of students: passing midterm grade (N = 307) and a failing midterm grade as noted by DFW (N = 54). Distribution of scores for each measure were

visually inspected and found to be similar between the two groups (pass vs. DFW). Thus, the Mann-Whitney U test was employed to determine if there were statistical differences between the medians of the two groups on each measure. Results are summarized in Table 4.24.

Table 4.24 Results from the Mann-Whitney U test to determine differences in survey measure scores between students who reported passing or failing grades in their course.

Survey Measure	Medians		Mann-Whitney U Test Statistic	z-score	p-value
	Pass	DFW			
Intellectual accessibility	3.00	2.67	7357.0	-1.323	.186
Emotional satisfaction	5.00	4.00	4940.5	-4.744	< .001
Science identity	4.50	3.75	5542.5	-3.925	< .001
Academic self-worth	6.00	5.90	8401.0	.159	.874
Competition self-worth	5.20	5.10	7501.5	-1.115	.265
Others' approval self-worth	4.00	3.38	6436.5	-2.623	.009
Implicit theory of intelligence	2.33	2.33	8391.5	.146	.884
Self-doubt	3.75	4.06	9933.0	2.327	.020

The Mann-Whitney U test revealed group differences on four of the eight survey measures. Students who reported a passing midterm grade scored higher on the Emotional satisfaction (Mdn = 5.00, U = 4940.0, z = -4.744, p < .001), Science identity (Mdn = 4.50, U = 5542.5, z = -3.925, p < .001), and Others' approval self-worth (Mdn = 4.00, U = 6436.5, z = -2.623, p = .009) measures than their peers who reported a midterm grade of a D, F, or W (Mdn = 4.00, 3.75, and 3.38, respectively). Further, students who reported a midterm grade of DFW scored higher on the Self-doubt measure (Mdn = 4.06, U = 9933.0, z = 2.327, p = .020) than their peers who reported a passing midterm grade (Mdn = 3.75). There were no statistically significant differences between the two groups on the remaining measures.

Cluster Analysis – Distinguished clusters

Though many decisions made in performing a cluster analysis vary widely and depend on theory and the researcher, Milligan[162] and Everitt[158] provide suggested steps of carrying out such an analysis. The details of the cluster analysis as it pertains to this dissertation are described

below. The objects clustered are the students who responded to the survey and the variables included are the 8 survey measure constructs described above.[10] Though the variables included have different scales, standardization of the variables was purposefully not carried out. Standardization (i.e. converting to z-scores) would give equal weight to all variables. I decided to not do this because I do not want to impose equal weight on student responses, and thus student experiences (see *Galloway and Bretz*[23]). Hierarchical agglomerative clustering (HAC), as opposed to k-means clustering, was chosen because there was no *a priori* hypothesis to the number of clusters in the data. HAC builds clusters starting at individual cases and continue to merge into larger clusters. I used the "best cut" method on the outputted dendrogram determined by the agglomeration schedule (Appendix B) to determine the number of clusters. Squared Euclidian distance was used as the dissimilarity measure as I am using interval data. Finally, the clustering method, or linkage, used was Ward's method, or Ward's minimum variance method. This method minimizes total variance within clusters, while increasing variance between clusters.

Upon visual inspection of the dendrogram and making a "best cut" using the output of the agglomeration schedule (see Appendix B), I determined the cluster analysis yielded six distinct clusters.

Table 4.25 Frequency of each cluster yielded from the HAC analysis.

Cluster	N	Percent
1	54	14.3
2	114	30.2
3	96	25.5
4	53	14.1
5	30	8.0
6	30	8.0
Total	377	100

[10] Social influences were not included in the cluster analysis since it is not an affective construct measured on a scale similar to the others.

To determine cluster distinctness, I employed a Kruskal-Wallis H test to determine if clusters were truly different on each survey measure. Visual inspection of measure boxplots determined the distributions of each measure were similar and therefore the medians can be used for interpretation. Significant differences between clusters were found for each measure. Pairwise comparisons, with Bonferroni corrections ($\alpha_{adjusted} = .0010$), were performed to determine which clusters showed differences.

Though respondents of this survey scored high on Science Identity collectively, median Science Identity scores were statistically significantly different between clusters, $X^2(5) = 65.393$, $p < .001$. Pairwise comparisons revealed that Cluster 2 (Mdn = 4.5) and Cluster 3 (Mdn = 4.5) reported a higher sense of Science Identity than those in Cluster 4 (Mdn = 3.5) and Cluster 5 (Mdn = 3.5), both adj. $p < .001$.

The ITI survey items measure whether a respondent has an entity or incremental mindset. Higher agreement indicates a more entity theory. ITI scores were statistically different between clusters, $X^2(5) = 132.339$, $p < .001$. Pairwise comparisons showed that Cluster 1 (Mdn = 4.3) scored significantly higher on this measure than almost all other clusters: Cluster 2 (Mdn = 2.0), Cluster 3 (Mdn = 2.0), Cluster 4 (Mdn = 2.7), Cluster 5 (Mdn = 2.0), and Cluster 6 (Mdn = 2.0), all adj. $p < .001$.

While Self-doubt had among the lowest variance between survey respondents, clusters significantly differed in their scores, $X^2(5) = 55.845$, $p < .001$. Pairwise comparisons revealed that Cluster 3 (Mdn = 3.4) had significantly lower Self-doubt scores than Cluster 1 (Mdn = 4.1), Cluster 2 (Mdn = 4.0), and Cluster 5 (Mdn = 4.6), all adj. $p < .001$. Cluster 4 (Mdn = 3.6) scored significantly lower than Cluster 5 (Mdn = 4.6, adj. $p < .001$).

Clusters scored significantly different on the Emotional Satisfaction measure, $X^2(5) = 135.060$, $p < .001$. Through pairwise comparisons, several clusters differed from one another. Cluster 2 (Mdn = 5.3) and Cluster 3 (Mdn = 5.3) reported a higher sense of science being emotionally satisfying than Cluster 4 (Mdn = 4.0), Cluster 5 (Mdn = 2.9), and Cluster 6 (Mdn = 3.8), with all adj. $p < .001$. Conversely, Cluster 5 (Mdn = 2.9) reported significantly lower Emotional satisfaction than Cluster 1 (Mdn = 4.5, adj. $p < .001$).

Some clusters were divided on if they thought science was intellectually accessible, which was evident since clusters did differ significantly in their scores, $X^2(5) = 114.737$, $p < .001$. Two clusters were on the extremes of the range while the other four clusters grouped together near a median of 3. Pairwise comparisons revealed Cluster 5 (Mdn = 1.7) reported significantly lower Intellectual Accessibility when compared to Cluster 1 (Mdn = 3.0), Cluster 2 (Mdn = 2.7), Cluster 3 (Mdn = 3.0), Cluster 4 (Mdn = 3.0), and Cluster 6 (Mdn = 5.3), with all adj. $p < .001$. The other extreme, Cluster 6 (Mdn = 5.3), reported significantly higher Intellectual Accessibility than Cluster 1 (Mdn = 3.0), Cluster 2 (Mdn = 2.7), Cluster 3 (Mdn = 3.0), and Cluster 4 (Mdn = 3.0), with all adj. $p < .001$.

For Academic SW, clusters scored significantly different, $X^2(5) = 82.732$, $p < .001$. Again, the two clusters on the extremes of the range showed significant differences, via pairwise comparisons, to those clusters in the middle of the range. Cluster 4 (Mdn = 5.0) reported significantly lower contingency of academics on their self-worth than Cluster 1 (Mdn = 5.8), Cluster 2 (Mdn = 6.4), Cluster 3 (Mdn = 5.8), and Cluster 5 (Mdn = 6.2) with all adj. $p < .001$. Whereas Cluster 2 (Mdn = 6.4) reported significantly higher contingency of academics on self-worth when compared to Cluster 3 (Mdn = 5.8, adj. $p < .001$).

As for Competition SW, again, clusters scored significantly different from one another, $X^2(5) = 103.792$, $p < .001$. Pairwise comparisons revealed that Cluster 4 (Mdn = 3.6) reported significantly lower contingency of competition on their self-worth than Cluster 1 (Mdn = 5.8), Cluster 2 (Mdn = 5.4), Cluster 3 (Mdn = 5.2), and Cluster 5 (Mdn = 5.8), with all adj. $p < .001$.

Finally, clusters scored significantly different on how Others' Approval is contingent on their self-worth, $X^2(5) = 217.244$, $p < .001$. Pairwise comparisons revealed significant differences between clusters. Clusters 3 (Mdn = 2.5) and 4 (Mdn = 2.8) reported significantly lower contingency of others' approval on their self-worth when compared to Cluster 1 (Mdn = 4.3), Cluster 2 (Mdn = 5.0), Cluster 5 (Mdn = 4.6), and Cluster 6 (Mdn = 4.0), with all adj. $p < .001$.

Table 4.26 Median scores for each survey subscale measure by cluster (1-6).

Subscale	Possible Scores	Cluster Median Scores					
		1	2	3	4	5	6
Science Identity	1-5	4.00	4.50	4.50	3.50	3.50	4.25
Implicit Theory of Intelligence	1-6	4.67	2.00	2.00	2.67	2.00	2.00
Self-doubt	1-6	4.13	4.00	3.38	3.63	4.56	4.00
Emotional Satisfaction	1-7	4.50	5.25	5.25	4.00	2.88	3.75
Intellectual Accessibility	1-7	3.00	2.67	3.00	3.00	1.67	5.33
Contingency of self-worth Academics	1-7	5.80	6.40	5.80	5.00	6.20	5.80
Contingency of self-worth Competition	1-7	5.80	5.40	5.20	3.60	5.80	4.60
Contingency of self-worth Others' Approval	1-7	4.25	5.00	2.50	2.75	4.63	4.00

As seen from the analyses above and Table 4.26, many of the clusters only differ on one construct that makes them distinct from one another (e.g. Cluster 1, 5, and between 2 and 3). In fact, there are small or large groupings of clusters in each of the constructs. It is important to consider how clusters are similar or different when looking at all constructs collectively. The

next section describes each of the clusters in detail and how they differ from others in order to create a label that accurately depicts the characteristics of students belonging to that cluster.

Cluster Descriptions and Labels

While the significance tests reported above show quantitative distinctness between clusters, the clusters can be qualitatively described taking each of the constructs into consideration and give a more complete account of those that are included in each cluster. Detailed descriptions of each cluster are below and followed by a label the clusters were given beyond numbers.

Cluster 1. Respondents in Cluster 1 did not differ from other clusters in seven of the eight measures. Cluster 1's median scores in Academic self-worth, Competition self-worth, Others' approval self-worth, Emotional satisfaction, Intellectual accessibility, Science identity, and Self-doubt were all "middle of the road" and not distinguishable from other clusters. The only measure that was unique to Cluster 1 is that of their ITI median score. Students in Cluster 1 overwhelmingly had an entity mindset, which no other cluster reported (i.e. all other clusters reported incremental mindsets). Considering the unique characteristics of Cluster 1, the label of *Entity Mindsets* was applied.

Cluster 2. Students in Cluster 2 reported high Science Identity, high Emotional Satisfaction, and high contingency to their self-worth as it relates to Academics and Others' Approval. Because this cluster scored among the highest on Science Identity and Emotional Satisfaction, these students clearly hold science as being central to their identity and see science as being enjoyable and fulfilling. I surmise these students can be considered "science enthusiasts." Further, the scores relating to self-worth for this cluster suggest the self-worth of

these students were highly contingent on matters relating to academics and others' opinions of them. Thus, Cluster 2 received the label of *Science Enthusiast, High Contingency*.

Cluster 3. Students in Cluster 3 could also be considered "science enthusiasts" due to their high scores in Science Identity and Emotional Satisfaction. If fact, Cluster 2 and 3 are alike in all measures, with the exception of measures on self-doubt and self-worth. While there is a smaller variance between Cluster 2 and 3 in Self-doubt, Academic and Competition self-worth, Cluster 3 is consistently lower than Cluster 2. Further, Cluster 3 reported the lowest contingency of self-worth for Others' Approval. Students in Cluster 3 have lower self-doubt and have a lower contingency of their self-worth being swayed by outside factors. Therefore, Cluster 3 was given the label *Science Enthusiast, Low Contingency.*

Cluster 4. Across the three factors that could affect one's self-worth, Cluster 4 consistently scored as low contingency and was, in fact, the lowest on two of the three factors. The self-worth of these students is not easily rattled by academics, competition, or others' opinions. In addition to this, Cluster 4 was undistinguishable in Self-doubt, Emotional Satisfaction, and Intellectual Accessibility. This cluster was near neutral on Science Identity and ITI. Due to their neutrality to science and their low contingency on their self-worth, Cluster 4 was labeled *Science Neutral, Low Contingency*.

Cluster 5. Cluster 5 reported the lowest scores for Emotional Satisfaction and Intellectual Accessibility. These students characterized science as being "challenging," "unpleasant," "frustrating," and "complicated." Further, these students reported the highest self-doubt among those with the highest contingencies to their self-worth from academics, competition, and others' opinions. Therefore, Cluster 5 was labeled as *Non-Science Enthusiast, High Contingency*.

Cluster 6. Similar to Cluster 1, Cluster 6 only differed from the other clusters on one measure: Intellectual Accessibility. This cluster scored the highest, by far, on science being intellectually accessible. Because of this one unique factor, Cluster 6 was labeled as *Science Accessible*.

Table 4.27 Labeling of each cluster.

Cluster	***Label***
1	Entity Mindsets
2	Science Enthusiast, High Contingency
3	Science Enthusiast, Low Contingency
4	Science Neutral, Low Contingency
5	Non-Science Enthusiast, High Contingency
6	Science Accessible

Cluster Demographics

With the clusters described and labeled, I wanted to explore if there were differences in the populations of each of the clusters. Only students that provided the demographic information needed to run the analyses were included.

Midterm grades. A central aim of Study 2 is to consider the source of differences between students who pass versus students who receive a DFW in an introductory science course. Thus, the first analysis was to determine if the proportion of those that received DFWs for midterm grades would differ between clusters. Observed frequencies and percentages of clusters for midterm grade (pass vs. DFW) are presented in Table 4.28.

Table 4.28 Observed frequencies and percentages of each cluster represented by midterm grades.

Cluster	***Pass***	***DFW***
Science Enthusiast, High Contingency	103 (33.6%)	6 (11.1%)
Science Enthusiast, Low Contingency	79 (25.7%)	13 (24.1%)
Science Neutral, Low Contingency	35 (11.4%)	15 (27.8%)
Non-Science Enthusiast, High Contingency	21 (6.8%)	9 (16.7%)
Science Accessible	22 (7.2%)	6 (11.1%)

Entity Mindsets	47 (15.3%)	5 (9.3%)
TOTAL	307 (100%)	54 (100%)

Because of small cell sizes a chi-square test of homogeneity could not be completed and instead a Fisher's Exact test was performed. The Fisher's Exact test, which was employed to determine if the two probability distributions were equal for the two groups, revealed that the proportions of students in clusters were not equal between the groups of midterm grades, $p < .05$. Post hoc pairwise comparisons, via individual Fisher Exact test (2 x 2) with Bonferroni corrections, for each cluster were performed to determine in which clusters did proportions of midterm grades differ. There were statistically significant differences in the *Science Enthusiasts, High Contingency* cluster, where there were higher proportions of students who reported passing midterm grades (N = 103, 33.6%) than those that reported a midterm grade of DFW (N = 6, 11.1%), adj. $p < .0083$. Additionally, the *Science Neutral, Low Contingency* cluster differed in its proportion of passing (N = 35, 11.4%) and DFW (N = 15, 27.8%) reported midterm grades, adj. $p < .0083$. All other clusters did not differ significantly in their proportion of the two midterm grade groups.

Race/ethnicity and gender. Study 1 confirmed that students belonging to underrepresented racial/ethnic groups do have a higher likelihood of receiving a failing grade and have higher rates of attrition than their White URM students. Further, it is clear from the previous analysis that membership in two of the clusters is associated with one's outcome in their science course. So, the next analysis was to determine if there were differences in cluster membership by the intersection of race/ethnicity and gender. Unfortunately, due to small cell sizes, a statistical comparison was not viable. However, I did study patterns in cluster membership through a descriptive analysis. As in Study 1, only the demographic groups of

interest (Hispanic, Black/African American, and White at the intersection of gender) were included in this analysis.

Table 4.29 Observed frequencies and percentages of each cluster represented by the intersection of race/ethnicity and gender.

Cluster	***Hispanic female***	***Hispanic male***	***Black/AA female***	***Black/AA male***	***White female***	***White male***
Science Enthusiast, High Contingency	14 (26.9%)	3 (13.6%)	8 (30.8%)	1 (20.0%)	24 (41.4%)	13 (40.6%)
Science Enthusiast, Low Contingency	16 (30.8%)	12 (54.5%)	3 (11.5%)	1 (20.0%)	9 (15.5%)	11 (34.3%)
Science Neutral, Low Contingency	9 (17.3%)	3 (13.6%)	8 (30.8%)	0 (0%)	8 (13.8%)	2 (6.3%)
Non-Science Enthusiast, High Contingency	5 (9.6%)	3 (13.6%)	3 (11.5%)	0 (0%)	6 (10.3%)	0 (0%)
Science Accessible	5 (9.6%)	0 (0%)	3 (11.5%)	1 (20.0%)	1 (1.7%)	1 (3.1%)
Entity Mindsets	3 (5.8%)	1 (4.5%)	1 (3.8%)	2 (40.0%)	10 (17.2%)	5 (15.6%)
TOTAL	52 (100%)	22 (100%)	26 (100%)	5 (100%)	58 (100%)	32 (100%)

As seen in Table 4.29, several patterns emerged when observing the frequencies and percentages of demographic group within each cluster. Firstly, there was a gender difference for two clusters. More female students constituted the *Science Enthusiast, High Contingency* cluster when compared to males within their same racial/ethnic group. Conversely, more male students comprised the *Science Enthusiast, Low Contingency* cluster than their female URM students in the same racial/ethnic group. Secondly, Black/African American female students were represented more than any other demographic group in *Science Neutral, Low Contingency*. Lastly, White students, both female and male, and Black/African American male students had among the highest representation in the *Entity Mindsets* cluster than their other URM students. However, due to a low number of Black/African American male respondents ($N_{total} = 5$), more respondents would be needed in order to substantiate the claim that the majority of Black/African American male students belong to the *Entity Mindsets* cluster.

Income level. As previously mentioned, students facing financial issues or who come from communities that historically have lower incomes are not afforded the same opportunities

to develop an enthusiasm for science or encounter financial circumstances that affect their persistence in science. Since many of the clusters give sense of a student's enthusiasm towards science and their self-esteem, it was of interest to me to learn if differences are present between income level and cluster belonging. Further, because the race/ethnicity and gender analysis could not be completed with the current cell sizes, following up with a similar analysis on income level, especially when income level has divided largely on racial/ethnic lines, provided additional results to consider. Observed frequencies and percentages of clusters for income level (high vs. low or median) are presented in Table 4.30.

Table 4.30 Observed frequencies and percentages of each cluster represented by income level.

Cluster	***High***	***Low or median***
Science Enthusiast, High Contingency	62 (41.3%)	51 (23.5%)
Science Enthusiast, Low Contingency	37 (24.7%)	55 (25.3%)
Science Neutral, Low Contingency	9 (6.0%)	41 (18.9%)
Non-Science Enthusiast, High Contingency	12 (8.0%)	18 (8.3%)
Science Accessible	11 (7.3%)	19 (8.8%)
Entity Mindsets	19 (12.7%)	33 (15.2%)
TOTAL	150 (100%)	217 (100%)

A chi-square test of homogeneity was conducted between income level and cluster category. All assumptions and expected cell counts were met the minimum requirement to run this test. The chi-square test for homogeneity revealed that the proportions of students in clusters were not equal between income levels, X^2 (5) = 20.631, $p < .001$. Because there are differences in the two income levels, I conducted post hoc pairwise comparisons, via individual z-tests of two proportions with Bonferroni corrections (adj. $\alpha = .0083$), for each cluster to determine in which clusters did proportions of income level differ. There were statistically significant differences in the *Science Enthusiasts, High Contingency* cluster, where there were higher

proportions of students who reported high household income (N = 62, 41.3%) than those that reported a low or median household income (N = 51, 23.5%), adj. $p < .0083$. Additionally, the *Science Neutral, Low Contingency* cluster differed in its proportion, with higher proportion of students from low or median household incomes (N = 41, 18.9%) than high household incomes (N = 9, 6.0%), adj. $p < .0083$. All other clusters did not differ significantly in their proportion of the two income level groups.

Social influences. Another piece of information collected from students during the survey was their social influences. Social influences are people at various junctures in a student's life that influenced them in some way to major in science. Of all the different types of people included in the student responses, four categories emerged: *personal* (family, friends, myself), *high school* (high school teachers and guidance counselors), *collegiate* (professors, TAs, and advisors), and *other* (write-in responses such as no social influences, YouTube videos, books, etc.). Having social influencers impact your decision to major in a science discipline can give a student additional supports, science capital, sense of belonging, and motivation, which is why it was included in the analyses. Table 4.31 includes the observed frequencies and percentages for each social influence (present or not present) for each cluster.

Table 4.31 Observed frequencies and percentages of each cluster represented by the presence of a social influence.

	Personal		***High school***		***Collegiate***		***Other***	
Cluster	*Present*	*Not present*	*Present*	*Not present*	*Present*	*Not present*	*Present*	*Not present*
Science Enthusiast, High Contingency	99 (31.5%)	15 (23.8%)	59 (33.0%)	55 (27.8%)	18 (16.1%)	36 (13.6%)	3 (13.0%)	111 (31.4%)
Science Enthusiast, Low Contingency	76 (24.2%)	20 (31.7%)	50 (27.9%)	46 (23.2%)	36 (32.1%)	78 (29.4%)	7 (30.4%)	89 (25.1%)
Science Neutral, Low Contingency	46 (14.6%)	7 (11.1%)	14 (7.8%)	39 (19.7%)	11 (9.8%)	42 (15.8%)	8 (34.8%)	45 (12.7%)

Non-Science Enthusiast, High Contingency	25 (8.0%)	5 (7.9%)	12 (6.7%)	18 (9.1%)	8 (7.1%)	22 (8.3%)	2 (8.7%)	28 (7.9%)
Science Accessible	25 (8.0%)	5 (7.9%)	16 (8.9%)	14 (7.1%)	10 (8.9%)	20 (7.5%)	1 (4.3%)	29 (8.2%)
Entity Mindsets	43 (13.7%)	11 (17.5%)	28 (15.6%)	26 (13.1%)	18 (16.1%)	36 (13.6%)	2 (8.7%)	52 (14.7%)
TOTAL	314 (100%)	63 (100%)	179 (100%)	198 (100%)	112 (100%)	265 (100%)	23 (100%)	354 (100%)

A chi-square test of homogeneity was conducted between types of social influence and cluster membership. All assumptions and expected cell counts were met the minimum requirement to run this test for three of the four types: personal, high school, and collegiate. The fourth type of social influence, other, did not meet the cell requirements and thus a Fisher's exact test was run. The chi-square test for homogeneity revealed that the proportions of students in clusters were not equal based on their indication of having a high school social influence, X^2 (5) = 12.851, p = .028. Because of the significant result, I conducted post hoc pairwise comparisons, via individual z-tests of two proportions with Bonferroni corrections (adj. α = .0083), for each cluster to determine in which clusters did proportions of high school social influence indication differ. Only one cluster differed significantly: *Science Neutral, Low Contingency* had a significantly higher proportion of students who indicated no high school influences (N = 39, 19.7%) to major than students who did indicate they had at least one high school influence (N = 17, 7.8%), adj. p < .0083. Clusters did not differ in whether or not they indicated personal, collegiate, and other social influences, all p > .05.

Discipline. A reoccurring theme of this dissertation is the comparison of three large science disciplines: chemistry, biology, and physics. While the cell sizes were too small to compare clusters at the course level, the courses could be collapsed into their respective

disciplines. Observed frequencies and percentages of clusters for each discipline are presented in Table 4.32.

Table 4.32 Observed frequencies and percentages of each cluster represented by discipline.

Cluster	***Chemistry***	***Biology***	***Physics***
Science Enthusiast, High Contingency	65 (33.3%)	31 (29.5%)	7 (17.9%)
Science Enthusiast, Low Contingency	42 (21.5%)	26 (24.8%)	14 (35.9%)
Science Neutral, Low Contingency	33 (16.9%)	16 (15.2%)	4 (10.3%)
Non-Science Enthusiast, High Contingency	13 (6.7%)	10 (9.5%)	3 (7.7%)
Science Accessible	15 (7.7%)	9 (8.6%)	4 (10.3%)
Entity Mindsets	27 (13.8%)	13 (12.4%)	7 (17.9%)
TOTAL	195 (100%)	105 (100%)	39 (100%)

Because of small cell sizes even at the collapsed level (i.e. physics), a chi-square test of homogeneity could not be completed and instead a Monte Carlo's exact test was performed. The Monte Carlo exact test was chosen over the Fisher's exact test because of the unequal distribution between the three disciplines, which made the Fisher's Exact test impossible to compute. The Monte Carlo test revealed that the proportions of students in clusters were not different between the three disciplines, $p = .643$.

Discussion

In this chapter, survey responses to several demographic and affective subscales were analyzed to create clusters of similar traits. Before completing the cluster analysis, reliability tests and confirmatory factor analysis revealed, overall, the chosen survey subscales measured what I had intended, with only two items removed from analyses for better reliability. I then analyzed the affective measures as a function of the self-reported midterm grade and found

differences on four constructs. Lastly, the clusters were analyzed against five factors to better understand relationships between affective traits and other individual differences.

Affect differs by midterm grades

When analyzing the eight affective constructs I found that students differed on four affective measures based on their self-reported midterm grades. Students who reported a passing midterm grade also scored higher on emotional satisfaction of science, science identity, and had a higher contingency of their self-worth based on others' approval. Conversely, students who reported a failing midterm grade scored higher on the self-doubt measure. The association I found between passing grades and higher science identity are consistent with previous literature linking higher science identity to higher science achievement.[65] Further, increased emotional satisfaction with science aligns with higher motivation per expectancy-value theory, which states that if you highly value a subject, you are more likely to have higher achievement in that subject.[68] What is less certain is how a higher contingency of self-worth based on others' approval is associated with passing midterm grades. Unfortunately, there is little research to date on course outcome or achievement and contingency of self-worth. As for the finding associating failing midterm grades and higher self-doubt, this is also consistent with previous research which found that students who left the chemistry discipline were more likely to have a higher self-doubt than those that persisted in the major.[15]

Cluster Analysis

The hierarchical agglomerative clustering yielded six distinct clusters, with the Kruskal-Wallis test confirming statistical distinctness. While there was little variance on subscales for

some clusters, it seemed that others were formed based on only one construct, for example *Entity Mindsets*. Respondents in this cluster did not differ wildly from their URM students in many respects but did, overwhelmingly, diverge on the ITI construct. *Science Accessible* is alike in this vein, where this cluster only differed from the others on the construct of Intellectual Accessibility. Students in this cluster scored science as being simple, easy, and uncomplicated, but aligned with the majority of clusters on all other constructs. Another pattern that resulted from the HAC, were when two clusters were almost identical in all constructs but hold opposite views in a subset of constructs. *Science Enthusiast, High Contingency* (Cluster 2) and *Science Enthusiast, Low Contingency* (Cluster 3) were both characterized by respondents who are motivated and stimulated by science but differ on how their self-worth is or is not affected by extrinsic factors. Along these same lines, *Science Neutral, Low Contingency* was described by students who were neutral in their feelings of science – not particularly central to their identity, not exciting but not boring, and not challenging but not easy. This cluster also was consistently among the lowest contingent on all factors on self-worth. Lastly, *Non-Science Enthusiast, High Contingency* were among or the lowest in Science Identity, Emotional Satisfaction, and Intellectual Accessibility. They see science as not being very central to their identity, hard, complicated, frustrating, and unpleasant. The self-worth of these students also highly varies as a function of extrinsic factors.

Once the clusters were described and labeled, it was of interest to me to understand other characteristics of the clusters with the information collected from the survey. Three running themes in this dissertation revolve around science discipline, course outcome, and the intersection of race/ethnicity and gender. Thus, these demographics were analyzed against the

clusters. Income level and social influences were also included in the analyses to analyze cluster membership on household income and mentorship, support, and sense of belonging.

Midterm grades and Clusters. When exploring differences of cluster demographics based on self-reported midterm grades, only two clusters differed significantly in their proportions. The *Science Enthusiasts, High Contingency* cluster had a significantly higher proportion of students who reported a passing grade than those that reported a DFW. The other cluster that showed significant differences, *Science Neutral, Low Contingency,* included a significantly higher proportion of students that reported a DFW than a passing midterm grade.

It is not entirely surprising that the *Science Enthusiasts, High Contingency* cluster had significantly more members with self-reported passing midterm grades than failing grades. We know from expectancy-value theory of motivation literature that what one values and has expectations of success can predict their outcome whether that be in terms of choices made or achievement.[68] Contextualizing this theory for the purposes of this dissertation, in the case of a science course and science identity, those who highly value science and expect to do well in the course (as measured by several constructs above), will have a better outcome (measured by the self-report midterm grade). This theory has been corroborated by other studies, using the same Science Identity instrument as this dissertation. For example, Robinson and colleagues found that undergraduate science students with higher self-efficacy and higher perceived competence were more likely to have higher science identity scores.[55] Further, Robinson et al. used the same instrument in another study with chemistry students where they linked higher science identity scores to higher performance on the final exam.[65] These findings collectively attribute performance to self-efficacy, perceived competence, and science identity. Thus, my findings from this analysis, which associated a more positive course outcome based on being in the

Science Enthusiasts, High Contingency, subscribe to the existing literature. Further, Crocker and Luhtanen did find some (positive) association between academic contingency of self-worth and GPA, but this could be explained by joint associations with another factor (virtue).[126] The authors go on to suggest that high contingency, especially with academics, result in higher stress levels that may, in turn, inadvertently decrease performance over time. It may be worth further study of these factors influencing self-worth over time to understand their effects more.

Similar to the argument detailed above concerning expectancy-value theory of motivation, it should not be unexpected that members of the *Science Neutral, Low Contingency* cluster had higher proportions of DFW midterm grades than passing grades. Being apathetic towards science would not yield much motivation or place a high value on science. If we hold to the expectancy-value theory of motivation, there should not be a high proportion of students in this cluster with passing grades. Though there was no statistically significant difference between proportions of grades within the *Non-Science Enthusiast, High Contingency* cluster, there is still a higher proportion of DFW midterm grades (16.7%) than passing grades (6.8%), which would also align with this theory.

In addition, the other three clusters (*Science Enthusiasts, Low Contingency, Science Accessible,* and *Entity Mindsets*) did not show differences in their proportion of students based on the self-report midterm grades. The two groups of midterm grades were almost identical in their proportion within the *Science Enthusiasts, Low Contingency* cluster. This cluster is unique from the other *Science Enthusiast*-type clusters because there is no difference in their proportion of students. In this cluster, students who are just as excited, intellectually and emotionally, by science as one another were equally passing or failing at midterm grades. The difference in outcome of the students in this cluster could come down to individual, environmental, or

situational differences, or errors in the measurement itself. It is plausible that a student in this cluster is excited about science but for a multitude of reasons (e.g. family or job responsibilities, difficulty with taking exams or completing homework, etc.) was failing the course at midterm. There could also be an error with the survey itself. If students were answering the items as science generally but reported a grade in a specific science course (e.g. survey answered by a chemistry major who dislikes or does not excel in biology but reported a biology grade) there could be a disconnect with the constructs tying to midterm grades. Ultimately, there are many reasons why this cluster is unique. Further study of the members of the *Science Enthusiasts, Low Contingency* cluster is warranted to understand their differing experiences more.

The *Science Accessible* and *Entity Mindsets* clusters also did not differ in their proportion of students based on the self-reported midterm grades. Again, these two clusters were the only clusters where one construct ultimately defined them. Science could be viewed as accessible (i.e. easy, simple, or not challenging) but not have influence on motivation, value, or a students' outcome. It is plausible that there would be no significant difference in outcomes for the *Science Accessible* cluster. Just the same, members of the *Entity Mindsets* cluster did not differ in their outcomes. A meta-analytic review of the literature that links ITI with academic achievement found a low-to-moderate association between the two factors, with entity views having a lower effect than incremental views.[85] My findings concur with the literature based on this population of entity mindsets.

Race/ethnicity x gender and Clusters. While only a descriptive analysis was completed for cluster membership based on the intersection of race/ethnicity and gender, I did uncover differences in the representation of demographic groups in each cluster. It should be noted that division of the clusters by demographic group resulted in small cell sizes and no formal

statistical analysis was completed. Thus, discussions below are purely speculative and not meant to be generalizable. Further analyses with a larger population must be done to better establish the trends I saw in cluster membership and race/ethnicity and gender.

Notably, there were gendered differences in the *Science Enthusiast, High Contingency* and *Science Enthusiast, Low Contingency* clusters. Within racial/ethnic groups, female students were more represented in the high contingency cluster than their male URM students while male students were more represented in the low contingency cluster of *Science Enthusiast*. In other words, I observed a gendered difference of self-worth and self-esteem being contingent on external factors, where the self-worth of female students is more malleable or sensitive to change than their male URM students. In fact, the two clusters showed their largest difference on the Others' Approval subscale, where female students in their respective racial/ethnic group were the majority, and their smallest difference on the Competition subscale, where male students in their respective racial/ethnic group were more represented. This is in tune with work in social psychology, where researchers have observed that females report their self-esteem is more dependent on others' approval, whereas males report that their self-esteem stems from social comparisons or competition.[163,164] Moreover, the creators of the CSW subscales reported similar gendered findings. Female respondents scored significantly higher on the Others' Approval and Academic Competence subscales, when compared to male respondents.[159] It is worth noting that, as discussed above, the *Science Enthusiast, High Contingency* cluster had an association with a positive outcome at midterm which, when combined with these results, could mean a greater, positive impact on female students in retention within the course.

This analysis also showed that Black/African American female students were represented more in the *Science Neutral, Low Contingency* cluster than any other demographic group. I

already discussed above how being *Science Neutral* could lead to lower performance and therefore higher attrition. However, there are different, and more severe, implications when this cluster is largely represented by Black/African American female students. We know that Black/African American female students do not differ in their intent to major in the sciences (and therefore do not differ in their initial interest), but the same literature and results from Study 1 of this dissertation show that Black/African American female students are disproportionately excluded from the sciences more so than other students.[7,13,14,165] In Study 1, this was seen by Black/African American female students (1) being awarded lower proportions of chemistry and physics degrees compared to biology, (2) having the highest rates of switching out of CBP majors, and (3) having the highest DFW rates across CBP introductory courses. While the results take the appearance of higher DFW rates, higher attrition rates, and lower degree turnout when compared to their peers, the exclusion of Black/African American female students comes well before final grades are submitted and degrees are awarded, typically in the form of structural barriers and negative interactions.

When creating a grounded model for science identity using successful female students of color as sources, Carlone and Johnson (2007) found that their participants fell into three groups: research science identity, altruistic science identity, and disruptive science identity.[61] While their paths to success all looked different, members of each group cited experiences of discrimination and neglect based on gender and/or race/ethnicity in their field or related science courses. Further, it seemed that group placement was contingent on the ability of students to reimagine who deemed them worthy of recognition as a science person or who they saw as being "meaningful others."[61] This is not unlike other studies that found "success" (i.e. persistence or higher science identity) of students of color was associated with assimilation to the culture of

science or the ability to tolerate discrimination.[11,34] If we subscribe to Carlone and Johnson's model of science identity, increasing the recognition of Black/African American female students as scientists and promoting enculturation (as opposed to assimilation) may help bridge the divide between *Science Neutral* and *Science Enthusiasts* for Black/African American female students.

Finally, within the *Entity Mindsets* cluster, White students, both female and male, and Black/African American male students were represented more so than their other URM students. People who believe in an entity view of intelligence believe that while you can learn new things, your overall intelligence will not change, viewing intelligence as a fixed trait.[83] There has been little research on Dweck's ITI when it comes to gender and race/ethnicity. One study from Dweck found that the theory of intelligence is independent of gender.[83] As for race/ethnicity, there are no documented differences in theory beliefs based on race. However, it has been found that instructor beliefs on theory of intelligence, particularly entity beliefs, influence students' views of themselves which could be detrimental to a students' motivation and their performance in the course.[88,89] This is of particular concern regarding URM students, since it has been found that racial achievement gaps widen when an instructor holds an entity, or fixed, view on intelligence.[89] What is encouraging is that when interventions have students change their thinking to believe intelligence is malleable, students, particularly Black/African American students, reported higher achievement and more engagement and more enjoyment in that course.[87]

Income level and Clusters. Next, I analyzed the differences of cluster membership based on self-reported household income. This analysis was done to better understand the link between socioeconomic status (through income level) and affective characteristics tied to science. Again, only two clusters differed significantly in their proportions: *Science Enthusiasts, High*

Contingency and *Science Neutral, Low Contingency*. In the *Science Enthusiasts, High Contingency* cluster, there were higher proportions of students who reported high household income than those that reported a low or median household income. In contrast, the *Science Neutral, Low Contingency* cluster differed in its proportion, with higher proportion of students from low or median household incomes than high household incomes. All other clusters did not differ significantly in their proportion of high or low/median income students.

Most notably, these results bear a striking resemblance to those of the pass vs DFW analysis. In fact, the same two clusters that showed significant differences in proportion for those students who passed or failed, are the same that correspond with high or low incomes. *Science Enthusiasts, High Contingency* had higher proportions of passing grades and high-income students, whereas *Science Neutral, Low Contingency* had higher proportions of failing grades and low or median incomes.

Social Influences and Clusters. The next analysis studied the differences of cluster membership based on the presence of four types of social influences. I explored this relationship to identify whether or not having mentors, support of family, friends, or teachers gave students a sense of motivation, confidence and sense of belonging. Based on this analysis, only one cluster differed significantly in their proportions of one type of social influence. In the *Science Neutral, Low Contingency* cluster, a higher proportion of students indicated no high school influences as opposed to having that influence. All other clusters and types of social influences did not differ significantly in their proportion of whether or not they exhibited that social influence.

It is interesting that there was a significant difference for high school influences on one's decision to major in science. Both *Science Enthusiasts* clusters and the *Non-Science Enthusiasts* cluster did not differ in their proportion of students that either did or did not have high school

influences. It could be that the science neutrality component of the *Science Neutral, Low Contingency* cluster is what is being affected by the lack of influence while in high school. It may be the case that students within the *Science Neutral, Low Contingency* cluster have not formed an opinion about science due to the lack of influence in their earlier science education. If this is true, exposing students to science earlier in their academic careers, making science relevant to all students, and continued encouragement from their STEM high school teachers could increase their science identity.[166] Further, covering content in depth in high school will lead to better achievement in those same courses in college[167], which will lead to higher confidence and possible higher science identity. More detail is needed from the students in this cluster to better understand the link between high school influences and science identity.

While no other statistically significant results were reported there are some interesting descriptive findings. Eighty-three percent of all survey respondents indicated they did have someone close to them, such as a family member or friend, influence them in some way to major in science. What is not known from this data is if all those personal influences were positive in nature. Interviews in the next chapter will probe students about these influences to understand their exact nature in helping or hindering them in science. Another interesting descriptive is that 70% of respondents stated they had no collegiate (professor, TA, advisor) that influenced them to choose their major. Because respondents came from introductory science courses, it is possible they already have a declared major before ever interacting with anyone at the collegiate level. However, many students come into college as undeclared and could base their decision to major in science off their experiences with members of the collegiate. Whether students have positive or negative experiences with these people will impact their sense of belonging in the field.[58,126]

Further study is needed into the relationships between students and professors and other academic persons to grasp the potential impact on student retention.

Discipline and Clusters. Lastly, I analyzed cluster membership in relation to the discipline in which the student was enrolled when completing the survey. While initially I wanted to analyze clusters at the course level, the cell sizes were too small and unbalanced between disciplines that it was not possible. The analysis including the disciplines showed no difference between chemistry, biology, or physics on the cluster level. Further analysis could be completed with a larger sample size and more balanced cell sizes between the three disciplines.

Though no significant differences were found, there are some interesting trends seen in the descriptives that were mirrored in other analysis. There were higher proportions in chemistry and biology of the *Science Enthusiasts, High Contingency* cluster than in physics. Conversely, there was a higher proportion of *Science Enthusiasts, Low Contingency* in physics than in chemistry or biology, where there was a lower proportion of that same cluster. These are interesting because in the race/ethnicity x gender analysis, these same clusters showed a gendered difference with their respective racial/ethnic groups. In fact, the results correspond to the established trend of physics being a more male-dominated discipline, whereas biology is overwhelmingly female, and chemistry is mostly equal between those genders. Beyond these two clusters, whose differences can be explained by gender, all other clusters are quite similar in their proportions across the three disciplines.

In summary, my cluster analysis yielded six distinct clusters formed by shared affective characteristics: *Science Enthusiast, High Contingency*, *Science Enthusiast, Low Contingency*, *Science Neutral, Low Contingency*, *Non-Science Enthusiast, High Contingency*, *Science*

Accessible, and *Entity Mindsets*. The analyses above explained why some of the cluster groups, particularly those with the Science Enthusiasts, Science Non-Enthusiasts, or Science Neutral distinctions, may or may not persist in the sciences due to how closely science is tied to their identity and their overall attitudes towards science. The other two clusters, *Science Accessible* and *Entity Mindsets*, did not differ in the individual analyses. However, these clusters do contribute to the understanding of affective characteristics of students. Those who see science as only accessible but do not see it closely related to their identity or emotionally satisfying did not show differences in their outcome in a course. This is a stark contrast from the *Science Enthusiast* clusters whose students scored similarly on all science identity and attitudinal measures. Further, students who hold entity, or fixed, mindsets of their intelligence (who also did not differ in their persistence) would consider their failure of a course to reflect their overall intelligence and not their study habits or other factors. Together, the collective affective traits of students do play some role in their persistence in a course. How they view themselves, science, and general academics was important for some students to achieve a passing grade. While the surveys did provide links between affective characteristics and persistence (or attrition), they do not tell us the details as to why marginalized students are leaving the sciences at high rates. In Chapter 5, I explore these specific reasons through one-on-one interviews with marginalized students who withdrew or failed an introductory chemistry, biology, or physics course.

CHAPTER V: STUDY 3 – Should I Stay, or Should I Go?

Introduction

My investigation in Chapter 4 found associations between affective characteristics of students and several individual differences like course outcome, income, and the intersection of gender and race/ethnicity. These affective characteristics are explored in more detail in this chapter and how they connect to the experiences of marginalized students in the sciences. Thus, Study 3 answers the following research question:

S3. *What are the common personal experiences of underrepresented minority students who fail, withdraw, or leave a chemistry, biology, or physics course or major?*

Seminal work from Seymour and Hewitt used interviews to investigate the various reasons students switched majors. The authors identified decision to major, high school preparation, student experiences with science and pedagogy, career and lifestyle, gender, and race/ethnicity as major contributors to the decision to switch. While students of all demographics and STEM majors varied in their responses, ultimately, Seymour and Hewitt found that the main reasons for switching were a reaction to the same issues experienced by both switchers and non-switchers.[11] What differed was how the individual experiences affected the students differently and contributed to their decision to leave or stay. Other scholars, who have focused their research efforts specifically on women of color, cite similar student experiences as Seymour and Hewitt as playing a paramount role in their persistence in STEM, but were different in kind because of their relation to a gender or racial/ethnic group. These studies cite student's relationships with

other students or instructors, effects on science identity and other affective traits, and choices to pursue majors and STEM-related organizations.[19,61] Given the findings of these prior studies, the interviews I employed to address the research question were constructed to explore the relevance of these factors for students at this institution. Specifically, the interviews in this study focused on (1) student experiences in the course, major, or discipline, (2) interactions with other students, instructors, and TAs, and (3) various support structures formed by family, friends, or the institution.

I employed a thematic analysis framework to analyze the interview data. As argued by Guest and colleagues, the purpose of thematic analysis is to "identify and describe both implicit and explicit ideas"[168] that connect, for this research, student experiences to the phenomenon of interest: persistence (or not) in the sciences. A thematic analysis requires more involvement from the researcher to make interpretations from the data, interview transcripts in this case. From the raw data, codes are developed to represent the overall themes of the research topic and then applied to the data for later cross-case analysis. By following this approach, I was able to define the key reasons why the marginalized students interviewed believed they were not successful in a science course or chose not to continue in a major.

Methods

Participants

The survey from Chapter 4 acted as a pre-interview schematic to extract the intended subject pool based on their responses to racial/ethnic identity and self-reported midterm grade. Because I was interested in the experiences of URM students, specifically those who identify as Hispanic and Black/African American, only these racial groups were recruited to participate in the interview. The initial method for recruiting was to interview a total of at least 30 students: 10

students from each of the racial/ethnicity groups of interest (Black/African American, Hispanic, and White) with half the participants having a passing midterm grade and the other half from the DFW pool. This design would permit comparison of all groups on pass/fail measures administered. Further, the sampling procedure was designed around demographic group and not by the previous study's cluster analysis. Recruitment was to begin Spring 2020. Unfortunately, due to COVID-19, interest in participating in research was scarce. After three months of persistent recruitment solicitations sent to 27 eligible students, only five students responded and were interviewed. Three participants identified as Hispanic/Latinx females and two participants identified as African American females[11]. Each participant was given a pseudonym that I refer to for the remainder of the dissertation. All five participants received a D, F, or W in at least one science course discussed.

Interview Protocol

All interviews occurred during the Spring 2020 semester. Due to COVID-19, I interviewed all participants via an online platform, Webex™, which were recorded (audio and video).[12] Interview participants were compensated $20 for their time.

Before beginning each interview, I used the survey responses (see Chapter 4) to aid in the development of the interview protocol. Upon entering the private video call, students were welcomed, instructed on the interview process, reviewed terms of the consent, and verified some demographic information. The main interview protocol was segmented into four sections: (1) decision to major in science, (2) performance in previous course (reported in survey), (3) self-

[11] Both gender and racial/ethnic identity labels used are how each individual described themselves.
[12] Unfortunately, the recorded session for one participant was lost due to technical errors, so the analysis of that individual was completed from detailed field notes.

worth and self-doubt, and (4) instructors and teaching assistants (TAs). Between two to six questions were within each theme, but since the interviews were semi-structured in nature, unique follow-up questions were asked when appropriate. Several times I pointed to how a student responded to a specific question or series of questions on the survey to probe for further information. The interviews lasted between 28 to 46 minutes in length. The full interview protocol is located in Appendix C.

The first section, decision to major in science, included questions about the participant's path to choosing their major, discussion about any significant social influences that helped them decide their major, and what they would like to do with their degrees once completed. These questions were intended to unearth the motivations, reasons, and people behind this important decision in their young academic path. The second section of performance in the sampled course was included to give the participant the opportunity to recall positive and negative experiences in that course, what they or the course could have done differently, an explanation and reflection of their final grade, their sense of belonging in the course, and whether their perception of belonging was contingent on their identity. This section allowed for conversations about the student experience and their perception of themselves and a course in which they received a failing grade. It also gave way to start the conversation as to how they identify themselves when they are within a science course and how they experienced a sense of belonging in that course. The third section on self-worth and self-doubt had participants talk about their self-esteem and confidence within and outside of academia. It permitted students to differentiate how their self-esteem and confidence is affected by their science courses, major, and other's opinions of them. This section was intended to contextualize how each student views their abilities and others' impact on them. Lastly, the fourth section discussed instructors and TAs. This section probed

students' perceptions of the role instructors and TAs played in their success and how, if at all, their identity impacted the student's sense of belonging.

Analytic Plan

Four of the five interviews were manually transcribed verbatim. Transcripts were then uploaded to Atlas.ti Cloud™ where I engaged in a constant comparative analysis[25,26] of codes. Codes were developed to capture possible reasons why a student failed their course or left their major or science discipline. Consistent with a grounded theory approach[25,26], codes were generated from the data, itself, and not determined *a priori*, but were shaped by the research question and prior findings of various predictors associated with persistence, such as affect[15,20,34,169], instructors and TAs[11,79,88,170], course issues[11,117,121,124], and supports either social or structural[58,75,107]. Ultimately, the resultant codelist captured a student's affective traits (identity, individual attributes, confidence, self-esteem, sense of belonging, etc.), course-specific information (experiences and aspects of their course, reason for course withdraw, environment, etc.), student relationships (family, friends, instructors, TAs, etc.), and discipline or major experiences (decision to major and comparison between disciplines). After several rounds of code comparison among the four transcripts, the code book was fixed and applied to the fifth participant's field notes. The final code book can be found in Appendix C. The codes are based in the student's own experiences and while I apply codes to their transcripts and interpret meaning, I take care to stay true to the student's stories they shared.

Participant's Stories

After coding each of the transcripts and applying the code book to the fifth interview participant, I analyzed the shared codes of all five participants for themes that appeared in each

of the interviews. Before discussing the themes in detail, I present a narrative description of each of the five participants to illustrate the unique experiences of these students in their science courses. In these narratives, I included specific transcript quotations that highlight the emergent themes as they manifested in each interview. These quotes are critical data on students' experiences and in the context of the entire transcript serve to support my interpretation of the students' stories.

Adriana

Adriana is a Hispanic/Latinx female who recently switched from a pre-nursing major to kinesiology. Adriana completed the survey while enrolled in a chemistry course. In that course, she had a midterm grade of an F and maintained that F for the final grade.

Adriana began college as a pre-nursing major mostly because of her family's influence and their experiences in the medical field. Even though Adriana had family in medicine (a form of science capital[92,104]), Adriana's personal interests did not align with those of her family. Her personal interests led her to another major, kinesiology, though still science and health focused. Adriana's switch to a kinesiology major still incorporated science and health but added more elements of what she is passionate about. Further, she maintained the altruistic nature of a pre-health major with the major switch by "wanting to incorporate [being healthy] into other people's lives too." Moreover, her family was supportive of her major switch even though it was different from what many in her family pursue.

Adriana: *Yeah I was like talking with my brother and then he- I told him like how I was like iffy about going into nursing and he just assured me that whatever I want to do is*

what I want to do and I shouldn't like have - be influenced to do something else because I have all these other examples. I should just do my own thing and be proud of what I do.

Stephanie: *Any of your other family support or influence you besides your brother?*

Adriana: *Yeah my mom. She was like ya know like yeah "kinesiology would be a good degree for you cause you do always work out and you do eat healthy so you know that's your thing" (laughs)*

Adriana had a large support system at home that were sources of encouragement to follow her aspirations and choose a major that she was passionate about regardless of what field her family traditionally practiced.

When discussing her sense of belonging in her courses, Adriana, for the most part, felt just as included as her other classmates in her course in terms of her identity (gender and race/ethnicity). However, Adriana felt her sense of belonging was affected by class size in her chemistry course.

Adriana: *I think it depends. Because in like those big lecture courses you know like 100+ kids or more, it's hard to get to everybody and that's understandable […] I don't know how I feel about that to be honest. I feel like it depends - cause if it's a smaller, more closed and well-kept environment, then it's easier to get to everyone. But since it's bigger it didn't really help.*

Adriana's sense of belonging changed when the class size was reduced in her discussion sections. Smaller class sizes allowed Adriana to get more individual attention and academic support from instructional staff, which affected how she was included with the rest of her classmates and her sense of belonging in the course.

Over the course of our conversation, Adriana described several negative experiences she had in her chemistry course that were rooted in instructor behaviors and practices. Both Adriana and her classmates questioned whether their instructor was qualified to teach. When probed further on how the instructor was less qualified, Adriana commented on the instructor's fast-paced teaching style and unclear expectations and explanations of the course material. Moreover, Adriana thought the instructor could have done more to help her succeed in the course.

Adriana: *Yeah like I would ask "hey what should I do to boost my grade or anything" and "Oh, just study with a friend or like go to the review session and stuff" And the thing was I don't think he understood that sometimes I couldn't be there [be]cause I had other things outside of school to do […] Ya know? It wasn't really helpful*

Stephanie: *So then how did that make you feel bad about yourself?*

Adriana: *[Be]cause I feel like I didn't get the best out of it. Like I didn't feel like I was able to pass because of that.*

The lack of support and specificity on how to succeed clearly affected Adriana's ability to understand course material and succeed in the course. While supplemental help was offered

through the review sessions, Adriana's responsibilities outside of school prevented her from attending. Her inability to use this supplemental help and lack of other opportunities were reasons she felt she did not pass. Adriana went on to discuss the perceived competence of her instructor in relation to content knowledge and teaching.

Adriana: *But the instructor, I mean of course he does know what he's doing [be]cause he doesn't have a PhD for no reason. (laughs) You know? They don't just give those out to anybody. (laughs) But um I don't think like- I'm sure he's taught for a good enough time, but I don't think […] he really knew how to approach us as a whole, like a class.*

Adriana recognized that her instructor held a terminal degree in the content of the course which would qualify him to teach the content, but that content knowledge did not necessarily mean effective teaching. Fortunately, Adriana had a different experience with the TA for that same course. In this case, Adriana had an effective TA that compensated for what she thought was lacking in the lead instructor.

Adriana was one of two interview participants that was in their first year of college at the time of the interview. Both of the first-year students exhibited attributes that would describe them as underprepared. For Adriana, she was underprepared in how to form student-instructor relationships and how to find extra resources available to her on campus. When asked what she could have done differently in her chemistry course based on the grade she received, Adriana cited her communication skills.

Adriana: *Communication […] Well it's my first year, ya know? I didn't necessarily know what to do to establish a relationship with the professors.*

Adriana did not have previous experiences with college instructors and understood the importance of building those relationships and communicating her needs to succeed in the course. Additionally, when Adriana knew she was struggling with the content of the course, she did not know where to look for supplemental support. While Adriana felt responsible for her own success in the course and that she had to look for supplemental help, she did not know what to do or where to look.

Adriana, as a first-year student, did not have other science courses with which to compare chemistry. However, her experience in chemistry had major effects on her science identity, confidence, and what courses she would choose to take in subsequent semesters. Adriana's responses on the science identity scale were split with her answering two items on one extreme and the other two items on the opposite extreme. I probed further to understand the contradiction.

Stephanie: *So, one of [the items] says "being involved in science is a key part of who I am" and the other one says, "I consider myself a science person". And you somewhat disagreed with both of those statements. Can you tell me a little bit about that?*

Adriana: *That was definitely because of my chem. (laughs) That was my "uhh I don't know man; I don't think this is for me"*

Her experience in chemistry was directly responsible for a lower science identity. Adriana's experience in chemistry gave her initially low confidence in science.

Adriana: *Because with the chemistry experience, I was thinking like "wow maybe science isn't my thing" but seeing like how it was, I'm doing pretty well in my [other] courses, I would say like maybe like I was wrong about that for myself. I shouldn't have to stoop so low for myself. I should always be there; you can do this. Si se puede [You can do this] (laughs)*

However, as Adriana had more exposure to other courses, she changed her attitude about herself. Along with affecting her science identity and confidence, Adriana's experience in chemistry impacted future course-taking decisions. Adriana was given the choice to retake her chemistry course after she received an F or to retake a math course that she also failed. Because of her bad experiences in chemistry, when given the option to continue in the introductory chemistry course sequence, Adriana joyfully opted to retake a math course over retaking a chemistry course.

In summary, Adriana's decision to switch her major from pre-nursing to kinesiology was largely due to her personal interests. Her switch, while strayed from family tradition, was met with overwhelming support by family members. The only factor that influenced Adriana's sense of belonging in her chemistry course was due to class size and the difficult nature of being able to help all students in a class as large as hers. Adriana's chemistry instructor, while qualified to teach the course, did not engage with the students in a way that Adriana thought would allow her to succeed. As a first-year college student, she had inexperience with communicating her needs to instructors more clearly and how to form those student-instructor relationships that are helpful

in course success. Finally, her unfortunate experience in chemistry negatively affected her science identity, confidence, and persistence in the discipline.

Aniyah

Aniyah identifies as an African American female with a major in chemistry. She previously completed the survey for her physics course. For that course, Aniyah shared a self-reported midterm grade of an F and a final grade of a W. Aniyah was retaking the same physics at the time of the interview.

Aniyah had many influences on her decision to major in chemistry and where to take her future career. Early exposure to science and family influences were largely responsible for Aniyah's decision to choose and remain a chemistry major. Aniyah had prior experiences in multiple science disciplines in high school and before. After taking biology in elementary school, then AP chemistry and physics in high school (form of science capital), Aniyah realized chemistry was the best fit for her due to the interest she took in the subject. Even though Aniyah enjoys chemistry, she intends to use her chemistry degree to go into another field, either medicine or pharmacy. Aniyah's desire to be a pharmacist or doctor stemmed from her family exposing her to those careers from a young age. Their constant encouragement for Aniyah to enter either of these fields gave her the support and exposure to explore these fields on her own. Moreover, Aniyah has a unique family history that influenced her to pursue pharmacy.

Aniyah: *...learning more about my family's history. My parents are both immigrants and [...] I've asked my mom about our like family in Africa and through generations [...] my mom told me like how our family has been herbal traders. Like they've*

been into herbalism. And so like is kinda like, a reason why I want to go into pharmacy, to like continue that.

This special influence on Aniyah is not only a form of inspiration but also motivation to continue in her chemistry major to get to a career she is passionate about. Additionally, Aniyah had similar personal interests for wanting to go into medicine after graduating, that largely had to do with her first-hand experiences of interacting with cardiologists for a medical condition of her own.

Aniyah: *Whereas for medicine […] just seeing like how much of an impact doctors have on people's lives and even like my own personal life. I have a heart disease so going to a cardiologist and being able to like see like what they do firsthand and knowing that I'm making an impact. That's another reason why I wanted to go into medicine.*

Aniyah's altruistic characteristics and her own experience with health issues shaped her interests to go into the medical field. While Aniyah was still unsure of her future career, she's passionate about her major and how it would guide her down either career path. More importantly, Aniyah knew she would be happy to pursue either medicine or pharmacy saying, "Whichever one I go into, I'll be happy".

Aniyah spoke at length on the factors that do and do not affect her sense of belonging in her physics course. Building a community, or lack of, affected Aniyah's perception of the physics discipline. The lack of discussion sections in the course and meeting in a large lecture

hall made it difficult for Aniyah to form relationships with other students. Aniyah was not alone in her feelings based on how she described student-student interactions.

Aniyah: *I don't feel like a lot of people really interact with each other in that course. Like we have a GroupMe but it's more like people asking for help on homework or stuff like that or people asking for help with lab. So, it's not like I feel like we're not really included with each other [be]cause it's not really like a sense of community in physics. It's everyone for themselves.*

Whether or not it was directly facilitated by the course itself, students in Aniyah's course interacted with one another only when it pertained to their own success in the course. Without a sense of community in this course, which would be a first encounter with the discipline in college for most of the students, physics was not setting up the opportunities to cultivate new students into their fold. Moreover, the inability to form more meaningful relationships in the course did have some effect on Aniyah's comfort level in the course.

Aniyah: *I feel like what affects [my comfort level] is more like the people I'm surrounded with. So, like if I know people in the course and I'm not taking it alone, then I feel I'm more comfortable in the course. Whereas if I don't know anybody then I feel less comfortable in the course.*

Continuing with the discussion of belonging, Aniyah did not feel a lower sense of belonging because of the racial/ethnic or gender make-up of her physics classroom.

Aniyah: *I notice a lot of students in physics are.... (looks over to the side) I don't know how to say this like (pauses) It's a diverse class. So, a lot of students are like from different parts of the world like honestly there's like there's like people there that are like me of like African decent and there are like people that are Pakistani or Indian. There's so many different diversities...there's so much diversity in the class. […]Um… I think it's predominately male as well. Uh there are a few female students in that class but there are a subst- ..predominately male class.*

Even though the majority of her classmates were male, Aniyah was not bothered by the gender disparity. Further, Aniyah recognized that there were students who were from diverse backgrounds, including those of African descent, similar to her.

Aniyah had the same professor and TA both times she took the same physics course. Aniyah had only positive things to say about her instructor, including his continued support and sense of care he gave to students and their success in his course.

Aniyah: *…just like [my professor] being there as a support, like he is like very vocal about when he is on campus and when he has office hours. He's like "Come to me. Imma be here. I'm here like just come. My door is always open." And just knowing you can just go to him for questions, that really helped me out [be]cause […] I'm not the type of person to like go ask for help but knowing that I have that available is like it was really helpful. […] like just knowing his door it open, I can just go to*

him. It really helped out [be]cause I could just go and ask for help, ask for guidance, ask for anything that I needed pertaining to the course.

While Aniyah did not frequently seek out help in the course, knowing her instructor was always there to help his students was a source of comfort for her. The TAs of the same course did help her and other students, but Aniyah felt they were "limited" to how much they could help with the content. Specifically, her physics course had no discussion section, so Aniyah only interacted with the TAs instructed lab. When she reached out to them for help with content taught in lecture, the TAs were unable to help her.

Being a chemistry major, Aniyah had experiences in many introductory chemistry courses. She also was enrolled in a physics and biology course. Because of her overlapping exposure to these disciplines, Aniyah was able to compare within and across science disciplines.

Similar to her physics instructor, Aniyah had only positive experiences with her chemistry instructors, describing both the chemistry instructors and TAs as "helpful". However, the chemistry TA she had at the time of the interview was not up to par with former chemistry TAs.

Aniyah: *My TA this semester is... for chemistry, he hasn't been as helpful. Like in the past my TA, I could email them, and they would respond within a day or two. Like my TA this semester, he's not as helpful as the others in the past.*

Stephanie: *Just for the lack of communication?*

Aniyah: *A lack of communication and also like... (pauses) Discussion is different. That's where we mostly see our TAs, so like I see him in discussion. […] He doesn't really like help us out as much as my TAs in the past. […] We'll have questions and he'll like give a vague answer and won't be as descriptive as we need. We need help. We don't know what we're doing. You're a PhD student. We're just undergrads. We don't know what we're doing. Like we need more help than that.*

Not only were there communication issues with Aniyah's chemistry TA, but he had difficulty explaining the material and attending to his student's needs. Aniyah was certain that content knowledge for her TA was not the issue (citing he was a PhD student), but there was a disconnect when delivering content instruction to the students.

Aniyah's confidence differed based on the science course in which she was enrolled. Aniyah's confidence in herself had a clear distinction between the courses she had to take for her major requirements, like biology or physics, versus her chemistry courses.

Aniyah: *My confidence is higher in my chemistry courses just cause I like it so much […] If you like something, you know you have to do good in it cause it's something that you enjoy. It's something that I pushed myself... like I have to do good in chemistry. […] Like I'm a chemistry major. I'm supposed to be good at this. And so, like it just makes my confidence... like shoots up in those courses. Whereas in other courses like bio[logy] or physics like I don't really like these courses. It's more like I have to take them. So, it's like my confidence is not as strong. […] So,*

> *like my non-chemistry courses aren't something I would want to... I wouldn't choose those for myself if it weren't a requirement.*

While Aniyah enjoys her chemistry courses and enjoys being a chemistry major, she feels she must do well in those chemistry courses *because* she is a chemistry major. This was a stressor Aniyah eluded to throughout the previous exchange and in the interview. Further, the lack of confidence and enjoyment in other science disciplines, do lead to poorer performance and achievement as seen in her first experience in physics.

In summary, Aniyah's decision to be a chemistry major and pursue a future career in either medicine or pharmacy were largely prompted by early introductions to the sciences by her family and high school opportunities. Her sense of belonging in her physics course was unhindered by gender disparities and because there were "people there that are like me." Aniyah did note that having friends in her courses does bring her comfort and knowing she would be in a course without friends did give her reasons to feel like she belonged less. Knowing her physics instructor was always open to answer their questions and help them was a big comfort to Aniyah and a boost to her confidence in the course. Lastly, Aniyah's chemistry major, while enjoyable and included overall positive experiences, was also a source of pressure to excel in those courses.

Gloria

Gloria, a Latinx female, switched to a biological sciences major after entering the university as a neuroscience major. Gloria came to this institution as a transfer student from a local community college. At the time of the survey, Gloria was enrolled in a biology course, where she had a midterm grade of a B then ended the course with a D.

One of her first encounters at this institution was with her academic advisor during orientation discussing her neuroscience major.

Gloria: *...well I did have a bad experience my first time when I went to orientation at [this institution]. This counselor she told me that I couldn't- that I wasn't going to be able to make it and I don't know. It feels- It doesn't feel good even more so when you're- Well I'm a transfer from [community college]*

Stephanie: *What was she saying that you couldn't make it?*

Gloria: *That was like three years ago, so I don't remember. I just remember her face and feeling super discouraged*

Gloria entered college as a transfer student majoring in a subject she was passionate about and immediately was met by discouragement and unsupportive advice from people within academia. Though this negative experience impacted Gloria, there were larger forces that weighed in on her major switch. The biggest reason for Gloria switching to a biological science major was her father.

Gloria: *Um..... (shrugs) it was just […] he's paying for my education so um he told me it was better and I should do biology because I would have more chances [inaudible] medical school and I didn't fight him on that*

Stephanie: *Okay. Any other reason why you wanted to go into biology?*

Gloria: *Not really. I wanted to do neuroscience*

Because her father was financially supporting her education, Gloria did not feel she could fight him to pursue the major she was more passionate about. This was further made clear when she talked about how neuroscience seemed right for her because of her interests in the brain and how the brain works. Before ending the interview, Gloria reflected on her time in college and regretted her major switch.

Stephanie: *Is there anything that you would change through your whole experience?*

Gloria: *I probably would switch my major*

Stephanie: *You would switch your major back?*

Gloria: *Yeah. I took Biology of the Brain this semester and I loved it. So, I would probably switch it back.*

Being one semester away from graduating and her father's hold over her major choice, Gloria would graduate with a biological sciences degree despite her deep passion and excitement for another discipline.

Throughout the interview Gloria had more examples of exclusion and not belonging than any positive experiences of a similar kind. When asked if she felt as included as a typical student in the course, Gloria felt just as included as everyone else. However, as the discussion carried on it became clear that large class size made it “hard to be included” and less acknowledged by instructors.

Gloria: *Oh, because the professors don't really know who you are. Sometimes they don't mean it, but asking a question, it- it was like they don't take it well when you ask certain types of questions. Not like that they go crazy. It's just that it doesn't make you feel good about yourself […] And yeah, it's harder to be noticed in larger classes or to feel part of the class almost.*

The lack of acknowledgement from instructors due to the considerable size of the class did influence Gloria’s sense of belonging in the course and, more broadly, the discipline.

Gloria: *…when you go to college, you want to be heard or seen you know? Without being there every office hours*

Gloria compared her experience in her large biology course to her experiences in community college, where she received the recognition that made her felt like she belonged.

Gloria: *Well the classrooms were smaller and the professors would- if you did good or if you did bad or like if you did- well if you did good they noticed it and they would*

congratulate you and stuff and if you did bad, they would try to talk to you and see what was wrong, what you didn't get about the content and stuff.

The smaller class sizes in community college allowed for more individualized attention for Gloria and instructors were able to acknowledge when she or other students succeeded and provide extra support when warranted.

While Gloria said her sense of belonging was not directly based on her race/ethnicity, later in the interview it was uncovered that her race/ethnicity does indirectly affect her sense of belonging in science.

Gloria: *…in science classes, it makes you feel good to participate and to say what you have to say and stuff, ask questions. But in science class, I don't think I've participated more than five times.*

Stephanie: *Why do you think you participate less in your science classes?*

Gloria: *Well there's a lot of factors. Sounds stupid but I don't like my accent first of all and I feel like I'm not going to be understood and that scares me if I ask a question and I'm not understood. (pauses) Yeah that's a big factor. Just that they don't take it the right way [be]cause you don't know how they're going to take it.*

Gloria knew that participating in her science courses was important. In fact, earlier in the interview Gloria noted she participated frequently in her German courses. However, when it

came to her science courses, she participated less due to her accent and the fear others would treat her differently because of it. Along this point, Gloria noted during our interview that it is difficult to make friends and build a community of her own. Gloria had not made many friends in science, even though she was graduating soon with a science major. Unfortunately, the lack of friends in her science classes contribute to a lower sense of belonging in the biology courses and discipline.

While recalling her experiences in her biology course (for which she received a failing grade), Gloria described mostly positive interactions with her instructors and TAs. While not including much detail as to how the TAs were helpful to Gloria, they clearly aided her and had a positive impact on her. As for the instructors of the course, Gloria experienced instability of changing professors frequently throughout the semester, which brought confusion for Gloria. However, when specking of the lead instructor, Gloria made a point to distinguish between a course that was difficult because of the content and not because of the instructors' behaviors or practices. In fact, Gloria was okay with the content being challenging as long as there were proper supports from the instructors.

Gloria: *Well the courses are interesting. It's very challenging […] well sometimes we did this things in class where we would do practice exercises and that makes you feel good. That makes you feel more prepared and it makes you see what's going to be in the exam.*

Because she was a biology major and closing in on graduating, Gloria had taken courses in all three science disciplines and was able to effectively compare her experiences. As described

before, Gloria felt a lack of belonging in her courses because of larger class sizes. However, not all large classes were exclusionary to students if they were more engaging or interactive.

Gloria: *Like in [other biology courses, those are] very big too but the professors made it interactive and made it seem like they did care about what they were teaching. They were not just reading off the slides like in chemistry class or deriving formulas like in physics. It's just like they know their content and they're fascinated by it and they want to pass [on] that passion*

However, the teaching practices of her chemistry and physics instructors relayed the perception that they were uninterested in teaching students.

Gloria: *I haven't had great experiences with a lot of them as I've said in physics and chemistry but there are other instructors that show interest like ecology and embryology and (inaudible) and that (shrugs) that impacts you in a good way because it makes you more interested about what they're teaching*

For Gloria, it was clear she was observant of her instructor's interest and it greatly affected her own interest and self-esteem in the course. Disappointing teaching practices and instructor behaviors contributed to Gloria's depiction of chemistry and physics professors.

Gloria: *Well for example, physics it was- like you could see that the professor was not interested at all. He was just there for his research and... He wasn't teaching at*

all. He would just write on a paper. [My physics] professor would just write where the formulas came from and did that the whole class period, derive the formulas. So, you have to teach yourself all the content […] And chemistry is kinda the same. I haven't been doing good in chemistry but it's just the uninterest the professor show, it takes you back. And I know people did good and they're there by always going to office hours and stuff. It's just doesn't seem like they care if that makes sense. […] there's a bunch that don't care and it's like a saying almost. Science [instructors], they're here to- they're just teaching [be]cause they need their grant and they need their research money

Multiple times in our interview Gloria commented on the fact she felt her science instructors were teaching because it was a required expectation of them to conduct their research at the university. While many of her instructors had research responsibilities, not all were characterized as uninterested to pass on their content knowledge to their students. Moreover, Gloria recognized she was not doing well in chemistry, but it was her instructor's lack of caring that negatively affected her more. Because of the perception the chemistry and physics disciplines possess, Gloria wished she had taken those courses at another institution.

Gloria: *A lot of people at [this institution], they don't take physics and chemistry there. They take it at other colleges and stuff. And I should have done that honestly.*

Stephanie: *Why do you think you should have done that?*

Gloria: *[Be]cause everyone gets great grades over at those schools […] They've taken it at both places and they say [this institution] was impossible so it would have been less stressful*

In summary, despite a strong passion and interest in neuroscience, Gloria switched from a neuroscience major to a biological sciences major due to the influence of her father. Gloria had contradicted herself when it came to inclusion in the sciences. At the start she said she felt just as included as other students but further in the interview she discussed several reasons why it is difficult to belong including her accent, class size, and lack of community. Overall, Gloria had positive interactions with her biology instructors and TAs. She admitted the content was challenging but tolerable if she was given the proper supports in the course to succeed. Finally, Gloria had more negative experiences in her chemistry courses than she did in her biology courses, largely due to her perception of instructor's lack of interest in the course content and in their students' success.

Malia

Malia is an African American female who is a pre-nursing major. Malia was enrolled in a chemistry course at the time of survey completion. She received a midterm grade of a F and a final grade of a F. At the time of the interview (the semester following her completion of the survey), Malia was retaking the same chemistry course. Due to COVID-19, her course went online mid-semester. Because of this, Malia ended up dropping the course.[13]

[13] The audio file of Malia's interview did not save properly so there is no transcript. I used my detailed field notes as her data. Codes were applied to my field notes once the coding scheme had been fixed.

In her own words, Malia said when it comes to being a nurse, there is “nothing else I want to do in life.” She cited several factors as to her decision to be a pre-nursing major: her personal interest, family experiences and support, and her desire to help others.

At a young age, Malia had many family members in and out of hospitals and nursing homes. What resonated with Malia was seeing the nurses and what they did to help her sick grandparents. She chose to be a pre-nursing major in order to help people in similar situations she experienced with her family.

In addition to Malia’s family being a source of inspiration for her major, her family also is a source of great motivation but also high expectations. Malia feels she needs to succeed for her mom and sister. Malia felt the need to meet the high expectations put in place by her sister’s educational success of earning a master’s degree. Malia also commented that she “owed” it to her mom to be successful in school.

Even though Malia was confident in her desire to become a nurse one day, interactions with her academic advisor about her course work and major left her uneasy. She met with or emailed her advisor regularly (3-4 times per month), but often left those meetings ill-informed and with little guidance. Conversations with her advisor had conflicting information on course requirements and what courses could or could not be taken at community colleges that may be easier for her to get a passing grade to succeed in her major. Nearly every meeting Malia had with her advisor included a conversation of a backup plan assuming Malia will not get into nursing school. Malia commented she wonders to her advisor: “do you think I can’t do this?”

When asked about sense of belonging in her chemistry course, Malia said she felt just as included as any other student in the class. She also said that her racial/ethnic and gender identity did not play a role in her sense of belonging.

As she described a typical student in that course (confused), Malia also commented that many of her fellow classmates gave up and failed the course. Because Malia felt that she and her fellow classmates felt the same way about the course, she did not feel alone in her feelings. Even though this was a negative experience for Malia, there was comfort in being included with her classmates in the mutual, albeit negative, experience.

Because Malia took the same course twice but with different instructional staff, she was able to compare her experiences and how they changed as a function of the instructors and TAs. The first time Malia took the course, she commented that the instructor did not care about teaching or the students' grades. They only cared about their research. Further, Malia did not like her instructor's teaching style, but did not specify which practices. In addition, though Malia's TA seemed to care about the students, the TA's teaching style did not help her understand the content despite many students sharing their concerns with the TA.

The second time Malia took the course, there were stark differences in instructor and TA attitudes, behaviors, and their effect on Malia. This instructor cared about students and explained the content in a way that was easier to understand. In contrast from her first TA, this TA broke down the material even further for easier understanding. Moreover, everyone in her discussion section participated and worked together to understand the content in the course.

At the time of the interview, Malia was completing her first year in college. Malia commented on two experiences that made her feel underprepared for college. First, Malia remarked she had a poor high school chemistry teacher that made her feel she was not prepared for college-level chemistry. Secondly, Malia recognized she was struggling in her chemistry course. She remarked that the academic help offered at the university was inadequate, but she was unaware of other supplemental support resources the university had to offer.

While Malia did not talk about taking courses or experiences in any other discipline besides chemistry, she did have both negative and positive experiences in her chemistry course.

Malia described her confidence in her chemistry course as low, and even “horrible.” Malia felt that her instructor (from taking the same chemistry course the first time) made too many assumptions on background knowledge and did not take into account that not all students were given “a good chemistry base knowledge in high school.” Fortunately, upon retaking the course Malia’s confidence got a boost because of the more positive interactions between her and the new instructor and TA. She also cited her increase in confidence attributed to having been exposed to the material before. Without providing more detail, Malia ended up dropping the course during her second semester because it moved to online instruction. It is unknown as to whether Malia plans to take the course a third time.

In summary, Malia was motivated and inspired by her family to pursue a pre-nursing major. Her family, while supportive, did act as a stressor where Malia felt she had to succeed to live up to the expectations of her sister and mother. Malia felt just as included as her classmates in her chemistry course even though there was an overall sense of confusion amongst the students in the course. Since Malia took the same chemistry course twice, she experienced two different instructional staffs. Fortunately, her experience in chemistry improved the second time due to the overall positive interactions and sense of interest the instructor showed. As a first-year student, Malia had trouble navigating college courses and where to find academic help on campus. Lastly, because Malia experienced the same course from the perspective of different instructors, she was able to articulate which practices and behaviors were most beneficial to her success.

Sara

Sara identifies as a Hispanic female. Though she started her undergraduate career as a biology major and completed several requirements for the major, Sara switched to a psychology major. Sara was enrolled in a biology course at the time of the survey and reported a midterm grade of a D then later withdrew from the course (final grade of W).

Before becoming a psychology major, Sara entered college as a biology major. The main reason Sara switched majors was because of the course requirements she needed to fulfill for biology. After taking several courses in biology and chemistry, Sara realized her lack of interest and decided to leave the biology major. Sara had many influences for her decision to major in psychology after her switch. As with every other interviewee, personal interest played a role in Sara deciding on a major. For her, it started with taking electives.

Sara: *Psychology was considered an "elective" for me but it was something that I really enjoyed and something that I was really good at so I decided to shift… So then I took more psychology classes and it was actually things that I liked to learn and was pretty good at.*

Sara was able to experience the discipline in an elective course and realized her interest and ability to interact with the content. Sara's enjoyment with learning more about her discipline, psychology, was seen throughout other exchanges she experienced with family, friends, and former teachers. Sara's family, specifically her sister, acted as a positive influence on her decision to major in psychology.

Sara: *So, in the family aspect of it, my older sister actually has a psychology degree, and she went on to do her masters and right now she is a child psychologist. So kinda like seeing her go through it all then just her like every now and then just randomly explaining certain things, it was always seemed really interesting for me.*

Having a sister who comes from the same discipline Sara is studying is a form of science capital that contributed to Sara's sense of belonging in psychology. In addition to having family influence Sara in her decision to major in psychology, she also had other social influences such as her former high school psychology teacher.

Sara: *As for like the teachers part of it, I had a really great psychology teacher in high school. And she was like really nice... She connected everything to real life type of thing so for me that was always like "oh like I didn't think about it that way" or "oh this is interesting like now I see." And she just kinda like- afterwards I kept in touch with her so we would just like - we would just do random psychology conversations so that just kept me interested in it.*

Specifically, a continued relationship with her high school teacher sustained her interest in her discipline and contributed to her expanding science capital to declare and maintain a psychology major.

Sara's time in various science courses gave her experiences of lower sense of belonging based on class size, her race/ethnicity, and her gender. However, Sara did experience a sense of

belonging when surrounded by friends. Since there was no discussion section and the lecture component of the course had a large class sizes, Sara felt just as included as everyone else because of the overall lack of interaction students had with one another and the instructor. On the contrary, Sara was one of the few subjects to comment on her sense of belonging, or lack thereof, in the sciences based on her race/ethnicity or gender. Sara recalled the gender disparities seen in her biology class that had unexpected effects on her.

Stephanie: *Did the racial or gender make up of your [biology] class, or any other class, with your classmates, instructors, TAs affect your comfort level in the course?*

Sara: *Yes and no*

Stephanie: *Can you explain both [of] those?*

Sara: *So, I can't exactly remember but I know that in my bio class there was more of one gender… I think it was more females but it's kinda like "Oh look, we know how to.. we know these things. We're smart so we can do this" But I also felt like because there was like a small number of males it was kinda like uhh we might have to try a little bit especially cause a lot of the people that participated -and I remember specifically- were all males and they would just take their turns. So, I felt like alright there's a little bit of competition here. But it was also something nice because like look at us, like we're trying to get a higher education, we're smart. Like we're taking these classes.*

Even though Sara was in the majority gender in this course, she still felt competition with her male peers because they were more outspoken during class. However, Sara was motivated by her seeming disadvantage (i.e. a John Henry effect)[171] by thinking she still belonged in the class. Sara shared similar feelings of exclusion in her chemistry course but in terms of race/ethnicity.

Sara: *I would say it was a lot with chem too as well. But for those I think that a lot of it also had to do with like the race/ethnicity make up of it. Especially because I didn't see a lot of people like myself that were Hispanic around. It was kinda like well this doesn't seem like, this doesn't like- this isn't a booster. This seems like a lot of people aren't taking these courses because of like maybe how difficult it may be and it's kinda like well maybe we shouldn't even be here in the first place.*

Unlike her reaction to her disadvantage based on gender, Sara did not echo the sentiments of feeling motivated by being amongst the only Hispanic students in the course. Instead, noticing a lack of diversity in her chemistry course made Sara question not only her sense of belonging but others who also identified as Hispanic. To combat any exclusion based on other means, Sara surrounded herself with friends of similar interests to hers, especially in psychology. Many of her friends were also psychology majors whether at the same or different institutions. Having a group of friends with whom Sara can interact in the same discipline, contributes to her feeling included and an overall sense of belonging in the discipline.

Sara had both positive and negative experiences with her instructors and TAs. When recalling how instructors or TAs played a role in her outcome of the course, Sara commented on

her biology instructor's lack of interest in teaching the content and student engagement and understanding.

Sara: *I would say that the professor himself, he was nice and all that, but when it came down to the actual lecture it was just him reading off the slides. And then there were instances where there was just a single picture and just go on and on and on and try to explain it while a lot of us were like "Wait, hold up. Let me write this down." And so, while we take the time to write it out like obviously, we're missing out on some information. So, it kinda seemed like he didn't really care.*

Sara's description of her instructor's teaching styles resulted in her thinking the instructor did not care about teaching the course due to the lack of perceived effort in presentation material and how quickly he would move on even if students were still processing information. Speaking of the same biology instructor, Sara remarked on the assumptions and expectations the instructor held of the students. Specifically, that his students should have mastered some content and his teaching was meant as more of a review for them. The expectations the instructor held could be detrimental to student understanding of the content and Sara knew this was not beneficial for her. While the interactions Sara had with her biology instructor were mostly negative, for that same course, Sara had a different, more positive experience with her TA:

Sara: *And as for the TAs, even though I never got the chance to actually meet with them or get some help, I know that when it came down to the test, there would be a study guide and they would take the time to actually answer them and show us*

how it's supposed to be answered. So, they had tried to show us "this is how we expect you to do it". And even when it came to […] in-class lectures, they would be on Blackboard […] they would just be online ready to answer any question we might have during the actual lecture

Not only did the TAs in the same course provide a different experience for Sara but they also supplemented in-class lectures with extra support and feedback to aid the lead instructor.

As an upperclassman in college, Sara shared experiences in multiple courses within multiple disciplines. When asked what she would change about one of the biology courses she had taken, Sara recalled a positive experience in one of her chemistry courses that she wished she saw in her biology class:

Sara: *I feel like in the chem courses, or at least with the professor that I had for them, she was really like "alright well what do you guys want to know or what do you guys want to see" and so if we were tell her we want to see more […]examples then she would go ahead and give us more examples. If we needed deeper explanation, she would go- she would take the time to actually do it*

Though not echoed in her biology course, Sara was able to recognize the behaviors and practices from a chemistry instructor that helped her succeed. Further, Sara had been enrolled in multiple chemistry courses. Thus, she was able to provide perspective between two introductory chemistry courses at this institution. Sara begins to describe her extremely positive experience in one chemistry course:

Sara: *So I'll go back to my [chemistry] class, […] we had a discussion and both the TA that I had and the professor, they were like really nice. They were really helpful actually. And I actually had the time to meet with both of them. And I know when I addressed my professor like "oh I'm having a hard time with this", she actually gave me like okay "you should sit down, read through the book, do this, this, and this". She gave me pointers as to how to improve so that was really helpful. And then with the TA, he would always take the time and show us sample questions. He would try to solve them then he would tell us "alright, now it's your turn" He would give us the time to actually solve the problems and then if we were off slightly he would tell us but not tell us exactly what it is. He'd make us figure it out and then he would if eventually we couldn't figure it out, he would let us know but he would explain it to us. And he would- I don't feel like he ever made any of us feel like we were dumb in a sense […] And like [the] TA from [this chemistry course] actually helped and actually helped me understand a lot of these things and how to put them into practice.*

While the TA Sara described for one chemistry course helped her with problem solving and content understanding, she had a vastly different experience with her a TA from a different chemistry course:

Sara: *…he would- if anybody didn't know the answers, he would just get mad and just like go off about how we should be knowing all of this. I didn't like him cause his*

way of teaching and explaining wasn't the best and it just confused a lot of us. But that compared to my TA for [the other chemistry course], it was night [and day], a huge difference.

In a follow-up question about a specific survey response to the ASCIv2 items, I asked Sara, when rating "science" in general, how she described it as equally chaotic and organized, equally pleasant and unpleasant, but overwhelmingly frustrating. Her explanation included an overall characterization that is detrimental to both chemistry and biology.

Sara: *Overall with chem and bio I feel like I rated it frustrating because there were so many concepts to it and some of the professors were just like "Here, take this information and do whatever you want to do with it" and others were like "Here, this is what you do, this is what this is" […] But I feel like a lot of them were just like throwing us into the fire and making us try to survive on our own in the course. I think that's how I saw it as frustrating [be]cause we were basically teaching ourselves while the professor was just kinda like up there just talking.*

Sara's frustration in these disciplines stemmed from unclear expectations and inadequate supports from the instructors. Sara felt she was tasked with teaching herself material and that it was completely on her to succeed in the course.

In summary, Sara switched from a biology major to a psychology major because she found herself more interested in the psychology content than in biology. When speaking of her sense of belonging based on gender in the sciences, Sara seemed to express a "John Henry

effect". However, Sara's self-esteem and confidence were negatively affected when she noticed she was one of only a handful of Hispanic students in her chemistry course. Her biology course left her uninspired due to her instructor's lack of interest in the content and students' success. Lastly, Sara made an overall characterization of the majority of her chemistry and biology instructors as "throwing us into the fire" and forcing them to teach themselves the material in order to succeed.

Emergent Themes

Five themes emerged from axial coding: (1) social capital and influences, (2) sense of belonging, (3) instructor/TA interactions and effects on student success, (4) college readiness, and (5) chemistry compared to biology and physics. As mentioned above, the themes were chosen because they were common throughout all interviews and they contributed to answering the research question for the study. Specifically, social capital and personal influences aided in a student's success or failures within a course or major by being an important support or visible discouragement. Sense of belonging deeply influenced how students saw themselves and others in their science disciplines and how they envisioned themselves as being a "science person". Positive and negative instructor and TA interactions greatly affected student outcomes in a course and collectively contributed to the overall perception of the discipline. The lack of college readiness influenced the degree to which students were prepared to navigate college-related relationships and resources that were essential to their retention. The last emergent theme (chemistry compared to biology and physics) was not a focal point of the student experiences but is singled out because I am interested in the cross-disciplinary differences of student experiences. In this section, each of the themes are discussed and how they differed, or were similar, across the students.

Social capital and influences

The participants shared several social capital and influential factors that prompted them, or most of them, in some way to declare or switch majors. These social capital or influencers included family as supports or stressors, personal interests, and academic advising.

Each of the interviewees cited *family* as having some influence over their decision to major or even switch their major. This is not surprising as research has identified family as being among the top influencers for pursuing a STEM major, usually due to a family's ability for early introduction to a field or discipline.[11] In a study that examined persistence of Latina and African American women in STEM, Talley and Martinez Ortiz found that family expectations were high motivators to pursue and persist in their STEM majors more so than their White peers.[35] As with the women of color in my study, family played an important role in their decision to major and persist in their majors, whether that influence was positive or negative.

As seen through the excerpts above, families were a positive support to the majority of participants. However, there were some instances of families being sources of stress and others of great power in the student's decision. Adriana and Sara both had support systems in their family that encouraged them to pursue their passions. Specifically, Adriana and Sara described how their parents and siblings engaged in meaningful conversations with them about the major to which they switched. Adriana relied on her brother for encouragement to not follow a common path within their family of pursuing nursing. This reassurance seemed to be an important factor in Adriana making the switch to kinesiology, a major that she was more passionate about. Moreover, Adriana's mother remarked that kinesiology was a perfect major for her, given Adriana's interests. As for Sara, her older sister was a practicing child psychologist and

frequently partook in conversations with Sara about psychology. These conversations certainly kept Sara interested in her major and gave her informal opportunities to learn more about the discipline. This is consistent with findings from Torres and Solberg, who found family support directly affected level of academic self-efficacy in Latino students.[172] This means that positive support structures provided by family members led to increased confidence in one's academic abilities and support to weather difficulties often presented in college.

While Sara and Adriana experienced positive family support, Gloria experienced quite the opposite. Gloria was an interesting case in that her decision to switch her major from neuroscience to biology was largely due to her father's influence over her because of financial support. Repeatedly in her interview, Gloria said that she wanted to remain a neuroscience and even ended the interview saying if she could change anything, it would be to switch back to a neuroscience major. Because of finances and her dependence, Gloria's father was able to dictate her educational choices despite her deep personal interest in another field. This aspect of Gloria's decision surely was the source of later discussion on lack of belonging she felt in her less preferred major of biology. To a lesser degree than Gloria, Malia made remarks that while her family supported her, they were also part of the pressure to do well in her major. Specifically, it was important to Malia that she succeed and to live up to the expectations her mother and sister put in place in terms of education. Malia's sister had achieved a post-graduate degree and Malia wanted to be able to meet that level of education. Further, Malia felt she owed her persistence in her pre-nursing major and overall education to her mother. While this is a type of motivation to Malia, it certainly is a source of stress and pressure to do well and succeed in her major. While Aniyah remarked on her family as being supports several times in her interview, they were sources of encouragement for future career paths and not her chemistry major specifically.

Personal interests and previous exposure to science greatly influenced her decision to major in chemistry, which are discussed further below.

Another factor every interviewee cited that affected their decision to major or switch majors was their *personal interests* in the subject matter. Personal interests in their major stemmed from course work, links to their everyday life, and experience in the field.

Several of the participants took courses in their major that made them want to enter that field of study. Sara was a biology major who switched to a psychology major. After taking several required courses for a biology major, Sara realized that discipline was not one she wanted to continue in, largely due to a lack of interest in the course material and the other required courses she needed to take for the major. Similarly, Sara rediscovered her passion for psychology by taking an elective course. Sara had previous exposure to psychology in high school and taking psychology in college resolidified her interests and thus she switched majors. Aniyah had a parallel experience to that of Sara. Aniyah had previously taken chemistry in high school, where she first discovered her interest. Aniyah also was exposed to other science disciplines early on. This early exposure led her to understand which science she wanted to pursue (chemistry). Malia also had early exposure to nursing through her grandparent's health issues. Frequent exposure to nursing duties gave Malia a sense of the profession that remained with her until deciding to enter a pre-nursing major. Lastly, Adriana switched to kinesiology because it was more aligned with her personal interests of exercising, an important aspect of her daily routine. It should be noted that the four women who were exposed to their major early on, persisted (to the time of the interview, anyways). Early exposure to science, whether that be at the high school level or in an informal setting, has been linked to students deciding to major and persisting in the sciences.[35,169]

While Sara was a switcher to non-STEM, she switched to a major that she was exposed to previously and persisted longer in her psychology major.

Lastly for personal interests, three of the participants pursued their major to achieve a career goal that was altruistic in nature. Malia, Aniyah, and Adriana all entered their respective majors in the hopes of achieving their career ambitions (all health-related) because they wanted to help others. Altruism is among the top reasons why women, and specifically women of color, enter and persist in STEM;[11,19,61] so, it is not surprising those reasons were cited in this study as well. Gloria and Sara also noted career goals that would help people but did not include that aspect as reasoning for major.

Crockett described academic advising as the "cornerstone of student retention" because of the relationship that is formed between the student and advisor and what that relationship can mean for student success.[173] Academic advisors are usually the one consistent academic person students interact with throughout their undergraduate career. Academic advisors assist in planning, but they also should be engaging in conversations about the students' career goals and how best to reach them. Two of the participants brought up experiences with their *academic advisor* that played a role in their decision or pursuit of a major. Malia and Gloria shared stories of discouragement and lack of support from their advisors. Gloria's first experience at this institution as a student was during an orientation meeting with her advisor. She recalled her advisor telling her that she would not persist as a neuroscience major. Gloria left disheartened by this conversation. It is unknown if Gloria continued to meet with that advisor after her first encounter. Malia, who meets with her advisor regularly, commented that nearly every meeting ends with her advisor pushing a contingency plan for another major with the assumption she will

not be accepted to nursing school. In these instances, academic advisors contributed to growing self-doubt and were, in a sense, a deterrent to persistence in the major.

Extant research shows that effective academic advising relies on both the student and advisor to commit, frequent communication, and quality interactions.[173–176] By meeting several times each semester, Malia clearly values academic advising. Unfortunately, she found the sessions unhelpful due to the advisor's vague or incorrect advice and continued suggestions to have a backup plan. As for Gloria, her first encounter with an academic advisor at this institution was negative and made her doubt her ability to succeed. Improvements to academic advising have been outlined extensively in the literature but can be summarized into the following: (1) training to be more effective and high-quality advisors and (2) evaluate advising methods over time to ensure value and success.[173,174,177] One specific adjustment, made by Powell and colleagues, was to have academic advisors incorporate micro-affirmations in their advising sessions. Practicing this method would ensure academic advisors are actively listening and recognizing and validating student experiences.[178,179]

Sense of belonging

Feeling as though one belongs in a discipline has been linked to persistence in STEM many times in the literature.[16,17,20,71,80] Sense of belonging can stem from acknowledgement by peers or discipline "experts", being surrounded by friends or colleagues in the discipline, and inclusion within the overall discipline community. Inclusion and sense of belonging lead to persistence in the discipline because of the increased confidence, self-efficacy, and acknowledgement the student gets to think of themselves as part of the community. The majority

of the participants discussed several aspects of the discipline that led to a sense of belonging or made them feel like they did not belong.

The most cited reason for lower sense of belonging in their CBP courses was due to the *large class sizes*. Gloria, Sara, Adriana, and Aniyah all commented organically on how the environment of large class sizes negatively affected and inhibited sense of belonging of all students. Gloria mentioned it was difficult to be acknowledged by the instructor and it was impossible for individualized attention. Sara and Aniyah had similar feelings in that larger class sizes made it difficult to interact with the instructor and other students. Adriana noticed that her smaller discussion sections allowed for more conversation, academic support, and instructor attention. While little research has been done to study the effect of class size and sense of belonging for students, several studies have described the link between class size and sense of belonging. While interviewing undergraduate students about sense of belonging, Marshall and colleagues found that several of their participants cited small class sizes as the reason for more participation in class as opposed to the larger lecture halls.[180] Smaller class sizes for introductory science courses may not be practical at large urban universities, such as this institution, but there is evidence of large class sizes achieving a sense of belonging. Two of the participants in this study described how two of their larger classes were inclusive. Gloria's biology instructors made the class interactive so that all students were participating every session. Sara's biology course incorporated virtual TA assistance during the live lectures to support the lead instructor. Similarly, students who were part of learning communities were able to make connections with other students in larger lecture courses because they already built those relationships in the learning community.[76]

Three of the participants noticed their sense of belonging was affected by their *racial/ethnic identity* in some way. Aniyah's physics class was diverse and included people "like her" of similar African descent. Unfortunately, Sara and Gloria did not have the same experience. Gloria, originally from South America, had an accent that affected how often she would speak in her science courses. Gloria was afraid of how those in the class (classmates and instructional staff) would treat her if they were unable to understand her because of her accent. This fear of being misunderstood prevented Gloria from feeling as though she belonged in the course and feeling as if she belonged. Because Sara was among the only Hispanic-identifying students in her chemistry course, she questioned whether she belonged because of the difficulty of the course and lack of representation of her peers. Previous literature on the association between sense of belonging and racial/ethnic identity found that, overall, women of color were least likely to have a sense of belonging in their STEM courses compared to their peers and hostile racial climates and microaggressions negatively affect students of color and their sense of belonging.[20,61,77,78] Neither Sara nor Gloria described overt hostile environments based on racial/ethnic divides. What is clear is that the lack of representation of people like Sara and Gloria affected their participation and perception of their own abilities in science.

The last aspect of sense of belonging that was discussed by the participants was having friends (or not) and *building a community* within the course or discipline. Each of the interviewees manifested this aspect differently but were all connected their sense of belonging in the discipline. As previously discussed, Sara had several influences for her decision to switch to a psychology major. Another important aspect was that all her friends were also psychology majors, either at this institution or another. The fact that Sara had a personal interest in psychology and is surrounded by people also interested in the field (sister, former high school

teacher, all her friends), she has a true sense of what the discipline is and how she "fits in." Moreover, when it came to Sara's CBP courses, she made sure to surround herself with friends in those courses so that she had a friendly face and study partner when the courses became difficult and demanding.

The exact opposite of Sara was Gloria. Gloria remarked several times in her interview that she had no friends in science and had a hard time interacting with students in any of her science courses. It is of no surprise that Gloria had a low sense of belonging in her major and all her courses and continually sought acknowledgement from her instructors in those courses. Malia was unique in how she found the sense of community in her chemistry course. She and the other students built relationships and a community around their shared misery and confusion in the course. Lastly, Aniyah found that it was difficult to make friends in her physics course (because of large class size). Because of this, when Aniyah did interact with other students, it seemed that everyone was "out for themselves" with no real community in the discipline. Making friends with whom to discuss course material and discipline matters with outside of class directly affected increased feelings of support and comfort.[76] Rainey and colleagues also found that students with friends in their major had a more positive sense of belonging.[20] Moreover, acknowledgement, or recognition, in the discipline has been found to directly affect science identity in women of color.[61] As an overall sense of belonging is positively related to persistence, making or having friends in the discipline and building a community in the discipline indirectly impacts persistence.

Instructor/TA interactions and effects on student success

Three main threads were common in the emergent theme of instructor and TA interactions which affected student success: (1) more positive experiences with TAs than instructors, (2) instructor uninterest and lack of care, and (3) lack of proper supports. These aspects seemed to have considerable impacts on student engagement and their own interest in the course and discipline.

Every interviewee had more overall *positive experiences with the TAs* of their courses than the instructors. Gloria, Sara, Adriana, and Malia all had TAs that were helpful and gave extra supports in courses where the instructor lagged. Aniyah had mixed experiences with her TAs in several courses. While most of her TAs were valuable, others lacked proper training to effectively teach or were limited in their content knowledge to help with all facets of the course. TAs interact the most with students, especially when the course has a larger class size. Continued support by TAs offer students greater chances of success and content understanding. Unfortunately, many of the students in this study were grateful to have exceptional TAs because of their overwhelming unfavorable experiences with their lead instructors.

Most of the students talked about the *uninterest and lack of care* the instructors showed for the content and their students' success. Both Gloria and Malia said their instructors did not care about the content or the students, and only cared about pursing their own research at the university. Sara shared similar feelings in that her instructor showed an overall lack of interest, which was made obvious through the lack of effort he put in to teach the content of the course. Unfortunately, the courses in which these students noticed the lack of interest and care in the instructors were the courses in which they did not pass or withdrew. While it is true that many instructors of introductory science courses also have research and other responsibilities to tend

to, not all instructors showed the same disregard to foster the next generation into the discipline. Gloria recalled several biology instructors that brought their passion to the lecture hall which contributed to the overall positive nature and engagement of that course. Instructor enthusiasm has been found to contribute to a student's higher motivation and vitality[181], more on-task behavior[182], and their intent to persist in college[183]. Appointing instructors that are enthusiastic and passionate about their discipline not only engage the students more but are likely retaining or even introducing more students to that discipline.

Lastly, several students were adamant that while the content was challenging, they would not have been deterred from engaging with the content if there were *proper supports* put in place by the instructor to aid in their understanding. Sara's instructor expected students to come to class with a good prior understanding of most material, which was unrealistic to Sara and her classmates. Adriana's instructor gave vague and unsupportive advice for how to improve her grade, including reading the book and attending out-of-hours review sessions when she had non-school commitments. Similarly, Gloria did not think her instructors prepared her adequately for exams and could have given more guidance on what they expected from students. Setting clear and distinct guidelines and expectation for students and how to succeed in the course is crucial for them actually succeeding. To be clear, none of these students said their courses were too difficult where they could not succeed or blamed the content for their low grade. They liked that courses were challenging and made them think critically. What deterred their success was a lack of support they thought their instructors should have provided. Detailed syllabi with updated campus resources and instructor expectations would have given these students a clear idea of what was required of them and how to better prepare themselves to succeed.

College readiness

At the time of the interview, two participants, Adriana and Malia, were just completing their first year in college. Through the course of the interview, they both alluded to being underprepared in different aspects of college-life that played some role in their failing grade.

Conley defines a student as college-ready if they have mastered the following: (1) cognitive strategies, (2) transition knowledge and skills, (3) learning skills and techniques, and (4) content knowledge.[184] The issues surrounding Adriana and Malia being underprepared for college actually all fall within these four elements.

It should be noted that both Adriana and Malia were enrolled in Preparatory Chemistry – a course in which students are enrolled when they do not pass the chemistry placement exam upon entering the university. In other words, Preparatory Chemistry is a "remedial" chemistry course. It was touched on in Chapter 3 some issues associated with this placement exam. However, Adriana's and Malia's enrollment in the course was the "system" supporting their academic needs by placing them in "remedial" chemistry because they were missing important content knowledge to succeed in the introductory course sequence. Further, this aligns with Malia citing a lack of preparation by her high school chemistry teacher that made her ill-equipped to enter college-level chemistry.

Unfortunately, both Adriana and Malia struggled in this course and were hard pressed to find supplemental support. When both Adriana and Malia searched for academic help on campus, neither of them knew where to turn since the support specific to the class was inadequate for their needs. This institution does offer supplemental tutoring to students, but it clearly needed to be promoted more within the course. Along this line, Adriana did not know

how to effectively communicate her needs to the instructor or how to build student-instructor relationships to make the ask of where to go find additional supports.

While both Adriana and Malia could have taken more responsibility to find resources offered on campus to support themselves, their high schools and this institution could have done more to better prepare them. The gap between high school preparation and college expectations is not a new problem and has been studied from many different angles.[184–190] Overall, Conley makes four recommendations to high schools, specifically, to better prepare their students for college: (1) create better alignment of high school curriculum and instruction with that of college, (2) develop high-quality course syllabi to mirror the expectations of college courses, (3) develop senior seminars to prepare students for the rigor expected of them in college, and (4) add important missing content often utilized in college into high school curriculum.[187] While implementing and meeting these recommendations would certainly help some students be more ready for college, the university should also be responsible for ensuring first-year students are properly situated with the institution and where to find critical resources. This institution does have an orientation program that provides this information, but as we learned from another student, Gloria, the supports given there are not always helpful or encouraging. Instructors can take initiative to gather institutional resources and place them in the course syllabi or regularly promote them in class to remind students there are existing supports available to them.

Chemistry compared to biology and physics

Each of the participants had been enrolled in a chemistry course at some point before the interview. Several of the participants had also completed courses in biology and/or physics, allowing for effective comparisons among the CBP disciplines. Further, several of the students

had taken multiple chemistry courses and were able to compare within the discipline but across courses. Lastly, two of my subjects had only taken chemistry and their outcome had considerable consequences on themselves and their future.

Two students had *positive* encounters in the chemistry discipline that they did not see in other disciplines or wish they saw in other science disciplines. The two students who shared these experiences, Sara and Aniyah, had both taken multiple chemistry courses on which they were able to reflect. Sara recalled that one of her chemistry instructors engaged the students and listened to their needs, on which she altered her instruction. Sara wished those practices were duplicated in her biology courses. This is a good example of where the disciplines can learn from one another. More interdisciplinary communication on teaching practices can improve the sciences more broadly for more students. Aniyah, the only chemistry major in the group, though she had mixed feelings on some of her chemistry TAs, had glowing reviews of her chemistry instructors. While this reflects well upon the chemistry discipline, it should be of concern that the only student to give only positive feedback for chemistry was indeed a chemistry major. Further discussion on how chemistry can be more accessible and inclusive to non-majors is warranted to better the discipline.

Both Sara and Gloria remarked on how chemistry (and physics) had more *negative* impacts than biology. Again, because Sara was an upperclassman and had taken many CBP courses, she was able to contrast many experiences against one another. One overall observation she made was that chemistry and physics instructors were more likely to “throw students into the fire” and make them fend for themselves with little help. This was a stark contrast to her overall experience in biology. Similarly, for Gloria, she felt that biology courses were more interactive and kept her engaged with the material. Her chemistry and physics instructors were more likely

to lack interest in what they were teaching. Moreover, Gloria had the idea from other students that chemistry and physics courses should be taken elsewhere because these courses are "impossible" to succeed in at this institution. The negative connotations associated with the physical sciences is not unfamiliar. However, these general assumptions made by students is deterring them from pursuing these disciplines in favor of more accessible, engaging disciplines like biology.

As previously mentioned, Sara completed several chemistry courses and was therefore able to give an *intradisciplinary* comparison of two introductory chemistry courses. One of Sara's instructors provided her specific feedback on how she could improve her grade and where to get this support. The TA for that course took the time to show detailed examples of sample problems and helped Sara better understand the material. Most importantly, this TA engaged and interacted with Sara and her classmates in a way that never made "any of us feel like we were dumb." This, however, was a marked contrast to her experience in another chemistry course. The TA for this course frequently became visibly angry with students when they did not or could not answer his questions. Further, he poorly explained the course content that made for misunderstandings and confusion. Aniyah was also able to compare chemistry TAs from two different courses. Unfortunately, she also notes the inconsistency in TA teaching ability and willingness to engage with students about course content. An important take-away from Sara's and Aniyah's experiences is how different the quality of instruction is within the same discipline. This should bring notice to the discipline on the necessity for "quality control" and consistency that students should be able to expect as they move through the introductory course sequence. High quality teaching by enthusiastic instructors will reflect highly on the chemistry discipline and possibly lead to higher retention of students.

Lastly, two of the students were first-year students who only had experience in *an introductory chemistry* course offered in the sequence. Malia and Adriana were both enrolled in the same chemistry course at the time they completed the survey and subsequently discussed their experiences in the interview. Adriana could only describe aspects of the chemistry course that made her feel bad about herself. Specifically, Adriana's negative experiences in chemistry lowered her science identity, lowered her confidence in sciences, and lead her to avoid chemistry altogether when given the choice between math and chemistry. Malia had similar feelings. Her "horrible" confidence in chemistry stemmed from the first time she took the course. Further, though she had a much better experience the second time taking the course, Malia dropped the course once it moved completely online. These are both instances in which negative experiences in chemistry directly deterred two students from persisting in the discipline. Being first-year students, there was an opportunity to show how accessible and inclusive the discipline can be but poor instructor behaviors and practices, mostly, steered Adriana and Malia in the opposite direction. Reimaging the introductory courses to show the accessibility and practicality of the discipline may engage more students and lead to further persistence.

Though not a primary focus of this study's analysis, I did identify the cluster membership of four of the five women interview subjects. Malia did not have a cluster membership because she was not included in the cluster analysis of Study 2. She did not answer all items on the survey (one item missing), which was a requirement of inclusion into the cluster analysis. As for the other interview subjects, Aniyah, Adriana, and Sara all belong to the same cluster: *Non-Science Enthusiast, High Contingency*. Based on their interviews in relation to the courses in which they were enrolled when answering the survey, a *Non-Science Enthusiast* membership fits. Each of these women were surely enthusiastic about their majors but not about

all science courses, particularly those in which they received a failing midterm grade. Their *High Contingency* membership is supported by their academic experiences, their relationships with others, and how those affect their self-esteem and confidence. Gloria belongs to the *Science Enthusiast, Low Contingency* cluster. Gloria's experiences and continued commitment to remaining within a science major and science coursework despite some negative experiences points to her membership of a *Science Enthusiast* cluster. However, based on Gloria's recounting of experiences on how others (instructors, her father, classmates) negatively affected her self-esteem and confidence, I would argue that she would be in a *High Contingency* cluster. The cluster membership analysis of Study 2 and how it adheres to experiences in science requires further investigation to be used more widely.

Chapter Summary

Taken together, personal interests, social influences, sense of belonging, instructor and TA interactions, and college readiness all played roles in the participant's success or withdraw from a chemistry, biology, or physics course, and in some cases the discipline. There is no one answer as to why these students did not persist. In fact, for each of them, it was a culmination of many external and internal factors that resulted in their retention or attrition in their science discipline. This result is quite similar to the conclusion at which Seymour and Hewitt arrived, where they described the final decision of leaving a major being triggered by a "last straw incident."[11] Every student I interviewed recounted many negative incidents, experiences, and feelings that concluded with a failing grade or removing themselves from the discipline or major. As such, interventions to increase persistence of underrepresented minority students should consider the myriad of causes and their consequences on student's decision to continue and not be overly reductive to say that one interaction or one attribute is the ultimate cause.

Study 3 had limitations, particularly in the recruitment of participants and collection of data. COVID-19 certainly interrupted recruitment methods. As noted in the Methods section, recruitment started just as COVID-19 started gaining ground and upon the first of the city- and state-wide lockdown. At that time, courses were moving online, and students had to navigate a new reality. I emailed my potential subject pool every week for most of the spring semester. Having to recruit amidst a global pandemic impacted interest in participating in research interviews and thus limited the subject pool. If I were able to gather the subject pool from the initial research plan, I would have been able to compare students of similar racial/ethnic and gender identities within the science but differed in their outcomes. This would have certainly given a more robust analysis to my study and possibly a more detailed answer to my research question. That said, I appreciate Aniyah, Adriana, Gloria, Malia, and Sara and their openness, vulnerability, and willingness to share their experiences.

The final chapter reviews the overall aims of this dissertation and how each of the research findings culminate together to answer the research questions. I consider the limitations of this research and, most importantly, discuss future directions of how to make these science disciplines more equitable for underrepresented minority students.

CHAPTER VI: GENERAL DISCUSSION

In this dissertation, I investigated the inequities underrepresented minority students encounter while attending a minority-serving institution. Specifically, the overall goal of this dissertation was to reach a comprehensive comparison of three STEM sciences (chemistry, biology, and physics) and their individual roles and contributions to the exclusion or inclusion of marginalized students. To achieve this goal, I took a mixed-methods approach to analyze the institutional history of representation and retention of URM students then put the focus on the students themselves and how their experiences within each of the disciplines affected their persistence. My dissertation undertook answering eight research questions to collectively characterize the representation, retention, attrition, and persistence of marginalized students in the sciences over three research studies.

Study 1, which included registrar data, answered six research questions throughout the three-tier institution analysis. Three research questions were posed as to the state of representation of those who achieve a chemistry, biology, or physics degree:

D1. How are underrepresented minority students represented among chemistry degrees compared to biology and physics?

D2. What is the likelihood that underrepresented minority students attain a degree in chemistry compared to biology and physics?

D3. Have the levels of representation of underrepresented minority students changed over time in chemistry compared to biology and physics?

The first question (*D1*) was to simply characterize the three disciplines. URM students were represented relatively equally between chemistry and biology but not as equitably as they were across campus. Moreover, there was little URM representation in physics, which was mostly White male degree recipients. Physics had few degree recipients in general, so statistical comparisons were not possible across all three disciplines for research question *D2*. This second research question was answered through a binary logistic regression which showed that female students were more likely to attain a degree in biology when compared to chemistry. Likelihood did not differ based on race/ethnicity. Lastly for degree holders (*D3*), representation of all demographic groups in all three science disciplines has increased to some extent over the thirteen years. However, White students, both female and male, their representation was quite steady over time, whereas marginalized student representation wavered with sharp peaks and dips.

Only one research question was posed to study student who switch STEM majors: (*M1) Who switches in or out of the STEM degrees?* I answered this research question by creating Sankey diagrams for each of the demographic groups to explore the various switching patterns of students. I found that Black/African American female and Hispanic female students switched out of CBP majors more than any other students and largely switched into Non-STEM majors. Black/African American male students switched more out of chemistry and physics and Hispanic male students switched more out of chemistry.

The last three research questions for Study 1 investigated representation and persistence in twelve introductory science courses:

C1. How are underrepresented minority students represented among chemistry courses compared to physics and biology?

C2. When do underrepresented minority students drop out of chemistry?

To answer the first course-specific research question (*C1*), I looked to DFW rates of the demographic groups, because while the representation of URM students enrolled in the course is important, what is of greater concern is who is receiving the passing or failing grades relative to their representation in the course. Through a series of regression models, I found that URM students were more likely to receive a failing grade across all courses relative to their White peers. Finally, research question *C2* was specific to chemistry courses. To answer this question, I investigated two tracks on which students are placed to complete the introductory chemistry sequences. Not only were URM students overrepresented in the track which included a remedial course that lengthened their time in the sequence, URM students were also less likely to be retained throughout the course sequences relative to their White peers.

Study 2 included one research question: (*S2*) *How do socio-affective characteristics affect persistence in chemistry, biology, and physics courses and disciplines?* To answer this question, I crafted a survey which measured five affective constructs to better understand how affective traits are linked to course outcomes. I performed a cluster analysis to group students on shared affective traits. This analysis yielded six clusters I was then able to compare against several individual differences and demographic information. Several clusters were associated with course outcome, income level, social influences, gender, and race/ethnicity. Collectively, science identity and intrinsic motivation for science are important factors in achievement in science courses.

The last question of this dissertation was answered in Study 3: (*S3*) *What personal experiences lead underrepresented minority students to fail, withdraw, or leave a chemistry,*

biology, or physics course or major? I interviewed five women of color who either failed or withdrew from at least one introductory science course. Several emergent themes arose from the thematic analysis of interview transcripts, including sense of belonging, instructor and TA interactions, and familial or social supports, that were all factors for not persisting. Most importantly, there was no one single reason for any of the students as to why they failed or did not persist in the sciences. A culmination of adverse experiences led to their failing grade or switching majors.

The aims of Study 1 were two-fold. The first aim was to achieve a comprehensive comparison of chemistry, biology, and physics and their respective representation and retention of URM students over thirteen years of institutional data. The second aim was to investigate three time points at which equitable representation of URM students is essential to diversifying the disciplines. To achieve these goals, I chose a three-tier approach to analyzing institutional registrar data at (1) the degree level, (2) the major level, and (3) the course level.

The degree-level analysis revealed similarities between the chemistry and biology disciplines in their racial/ethnic diversity of degrees awarded, but with female students being more likely to receive a degree in biology rather than chemistry. All science disciplines saw increases in representation of all demographic groups over the thirteen years. Although, representation of marginalized students in the sciences was not as steady over time as it was for their White peers. Physics degree holders, while few, were mostly White males. Furthermore, over the same 13 years, physics did not award any bachelor's degrees to Black/African American female students and the discipline did not show the same increase in Hispanic representation that chemistry, biology, and the campus observed. Lastly, neither chemistry, biology, nor physics had

equitable representation of URM degree holders compared to overall campus degree demographics.

The next analysis focused on the switching patterns of CBP majors compared to other STEM and non-STEM majors. I found that Hispanic female and Black/African American female students switched out of CBP more than switching into the same majors (net decrease). More specifically, chemistry saw the largest proportional decrease than all other majors for Hispanic female and Black/African American female students. Black/African American male students switched out of the physical sciences more so than switching into (net decrease), but showed net increases for biology, other STEM, and non-STEM. Finally, White students and Hispanic male students switched out more so (a net decrease) from chemistry than all other major categories investigated.

The last analysis in Study 1 focused on the introductory courses from the three disciplines. When examining the DFW rates the introductory courses, I found that of the three disciplines, chemistry courses had the highest DFW rates. Moreover, URM students were disproportionately represented by the DFW rates. The introductory courses varied in whether race or gender or the intersection of the two explained the variances seen in the likelihood of passing or failing those courses. For example, for the Organic Chemistry sequence and two biology courses (Cell Biology and Ecology and Evolution) female students were more likely to fail when compared to their male peers (even though females are overrepresented in those courses) and URM students were more likely to fail when compared to their White peers. Alternatively, Hispanic and Black/African American female students were less likely to pass when compared to their White female peers and Hispanic and Black/African American male students were less likely to pass when compared to their White male peers in two introductory

chemistry courses and cells and Organisms. The course-level analysis was concluded with an investigation into the retention of students in the introductory chemistry tracks. I found that in Track 1, which had a higher URM population, higher proportions of White students were retained than URM students across all courses within the track. However, in Track 2 Black/African American female students had higher retention than Hispanic male students, but White female students also were better retained than Hispanic students.

The findings of Study 1 add to the literature base on how different subgroups of gender and racially/ethnically marginalized students are represented and retained in the sciences at a minority-serving institution. Until now, there has not been a detailed, comparative analysis on three science disciplines at three time points across demographic groups. This research directly informs the disciplines and institution on the inequities of representation and retention and the disproportionate negative outcomes marginalized students face in chemistry, biology, and physics.

The aim of Study 2 and 3 was to understand why URM students have been historically less represented at all levels in the disciplines and why they fail or ultimately leave. For Study 2, which utilized survey methods, the aim was to characterize how a student's socio-affective characteristics might affect persistence. I used cluster analysis methods to group students with shared affective traits and analyzed how individual differences and demographics were associated with their cluster membership. This revealed six clusters: (1) *Entity Mindsets*, (2) *Science Enthusiast, High Contingency*, (3) *Science Enthusiast, Low Contingency*, (4) *Science Neutral, Low Contingency*, (5) *Non-Science Enthusiast, High Contingency*, and (6) *Science Accessible*.

Two of the six clusters showed multiple differences in their membership based on the other characteristics students possessed: the *Science Enthusiasts, High Contingency* cluster and the *Science Neutral, Low Contingency* cluster. Students within the *Science Enthusiasts, High Contingency* cluster were more likely to (1) pass than fail their introductory science course, (2) identify as female rather than male within the same racial/ethnic group, and (3) report a higher income than a lower household income. Conversely, students within the *Science Neutral, Low Contingency* cluster were more likely to (1) fail their science course rather than pass it, (2) identify as Black/African American female than another racial/ethnic group, (3) report a lower household income than a higher income, and (4) report no high school influences on their decision to choose a major. The only factor that did not differ across cluster membership was the discipline in which students were enrolled.

The findings of Study 2 add to the literature base on how multiple affective characteristics are related to persistence in the sciences. As previously mentioned, until now, there is no literature on how multiple affective characteristics collectively describe a student, their outcome in a course, and associations between affective traits to demographics and income level. However, several of my findings about individual affective constructs are consistent with the literature, such as my findings on science identity and positive attitudes towards science directly linked to achievement[34,55,65] and gender differences in high and low contingencies to self-worth and self-doubt[126,163,164].

The aim for Study 3 was to identify what personal experiences led marginalized students to fail, withdraw, or leave a science course or major. To achieve this aim, I interviewed five female students who identified as either Hispanic/Latinx or African American about their experiences in their introductory science courses in which they received a failing grade. While

the interviews were designed to discuss a range of topics, five overarching themes emerged from the students' shared experiences: social capital and influences, sense of belonging, instructor/TA interactions and effects on student success, college readiness, and disciplinary comparisons between chemistry and biology and physics. Each of the themes manifested in the students differently but contributed to their outcome in the course and, in some cases, their decision to leave a discipline or major. Most importantly, none of the women expressed one specific experience that led to a failing grade or decision to pursue or switch a major. Rather, it was a culmination of many adverse experiences that eventually resulted in their departure.

The findings of Study 3 are both consistent with similar research but also add to the growing literature on student experiences and their persistence. My interview subjects cited similar issues related to course content, organization, and workload that Seymour and Hewitt reported.[11] Further, the unexpected conversations about class size each of the interview subjects engaged in are consistent with the limited literature about enrollment and sense of belonging[76], but emphasize the importance of continuing research into class size and its unintended effects on students. Most importantly, Study 3 underscores the idea that persistence (or attrition) in the sciences does not boil down to one factor, but a culmination of multiple, uniquely weighted factors that influence the student.

Synthesis of Findings

Taken together, the findings of this dissertation tell a story of the inequities prevalent at a minority-serving institution and how other structures within the education system contribute to the exclusion of URM students in the sciences. Considering the outcomes of all three studies, I propose the research of this dissertation provides two contributions to the literature on representation and retention of marginalized students in the sciences: (1) marginalized groups do

not experience the same inequities to the same degree, and (2) science disciplines vary in their inequities but can learn how to improve from one another. I detail each of these contributions below and their impact on future research.

Marginalized groups do not experience the same inequities to the same degree

As previously discussed in this dissertation, I chose Black/African American and Hispanic/Latinx students as the demographic groups of interest because these groups are the most prominent marginalized groups at this diverse university (excluding Asian students who are overrepresented in STEM at this institution) so their relative representation in the sciences is an interesting phenomenon to investigate. Further, I used White students as the reference group for many analyses because White students were the most appropriate reference group for this population and are typically treated as such when analyzing racial/ethnic differences in the literature.

Although gender differences in STEM have been the focus of many significant studies[16,17,45,49,50,80], my findings suggest that White female students are not nearly as impacted as Black/African American female and Hispanic female students. In fact, Study 1 provided evidence that, at this institution, White female students were just as or overrepresented compared to White male students in biology and chemistry and better retained than their Black/African American and Hispanic peers in most introductory science courses. Further, my findings for male students from minoritized groups differed to that of their female peers. For example, Hispanic male students were slightly better represented in degrees awarded in CBP than Hispanic female students and bore similar switching patterns to those of White students. Black/African American students, both female and male, were more or less on par with one

another in Study 1 findings: low representation and retention across courses and degrees awarded. Black/African American male students switching patterns were not as severe as their female peers. Further, a low N for Black/African American male students in Study 2 did not allow for a more thorough analysis of their affective traits. The differences seen within racial groups across gender identity further amplifies the importance of intersectionality research. For these reasons, the rest of this section will focus on the similarities and differences in inequities between Hispanic female students and Black/African American female students.

This institution is designated as a Hispanic-serving Institution (HSI), which makes the findings of my research worth further discussion for Hispanic students in the sciences. In Study 1, I investigated retention in the introductory chemistry sequence. I found that Hispanic students were overrepresented in Track 1 (five course sequence) but not as well retained as White students. Further, across all introductory science courses Hispanic female students were less likely to pass the course when compared to their White peers. For the Hispanic female students who declared a chemistry, biology, or physics major, they left those majors more than switching into them (net decrease for the disciplines) and mostly moved to a non-STEM major. While Hispanic female degree holders were less represented in CBP than the overall undergraduate population, their representation in the science disciplines increased over time but varied wildly from year to year.

For Hispanic female students, while their representation at the degree level is improving, there is still much more to be done to make the courses and majors more equitable and inclusive. All interview participants shared examples of how the courses and majors could improve generally. However, two of the participants, Gloria and Sara did remark on how their sense of belonging in the sciences was interrupted because of their Hispanic/Latinx identities. Both

experiences were consequences from a lack of Hispanic/Latinx representation on campus in those disciplines. For example, Sara's discomfort in her chemistry class was largely due to the lack of other Hispanic/Latinx students, which made her feel alone and questioned her belonging in the course. Even though this institution has done a lot to improve the retention of Hispanic/Latinx students on campus and in STEM more broadly (i.e. campus-wide initiatives to improve Hispanic/Latinx representation in STEM), more work can be at the course level (via interventions for instructors, teaching staff, and administrators) to initiate a more welcoming and inclusive environment that can carry throughout the discipline.

Across the various studies of this dissertation, Black/African American female students were the most negatively impacted marginalized group in the sciences. For Study 1, similar to Hispanic students, Black/African American females were less likely to pass all introductory science courses when compared to their White peers. In chemistry specifically, Black/African American female students were overrepresented in Track 1 but were less retained when compared to White female students. Yet, Black/African American female students did not differ in their retention in Track 2 compared to White female students and were even better retained compared to Hispanic male students in two courses. Black/African American female students who declared a CBP major then subsequently switched, similarly to Hispanic female students, yielded a net decrease for CBP majors and moved mostly to non-STEM majors after leaving the sciences. In terms of degrees awarded, Black/African American female students were among the lowest represented in all three science disciplines. While their representation in each of the disciplines increased over time, representation from year to year fluctuated significantly. In fact, no physics degrees were awarded to Black/African American female students over the 13-year period of available data.

The analyses on affective characteristics in Study 2 also differed for Black/African American female students. While only a descriptive analysis was possible for differences in cluster membership based on race/ethnicity, Black/African American female students were more likely to be in the *Science Neutral, Low Contingency* cluster than any other cluster. This cluster was also associated with more DFW midterm grades, low and median income, and no high school influences to major in the sciences. Even though the institutional analysis for Black/African American female students did not yield very positive results, both African American female students interviewed (Aniyah and Malia) were intrinsically motivated and dedicated to their chemistry and pre-nursing majors, respectively. While Aniyah and Malia are two examples and not a general characterization for their respective identities, it is interesting to note that the seeming exclusionary nature of the sciences on Black/African American women did not deter these students from persisting in their majors. Both Malia and Aniyah had difficulty in their non-major science courses, but neither attributed their identities to their academic struggles. In fact, these women reported expansive family supports and intrinsic motivation that aided in their persistence.

Science disciplines vary in their inequities but can learn how to improve from one another

Study 1 set the background for differences seen across the three disciplines. In terms of degrees, chemistry and biology were remarkably similar in their racial/ethnic and gender representation, but female students more likely to attain a degree in biology than in chemistry. Physics, however, was predominately made up of White males (60%). Physics also had significantly fewer degrees awarded over the same 13-year period, which made racial/ethnic inequities more pronounced. Altogether, marginalized students were less represented in

chemistry, biology, and physics degrees than across all bachelor's degrees at the institution. For CBP majors, biology, along with non-STEM gained the most switchers of any group. Further, chemistry was the only major to observe net decreases for all demographic groups, with the largest decreases coming from Hispanic female and Black/African American female students. Chemistry must improve their retention of students and most importantly marginalized students. This was also seen at the course level where chemistry had the highest DFW rates across their introductory courses. Furthermore, these high DFW rates disproportionately affected Hispanic and Black/African American students in chemistry as well as biology and physics. With failing rates as high as reported, these introductory courses are acting as "weed outs", which is the largest source of attrition of marginalized students in the discipline. Extant research has found that "weed out" courses remove students, who are genuinely interested in the disciplines, because of the "cut throat" nature of academic science.[11,121] Recruiting more marginalized students into the sciences will not diversify the disciplines unless the "weed out" course and general culture of undergraduate science changes from gatekeeping to engagement and encouragement of students.

Study 3 continued the cross-discipline comparison with the interviews of students who were enrolled in multiple chemistry, biology, or physics courses. There were several instances where chemistry was seen in a more positive light when compared to other disciplines as well as when it could be improved. Specifically, Sara pointed to particular chemistry instructors that showed engagement and interest in the content and their students that they wished they saw in her biology course. Cross-disciplinary observations or professional development could allow for instructors to see the practices and behaviors of others and how to implement similarly in their classroom. This could be particularly beneficial for courses that are high enrollment. Gloria, who

was quite observant of teacher practices in her large lecture courses, noticed that biology courses were generally more equipped to keep students engaged despite the large class size. Gloria was also enrolled in large chemistry and physics courses; whose instructors went about teaching in a more lecture-based way that gave impressions of disinterest.

Returning to Seymour and Hewitt's hybrid definitions of those who switch majors (*more pushed than pulled* and *more pulled than pushed;* see Chapter 2)[11], I observed a range of switching types. Of the five women interviewed, three of them had switched majors at some point: Sara, Adriana, and Gloria. Gloria's negative experiences surrounding her major switch out of neuroscience, largely due to her father, and the regret she felt of her decision to switch majors is aligned with more pushed than pulled. However, even though she did persist in biology, her wish to switch back to neuroscience was mostly due to more interest. Similarly, Sara and Adriana left their biology and pre-nursing majors, respectively, due to higher genuine interest in other fields. They were much happier in their non-STEM fields after switching. So, they are part of the proportion of students that do switch majors because of lack of interest and not for other reasons. Malia's strive to become a nurse is persistent. However, her trouble in her introductory courses early on in her academic career and constant reminding by her advisor she may not get into nursing school puts her at risk for switching majors. If she were to switch, she would most likely fit the more pushed than pulled definition because of the negative experiences surrounding the introductory course that she felt she could succeed given the proper supports, her deep-rooted interest in her nursing major, and her feelings of frustration by the instructional and administer staff. Lastly, Aniyah gave no indication that she would ever switch out of her chemistry major.

Since curriculum engagement and instructional quality has been linked to greater likelihood of persistence of women of color in STEM[19,191] and instructor enthusiasm plays a vital

role in student motivation, study behaviors, and interest[181–183], assigning excited instructors that show passion about their content is a simple way to keep students engaged. Furthermore, two students took multiple chemistry courses and were able to compare within the discipline. From their experiences, Sara and Aniyah observed wide variations in the teaching effectiveness and engagement of TAs and instructors. TAs are responsible for large portions of undergraduate instruction in the sciences, particularly at large research universities. Because departments are responsible for the training of all their TAs, consistency in preparation and training can be achieved with support and interventions. A review of the literature on graduate teaching assistant training programs from Gardner and Jones found a range of formats ranging from 90 minute workshops to semester long courses with the programs focusing on faculty mentorship and observations, pedagogical training, interactive activities, and theory-based instruction and feedback.[192] While there may not be one best way to train TAs, they do have to be prepared for the responsibilities of fostering the understanding of science content and to help students excel in the course. As for instructors, ensuring multi-instructor courses are planned and delivered in similar fashion with enthusiasm and engagement is crucial to consistent and positive experiences for chemistry students. One way to achieve this is to have instructors observed by colleagues or the department regularly and are themselves engaged in constantly improving their teaching of chemistry content.

Limitations of this Research

My identity

Because the focus of this dissertation was on the intersection of gender and racial/ethnic identities of science students, it is important for me to recognize my identity as a limitation in this study. I identify as a White woman. Because of my identity and its relation to the students I

was studying and interviewing, I can make only partial inferences from their experiences as students of color in the sciences. The inferences and conclusions made herein are therefore more conservative in nature.

Additionally, I am a graduate student in the chemistry department where I have been employed as a TA for several chemistry courses. Because of this, I did notify the interview students, those who I interacted with the most, that their responses would not affect their standing in any way within the department or individual courses and that their identities would be shielded from anyone that was not me. Further, because of my relation to the chemistry department several analyses focused on that department specifically (e.g. course drop-out analysis in Study 1 and the fifth emergent theme in Study 3). The inclusion of the three disciplines were to not only characterize three dominant science disciplines in STEM but to also provide comparative disciplines to which I can analyze chemistry. Though my belonging to chemistry biased the analyses I chose to include, it did not influence my findings, discussion of my findings, or the discussed implications of my findings.

Context specificity of the findings

As previously mentioned, this dissertation was conducted at a large, urban Midwestern Hispanic-serving institution. The analyses were based on data collected from this institution's registrar database and from individuals who were enrolled as students at this institution. Thus, the findings are specific to this institution. Generalizability to institutions dissimilar in terms of structure and demographics is not possible.

In terms of the registrar data, I was only able to analyze data that was available to me. Because of the initial scope of my research plan, I was given data on students who were enrolled

in a 100- or 200-level course for the time the data was available (2004-2017), data on students who switched majors while enrolled in those same courses, and data on students who graduated during that same time period. Unfortunately, the data from the sources described above were in separate databases and did not talk to each other. Because of this, I was unable to answer more complex questions or follow the same student through multiple disciplines and ultimately to degree conferment. A more complete and interactive dataset would have yielded a better understanding of student trajectories at this institution.

Lastly, the range of students interviewed for Study 2 was not as diverse as I would have hoped. The initial plan was to interview about four times as many students to really define the URM student experience of persistence. Unfortunately, low recruitment due to COVID-19 made this impossible.

COVID-19

This dissertation's data collection was nearing its end just as COVID-19 was becoming a global pandemic. As previously discussed, I was beginning recruitment for the interview study just as courses went online. Amidst the confusion and frustration of converting to eLearning and navigating a new reality, I sent out recruitment emails to students eligible to participate in my research with little interest returned. I was fortunate that Adriana, Aniyah, Gloria, Malia, and Sara were willing to take time to talk with me for an hour about their experiences in the sciences. It would have been beneficial and made for stronger research to interview more students within the demographic groups to get a wider array of student experiences at this institution. Because of the nature of phenomenology and only having interviewed five students, it is impossible to make generalizations about the state of science disciplines.

Future Directions

While this dissertation makes several contributions to the ongoing work to improve the persistence of marginalized students in their sciences, there is still much work to be done to achieve equity. I have already discussed the ways in which the disciplines lacked representational equity for marginalized students in Study 1 and 3. While this certainly should be a priority for the individual disciplines and departments, the institution should also be taking part to increase support and retention of marginalized students. One step institutions can take to improve equity for marginalized students in the sciences to provide high-quality resources and ensure the resources are accessible for all students. Several of the interview participants cited lack of academic resources, unnavigable access to already provided resources, and poor academic advising as factors that impacted their success in a course. Adequate onboarding and orientation of new students is crucial for their continued success in college and certainly for introductory science courses that have reputations for their difficulty. Previous research has highlighted the importance of proper student orientation to campus resources. Specifically, students who were enrolled in an orientation course or first-year seminar were more likely to cultivate faculty-student relationships, be exposed to the necessary study skills, and be accustomed to advising information and academic planning.[193,194]

As discussed in Chapter 2, there are many problems with the “leaky pipeline” metaphor. One of the inconsistencies was the lack of consideration for students that come into the pipeline later in their career. The results discussed in this dissertation, for the most part, only pertain to the first two years of college. A true large-scale longitudinal study of marginalized students in the sciences post-graduation in warranted. Several scholars have examined students until graduation, but not many have continued into their career. In fact, many national statistics do not

consider all job sectors and in STEM and thus do not account for careers that utilize STEM in non-traditional capacities.[46–49] More detailed databases need to be created to effectively evaluate the representation of people of color in STEM careers.

Further, as discussed previously, the results for the three studies are unique to this institution, an HSI. I would be interested to see similar studies conducted at institutions of different types (e.g. HBCUs, PUIs, etc.) to see how URM representation and persistence differs dependent on institution type and student demographics. Prior research of similar kind has been done on HBCUs[195] but not on all kinds of minority-serving institutions.

Future research should continue to work through an intersectionality lens. I came into this dissertation with the idea that the sciences were still inequitable to all women, but it is clear that is no longer the case. White women have achieved equity in many disciplines, but women of color are not nearly as represented as they should and could be. I only considered racial/ethnic and gender identity, but intersectionality can bring together many different identities (first-generation, social class, sexual orientation, age, disability, etc.)[57,60,196] to explore interactions on inclusion in the sciences. There are many groups of students that are underrepresented that require further investigation and intervention to absolve.

Analyses in Study 1 on performance in introductory courses and the shared experiences from Study 3 point to further investigation into equitable resources in high school that better prepare students of color for college in general and college-level science courses. Segregated neighborhoods based on race/ethnicity, like those in Chicago, and systemic barriers lead to inequitable division of educational resources and opportunities. For example, schools within the city school district, Chicago Public Schools (CPS), where Black/African American students make up at least 60% of the student population are the least likely to offer Advanced Placement

(AP) or International Baccalaureate (IB) courses, physics courses, or calculus courses.[197] The lack of academic opportunities presented to students of color needs further study as to their impact on future persistence in STEM.

Recent national tragedies (like the murders of George Floyd, Breonna Taylor, and countless others) have sparked widespread initiatives to bring racial equity into all aspects of society and correct inequities of systemic racism. These movements have spread to academia and the sciences. Social media movements like #ShutDownAcademia and #ShutDownSTEM, #BlackintheIvory, and the #BlackIn series of various STEM disciplines have engaged the scientific community in conversations to examine their role of exclusionary practices and how to better amplify researchers, scientists, and students of color in their field.[198,199] Because of this, the formation of Diversity, Equity, and Inclusion (DEI) committees or taskforces in universities has increased drastically over the past year. While these committees are a significant first step, instructor's, administrator's and policymaker's practices and behaviors need to be changed if the sciences truly want to be diverse, equitable, and inclusive.

Throughout this dissertation, I have proposed several areas for improvement and the research behind successful initiatives and they should all be further explored and incorporated into academia for a more equitable and inclusive environment. However, for new institutional or discipline-wide attitudes and policies to change, individuals need to examine their own behaviors and how to position themselves as allies. Chaudhary and Berhe developed ten rules scientists and researchers can adhere to better allyship. Examples include advocating for racially diverse leadership in their departments and professional societies, evaluating department or lab mentoring practices, supporting URM students and colleagues, and holding those in power accountable.[200] The issue of equitable representation and increased persistence of marginalized

students in the sciences is of growing concern to educators, policymakers, and researchers. Much has been done in the space but there is significant room for improvement. Every level of the science disciplines should be working towards a more diverse, equitable, and inclusive environment for marginalized students to persist.

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APPENDIX A

Table A1 Counts of Black/African American, Hispanic, and White female and male students over the 14-year period in each course.

Course	Black/AA female	Hispanic female	White female	Black/AA male	Hispanic male	White male
Preparatory Chemistry	1495	3357	2998	457	1845	1844
General Chemistry I	1194	2715	4114	521	1963	3877
Organic Chemistry I	652	1217	2886	256	852	2139
Organic Chemistry II	391	760	2048	201	571	1765
Cells and Organisms	995	2001	3466	324	1085	2208
Genetics	370	684	1872	181	510	1480
Cell Biology	372	697	1606	177	478	1316
Ecology and Evolution	329	682	1504	133	425	1102
Introductory Physics I	432	661	1983	210	609	1531
Introductory Physics II	239	397	1348	128	331	999
General Physics I	170	290	640	229	941	2322
General Physics II	94	186	485	167	672	1889

Tables A2-A13 Wald Chi-square tests and betas of predictors for the binary logistic regression to determine if demographic group is associated with the likelihood of a student passing or failing a given course.

Table 2. Preparatory Chemistry								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	.117	.070	2.785	1	.095	1.124	.980	1.290
Whether Hispanic	-.556	.073	57.674	1	< .001	.574	.497	.662
Whether Black/AA	-.510	.113	20.490	1	< .001	.601	.482	.749
Whether Hispanic female	-.256	.093	7.679	1	.006	.774	.645	.928
Whether Black/AA female	-.538	.132	16.668	1	< .001	.584	.451	.756
Constant	1.157	.055	449.412	1	< .001	3.181		

Table 3. General Chemistry I								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	.147	.050	8.647	1	.003	1.158	1.050	1.278
Whether Hispanic	-.293	.059	24.813	1	< .001	.746	.664	.837
Whether Black/AA	-.619	.095	42.329	1	< .001	.538	.447	.649
Whether Hispanic female	-.271	.079	11.668	1	.001	.763	.653	.891
Whether Black/AA female	-.041	.117	.121	1	.728	.960	.763	1.208
Constant	.886	.035	628.868	1	< .001	2.425		

Table 4. Organic Chemistry I								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	-.230	.049	21.633	1	< .001	.795	.721	.875
Whether Hispanic	-.523	.055	91.363	1	< .001	.593	.533	.660
Whether Black/AA	-.641	.074	74.625	1	< .001	.527	.456	.609
Constant	1.050	.043	595.101	1	< .001	2.857		

Table 5. Organic Chemistry II								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	-.163	.055	8.623	1	.003	.850	.762	.947
Whether Hispanic	-.406	.065	39.176	1	< .001	.666	.587	.757
Whether Black/AA	-.399	.090	19.821	1	< .001	.671	.563	.800
Constant	.724	.046	251.302	1	< .001	2.063		

Table 6. Cells and Organisms								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	.178	.083	4.622	1	.032	1.195	1.016	1.406
Whether Hispanic	-.582	.097	35.791	1	< .001	.559	.462	.676
Whether Black/AA	-.807	.142	32.123	1	< .001	.446	.337	.590
Whether Hispanic female	-.299	.123	5.904	1	.015	.741	.583	.944
Whether Black/AA female	-.372	.168	4.933	1	.026	.689	.496	.957
Constant	1.890	.063	899.608	1	< .001	6.617		

Table 7. Genetics								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	.021	.071	.084	1	.771	1.021	.888	1.173
Whether Hispanic	-.642	.080	65.167	1	< .001	.526	.450	.615
Whether Black/AA	-.651	.106	37.626	1	< .001	.522	.424	.642
Constant	1.593	.061	686.821	1	< .001	4.918		

Table 8. Cell Biology								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	-.338	.080	18.062	1	< .001	.713	.610	.833
Whether Hispanic	-.514	.087	35.016	1	< .001	.598	.505	.709
Whether Black/AA	-.671	.110	37.004	1	< .001	.511	.412	.634
Constant	1.931	.071	741.006	1	< .001	6.897		

Table 9. Ecology and Evolution								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	-.346	.079	19.107	1	< .001	.708	.606	.826
Whether Hispanic	-.724	.084	74.941	1	< .001	.485	.412	.571

Whether Black/AA	-.888	.111	63.688	1	< .001	.412	.331	.512
Constant	1.773	.072	605.432	1	< .001	5.890		

Table 10. Introductory Physics I								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	-.036	.059	.367	1	.544	.965	.860	1.083
Whether Hispanic	-.607	.068	80.039	1	< .001	.545	.477	.622
Whether Black/AA	-.815	.088	86.825	1	< .001	.442	.373	.525
Constant	.914	.050	335.382	1	< .001	2.495		

Table 11. Introductory Physics II								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	.126	.086	2.171	1	.141	1.135	.959	1.342
Whether Hispanic	-.503	.101	24.931	1	< .001	.605	.496	.737
Whether Black/AA	-.825	.125	43.847	1	< .001	.438	.343	.559
Constant	1.490	.072	424.789	1	< .001	4.439		

Table 12. General Physics I								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	-.043	.075	.332	1	.564	.958	.827	1.109
Whether Hispanic	-.647	.071	82.955	1	< .001	.524	.456	.602
Whether Black/AA	-.987	.109	81.336	1	< .001	.373	.301	.462
Constant	.990	.044	497.242	1	< .001	2.691		

Table 13. General Physics II								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether female	-.013	.095	.018	1	.894	.988	.820	1.189
Whether Hispanic	-.604	.088	47.336	1	< .001	.547	.460	.649
Whether Black/AA	-.499	.143	12.138	1	< .001	.607	.459	.804
Constant	1.284	.053	577.272	1	< .001	3.610		

Tables A14-A16 Wald Chi-square tests and betas of predictors for the binary logistic regression to determine if racial groups among female students is associated with the likelihood of a student passing or failing a given course.

Table 14. Preparatory Chemistry								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether Hispanic	-.812	.057	205.355	1	< .001	.444	.397	.496
Whether Black/AA	-1.047	.068	235.272	1	< .001	.351	.307	.401
Constant	1.275	.044	831.567	1	< .001	3.577		

Table 15. General Chemistry I								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether Hispanic	-.564	.053	113.196	1	< .001	.569	.513	.631
Whether Black/AA	-.660	.069	92.266	1	< .001	.517	.452	.591
Constant	1.033	.035	849.785	1	< .001	2.809		

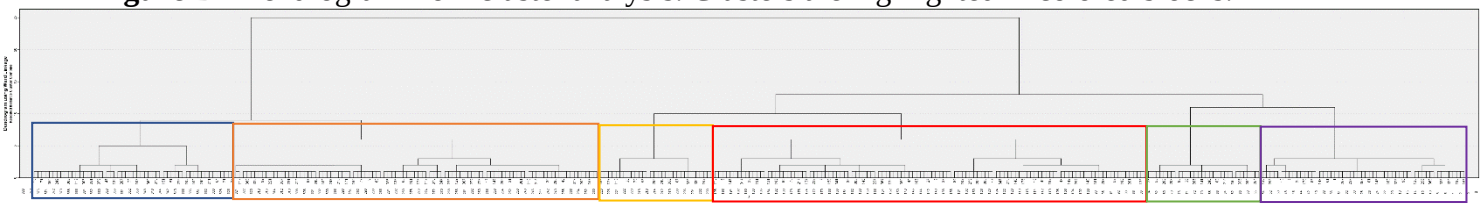
Table 16. Cells and Organisms								
	B	**SE**	**Wald Chi-Square**	**df**	**p**	**Exp (B) or Odds Ratio**	**95% CI for Exp(B)**	
							Lower	***Upper***
Whether Hispanic	-.881	.075	136.622	1	< .001	.414	.357	.480
Whether Black/AA	-1.179	.088	179.220	1	< .001	.307	.259	.365
Constant	2.068	.054	1476.564	1	< .001	7.907		

APPENDIX B

Table B1 The final ten rows of the agglomeration schedule for the cluster analysis. The "best cut" was made at the bolded row, where the change in coefficients saw the largest jump between stage 371 and 372. Based on this cut, the data will be divided into six clusters.

	Cluster Combined			Stage Cluster First Appears		Next	Change in
Stage	**Cluster 1**	**Cluster 2**	**Coefficients**	**Cluster 1**	**Cluster 2**	**Stage**	**coefficients**
367	14	16	2085.194	337	353	370	57.164
368	1	4	2153.06	364	346	374	67.866
369	10	21	2251.095	361	347	372	98.035
370	2	14	2371.312	363	367	373	120.217
371	8	11	2506.632	357	366	372	135.32
372	**8**	**10**	**2713.88**	**371**	**369**	**376**	**207.248**
373	2	12	2948.02	370	365	375	234.14
374	1	28	3187.88	368	360	375	239.86
375	1	2	3479.805	374	373	376	291.925
376	1	8	4074.158	375	372	0	594.353

Figure B1 Dendrogram from cluster analysis. Clusters are highlighted in colored blocks.



Qualtrics Survey

IRB Consent document was at the start of the survey then was followed by the items.

Q4 Do you agree to participate in the survey?

- ○ Yes, I agree to participate in the survey
- ○ No, I do NOT agree to participate in the survey

Q5 Do you agree to allow access to your UIC student records by the research team?

- ○ Yes, I agree to allow access to my UIC student records by the research team
- ○ No, I do NOT agree to allow access to my UIC student records by the research team

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Q6 Do you agree to be contacted to participate in a follow-up interview?

- ○ Yes, I agree to be contacted about an interview
- ○ No, I do NOT agree to be contacted about an interview

Q7 Do you agree to be contacted to participate in the testing of a new survey if all interview positions are filled?

- ○ Yes, I agree to be contacted about testing a new survey
- ○ No, I do NOT agree to be contacted about testing a new survey

---

Q8 Do you agree that your de-identified video- and/or audio-recordings may be viewed by others outside of the research group?

- ○ Yes, I agree that my de-identified video- and/or audio-recordings may be viewed by others outside of the research group
- ○ No, I do NOT agree that others outside of the research group may see my video- and/or audio-recordings

End of Block: Consent

Start of Block: Demographics

Q9 What is your natal sex (sex at birth)?

- ◯ Female
- ◯ Male

Q10 What is your gender identity?

- ◯ Female
- ◯ Male
- ◯ Transgender Female
- ◯ Transgender Male
- ◯ Genderqueer
- ◯ Gender-nonconforming
- ◯ Other _____

Q11 Please indicate your race/ethnicity.

- ○ White
- ○ Hispanic
- ○ Asian
- ○ Black or African American
- ○ International
- ○ American Indian or Alaska Native
- ○ Native Hawaiian or Pacific Islander
- ○ Multi-Race
- ○ Other _____

Q12 What was your status at the beginning of your first semester at UIC?

- ○ First-semester freshman
- ○ Transfer from another institution
- ○ Graduate student
- ○ Professional student
- ○ Other _____

End of Block: Demographics

Start of Block: Socio-economic status

Q13 Are you the head of your household?

- ◯ Yes
- ◯ No

Q14 How many people live in your household, including yourself?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 or more

Q15 What is your estimated household yearly income?

- ◯ $0 - $20,000
- ◯ $21,000 - $40,000
- ◯ $41,000 - $60,000
- ◯ $61,000 - $80,000
- ◯ $81,000 - $100,000
- ◯ $101,000 +

Q16 Do you currently have a job?

- ○ Yes
- ○ No

Q17 Is your job part-time (less than 40 hours per week) or full time (40 or more hours per week)?

- ○ I work part-time.
- ○ I work full-time.

Q18 How many jobs do you currently have?

- ○ I have one job.
- ○ I have two jobs.
- ○ I have three or more jobs.

End of Block: Socio-economic status

Start of Block: Course

Q19 From which course(s) were you enrolled in Fall 2019? Select all that apply.

- ☐ CHEM 101 (Preparatory Chemistry)
- ☐ CHEM 122 (General Chemistry I)
- ☐ CHEM 232 (Organic Chemistry I)
- ☐ CHEM 234 (Organic Chemistry II)
- ☐ BIOS 110 (Biology of Cells and Organisms)
- ☐ BIOS 220 (Mendelian and Molecular Genetics)
- ☐ BIOS 222 (Cell Biology)
- ☐ BIOS 230 (Ecology and Evolution)
- ☐ PHYS 107 (Introductory Physics II)
- ☐ PHYS 141 (General Physics I - Mechanics)
- ☐ PHYS 142 (General Physics II - Electricity and Magnetism)

End of Block: Course

Start of Block: Self-report Secondary Measures

Q20 What was your midterm grade in the course from which you received the invitation to take this survey?

- ○ A
- ○ B
- ○ C
- ○ D
- ○ F
- ○ W (You withdrew from the course)

Q21 What is your GPA?

- ○ 4.0
- ○ Between 3.0 - 3.9
- ○ Between 2.0 - 2.9
- ○ Below 2.0

Q22 Have you declared a major?

- ○ Yes
- ○ No, I am undeclared.

Q23 You have not declared a major. Do you intend to declare a major?

- ○ Yes
- ○ No

Q24 Please indicate your declared or intended major.

_____

End of Block: Self-report Secondary Measures

Start of Block: People of influence

Q25 Below is a list of people with whom you may have interacted. Indicate those in your life that influenced you to pursue your major.

- ☐ Family
- ☐ Friends
- ☐ College professors
- ☐ High school teachers
- ☐ Advisors
- ☐ Guidance counselors
- ☐ Mentors
- ☐ Teaching assistants (TAs)
- ☐ Other _____

End of Block: People of influence

Start of Block: ASCIv2

Q26

A list of opposing words appears below. Rate how well these words describe your feelings about science. Think carefully and try not to include your feelings toward specific science teachers or courses. For each line, choose a position between the two words that describes exactly how you feel. The middle position (#4) is if you are undecided or have no feelings related to the terms on that line.

Science is...

	1	2	3	4	5	6	7	
	1	2	3	4	5	6	7	
Chaotic	○	○	○	○	○	○	○	Organized
Satisfying	○	○	○	○	○	○	○	Frustrating
Comfortable	○	○	○	○	○	○	○	Uncomfortable
Complicated	○	○	○	○	○	○	○	Simple
Challenging	○	○	○	○	○	○	○	Not challenging
Pleasant	○	○	○	○	○	○	○	Unpleasant
Confusing	○	○	○	○	○	○	○	Clear
Easy	○	○	○	○	○	○	○	Hard

End of Block: ASCIv2

Start of Block: Science Identity

Q27 Read each statement carefully and decide how much you agree with it. There are no “right” or “wrong” answers. Please be as honest as possible.

Q28 Being involved in science is a key part of who I am.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Strongly disagree

Q29 Being someone who is good at science is important to me.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Strongly disagree

Q30 Being good in science is an important part of who I am.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Strongly disagree

Q31 I consider myself a science person.

- ○ Strongly agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Strongly disagree

End of Block: Science Identity

Start of Block: CSWS

Q32 Read each statement carefully and decide how much you agree with it. There are no “right” or “wrong” answers. Please be as honest as possible.

Q33 I feel bad about myself whenever my academic performance is lacking.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q34 My self-worth is affected by how well I do when I am competing with others.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q35 I feel better about myself when I know I'm doing well academically.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q36 I feel worthwhile when I perform better than others on a task or skill.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q37 My opinion about myself isn’t tied to how well I do in school.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q38 Doing well in school gives me a sense of self-respect.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q39 My self-worth is influenced by how well I do on competitive tasks.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q40 What others think of me has no effect on what I think about myself.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q41 My self-esteem is influenced by my academic performance.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q42 My self-esteem depends on the opinions others hold of me.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q43 Doing better than others gives me a sense of self-respect.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q44 I don’t care if other people have a negative opinion about me.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q45 Knowing that I am better than others on a task raises my self-esteem.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q46 I don’t care what other people think of me.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q47 I can't respect myself if others don't respect me.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Neutral
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

End of Block: CSWS

Start of Block: ITI

Q48 Read each statement carefully and decide how much you agree with it. There are no "right" or "wrong" answers. Please be as honest as possible.

Q49 Your intelligence is something about you that you can't change very much.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q50 You have a certain amount of intelligence and you really can’t do much to change it.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q51 You can learn new things, but you can’t really change your basic intelligence.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

End of Block: ITI

Start of Block: Self-doubt

Q52 Read each statement carefully and decide how much you agree with it. There are no “right” or “wrong” answers. Please be as honest as possible.

Q53 I sometimes find myself wondering if I have the ability to succeed at important activities.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q54 As I begin an important activity, I usually feel confident in the likely outcome.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q55 I often wish that I felt more certain of my strengths and weaknesses.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q56 For me, avoiding failure has a greater emotional impact (e.g., sense of relief) than the emotional impact of achieving success (e.g., joy, pride).

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q57 As I begin an important activity, I usually feel confident in my ability.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q58 Sometimes I feel that I don’t know why I have succeeded at something.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q59 When engaged in an important task, most of my thoughts turn to bad things that might happen (e.g., failing) than to good.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

Q60 More often than not I feel unsure about my abilities.

- ○ Strongly agree
- ○ Agree
- ○ Somewhat agree
- ○ Somewhat disagree
- ○ Disagree
- ○ Strongly disagree

End of Block: Self-doubt

APPENDIX C

Interview Protocol

Welcome

- Greetings and introductions
- We're together today to talk about your science major and your experiences in some UIC science courses.
    - If you don't want to answer a question or don't know how to answer, that's okay.
    - Even though you consented to this interview and to allow me to record this interview, we can end the interview or shut off recording devices at any time. Just ask. I have the consent form here if you wish to read it again.
    - I'm not your TA or an instructor so nothing you say here will affect your grades in any way. I'm interested in your experiences in science here at UIC. Your name will not be known to anyone besides me. If any part of this interview is used in my research, your name will not be attached to it.
    - You will receive $20 for the 1-hour interview.
- Before jumping into the interview, I'm going to verify some demographic information from the survey you completed
    - Major
    - Gender identity
    - Racial identity
    - Job status
    - Year at UIC
    - First generation

Theme 1: Decision to major in science

- Major/Science Identity
    - How did you come to choose your major?
    - What do you want to do with your degree?
- People of influence
    - In your survey response, you listed [these people] influenced you in some way with your decision to major in [science]. Describe how these people influenced you in this way.
- We're now going to switch over into talking about the course you were enrolled in when you answered the survey.

Theme 2: Performance in previous course (reported in survey)

- Tell me about a time in that course that made you feel good or bad about yourself [proud or disappointed].
- Looking back on the time you were in [this course], what could you have done differently or what could the course have done differently?
- You reported a midterm grade of a [grade] and a final grade of a [final grade]. Why do you think you received the grade you did in this course?
- Keeping in mind [this course], do you feel you were more or less connected/included [belonged more or less] with your classmates than a typical student in the same course?
    - Follow-up: how would you describe a typical student in this course?

- Follow-up: do you think your identity played a role in this feeling of [more/less] included?

Theme 3: Self-worth/Self-doubt

- **Now we are going to be talking about your self-esteem and your confidence. Here, self-esteem refers to how you feel about yourself overall. Confidence refers to how you feel about your abilities, which can be contextual.**
- How would you describe your self-esteem when it comes to your science courses or major?
  - Follow-up: Do you think your level of self-esteem changes when you take it out of the context of school? How?
- How do other's opinions affect your self-esteem? Are these the same people who influenced you [earlier]?
  - Follow-up: Do you think other's opinions of you affect you differently in school than outside of school? How?
- How would you describe your confidence when it comes to your science courses or major?
  - Follow-up: Do you think your level of confidence changes when you take it out of the context of school? How?

Theme 4: Instructors and TAs

- How did the instructor or TAs from the course play a role in your outcome in the course?
- Did the racial and/or gender make-up of your [course name] classmates and instructor/TA affect your comfort level in the course?

Wrap Up:

- Is there anything we didn't talk about that you would like to?
- Any questions for me before we end?
- Can I have some updated information as how to contact you in the future?

Probes:

- Anything else?
- What do you mean by that?
- Can you say more about that?
- In what way?
- How so?
- Tell me more about that.

Code Book

Code	Definition
attribute: altruistic	student attribute referring to one's altruistic sense of being selfless and desire to help others
attribute: comfort zone	student attribute referring to one's need to stay within their comfort zone
attribute: communication	student attribute referring to their communication skills
attribute: emotionally invested	student attribute referring to a student being emotionally invested in their major/course/discipline
attribute: hard worker	student attribute referring to one's willingness to work hard in courses
attribute: self-evaluation	student attribute referring to one's ability to self-evaluate and reflect on their practices and behaviors
attribute: self-teaching	student attribute referring to one teaching themselves course content
attribute: study skills	student attribute referring to one's study skills and practices
attribute: time management	student attribute referring to one's time management skills
CBP: negative chemistry	student had a negative experience in chemistry compared to biology or physics
CBP: positive chemistry	student had a positive experience in chemistry compared to biology or physics
comparing to other students: differences	student compares themselves to others based on how they are different
comparing to other students: similarities	student compares themselves to others based on how they are the same
confidence: affected by academics	a student's confidence level is affected by academics
confidence: affected by others	a student's confidence level is affected by others
confidence: contextual	a student’s confidence level is contextual on the situation, discipline, or course
confidence: high	showing high confidence as defined by how one thinks about their abilities

confidence: low	showing low confidence as defined by how one thinks about their abilities
confidence: over-confident	student is overestimating their abilities or understanding of content and results in negative outcomes
contradiction: confidence	student contradicts themselves in reference to their confidence
contradiction: inclusion based on race/ethnicity	student contradicts themselves in reference to being included (or not) based on their racial/ethnic identity
course withdraw: GPA impact	student withdrew from the course due to how the failing/W grade would impact their GPA
course withdraw: plan to retake	student withdrew from the course but has a plan to retake or did retake the course
course withdraw: workload	student withdrew from course due to their workload
course: assessments	student references course assessments as affecting their success in the course
course: challenging content	challenging content in a course
course: completing assignments	the task of completing assignment was of importance to success in the course
course: content application	applying content in a course/problem solving
course: content understanding	course content understanding
course: expectations	course expectations were clear, unclear, or differing from the perspective of the student
course: fast-paced	course is fast paced
course: fulfilling degree requirements	student is enrolled in the course simply to fulfill degree requirements
course: lack of content understanding	student comments on lacking content understanding in a course
course: no good experiences	student had no good experiences to report for a course
course: organization	comments on the organization of the course
course: supplemental help	student references supplemental help (SI, extra credit) in the course
course: workload	student references the workload of the course

COVID-19	reference to COVID-19 as being a factor on a course or decision
COVID-19: online learning	reference to COVID-19, specifically online learning, as being a factor on a course or decision
decision to major: counselor	academic advisor influenced the decision to choose a major
decision to major: degree requirements	degree requirements influenced the decision to choose a major
decision to major: experience in discipline	experiencing the major/courses/field influenced the decision to choose a major
decision to major: family	family influenced the decision to choose a major
decision to major: finances	finances influenced the decision to choose a major
decision to major: help others	wanting to help others influenced the decision to choose a major
decision to major: high school teachers	high school teachers influenced the decision to choose a major
decision to major: job prospects	future job prospects influenced the decision to choose a major
decision to major: personal interest	one's personal interest influenced the decision to choose a major
decision to major: unsupportive advice/discouragement	student received unsupportive advice and/or discouragement that influenced the decision to choose (or not) a major
discipline comparison: CBP	student makes comparison between chemistry, biology, and physics
discipline comparison: non-STEM to science	student makes comparison between non-STEM and science
disengagement	the student is actively being disengaged by themselves, the course, or the instructor/TA
engagement	student is being engaged in the discipline, course, major or instructor/TA
environment: class size	environmental factors that influence students: class size
environment: facilities	environmental factors that influence students: university facilities (buildings, classrooms)
environment: family	environmental factors that influence students: family problems

environment: lab	environmental factors that influence students: lab courses or lab environment
environment: multiple courses	environmental factors that influence students: student enrolled in multiple science courses at one time
external stress	student is experiencing external stressors that affect their success in school
growth mindset	student shows a growth mindset behavior
identity	student evoked the idea of identity in general
identity: gender	student's gender identity
identity: major	student's identity as being from a particular major
identity: race/ethnicity	student's racial/ethnic identity
identity: student	student's identity as a student
identity: transfer student	student's identity as a transfer student
identity: year	a student using their year in undergrad (freshman, sophomore, etc.) as part of their identity
inclusion	a sense of general inclusion
inclusion: contextual	student's idea of being included in the sciences is determined on the given situation
inclusion: gender	inclusion based on a student's gender
inclusion: lack of	the lack of inclusion
inclusion: race/ethnicity	inclusion based on a student's race/ethnicity
instructor/TA: communication	instructor/TA's commination methods affect a student's success
instructor/TA: expectations/commitments	instructor/TA expectations and commitments (other than the course) that negatively affect a student's success
instructor/TA: interactive	instructor/TA being interactive with students affect a student's success
instructor/TA: interest	instructor/TA shows interest in the subject matter or their students
instructor/TA: lack of interest	instructor/TA shows a lack of interest in the subject matter or their students

instructor/TA: negative interactions	instructor/TA negative interactions that affect a student's success
instructor/TA: perceived competence	instructor/TA's perceived competence affect a student's success
instructor/TA: positive interactions	instructor/TA positive interactions that affect a student's success
instructor/TA: teaching style	instructor/TA teaching style that affect a student's success
interdisciplinary content	student refers to learning the same content in more than one course of different disciplines
John Henry effect	The minority/control group is aware of their disadvantage and sees their competition with the majority/treatment group as motivation
major switch	student switched majors at some point in their undergraduate academic career
major switch: course load	student switched majors at some point in their undergraduate academic career because of course load
major switch: lack of interest	student showed a lack of interest in their major, which resulted in them switching out the major
major switch: perceived ability	a student's perception of their own ability resulted in switching their major
major switch: requirements	student switched majors at some point in their undergraduate academic career because of major requirements
non-school responsibilities	student refers to their responsibilities outside of school that affects their success
post-grad plan: change due to finances	student's post-graduation plan changed due to finances
post-grad plan: continue in STEM	student's post-graduation plan is to continue within STEM
post-grad plan: not using degree	student's post-graduation plan is to not use the degree they earned
post-grad plan: switch w/in STEM	student's post-graduation plan is to stay within STEM but in a different discipline/field
post-grad plan: undecided	student's post-graduation plan is undecided or unclear
science avoidance	student actively avoids enrolling in a science course after a negative experience

science capital: family	a student's family as being science capital
science capital: high school opportunities	a student's opportunities in high school as being science capital
science identity: change	student reports/refers to having a change in their science identity
science identity: high	student reports/refers to having a high science identity
science identity: low	student reports/refers to having a low science identity
self-doubt	student expresses doubting themselves or their abilities
self-esteem: affected by academics	referring to a student's self-esteem as defined as how they feel about themselves overall being affected by academics (either positive or negative)
self-esteem: affected by others	referring to a student's self-esteem as defined as how they feel about themselves overall being affected by others' opinions (e.g. family or others in general)
self-esteem: contextual	referring to a student's self-esteem as defined as how they feel about themselves overall being contextual
self-esteem: high	referring to a student's high self-esteem as defined as how they feel about themselves overall
self-esteem: low	referring to a student's low self-esteem as defined as how they feel about themselves overall
self-esteem: unaffected	referring to a student's unaffected self-esteem as defined as how they feel about themselves overall
sense of belonging: acknowledgement	student's sense of belonging affected by their acknowledgement by others in a field, discipline, or course
sense of belonging: family	student's sense of belonging affected by their family
sense of belonging: friends	student's sense of belonging affected by having friends or lack thereof
sense of belonging: other students	student's sense of belonging affected their position to other students in a field, discipline, or course
sense of belonging: transfer student	student's sense of belonging affected by their status as a transfer student
social influences: academic	student cites social influences within academia
social influences: family	student cites social influences within their family
social influences: friends	student cites friends as social influences

social influences: high school teachers	student cites former high school teachers as social influences
supportive advice/encouragement	student received supportive advice or encouragement that aided in their success
underprepared freshman	student exhibits behaviors of an underprepared freshman in not knowing how to navigate their first semester or year (i.e. navigating student-instructor relationships, communication, finding resources)
unsupportive advice/discouragement	student was given unsupportive advice or was discouraged from pursuing a major or succeeding in the course

VITA

STEPHANIE M. WERNER

Education

University of Illinois at Chicago **May 2021**
Doctor of Philosophy, Chemistry (Concentration: Chemistry Education Research)
Dissertation: "Representation and Retention in the Sciences: Investigating Inequities at a Minority-serving Institution"

University of Illinois at Chicago **May 2018**
Certificate, Educational Research Methodology

University of Iowa **May 2015**
Bachelor of Science, Chemistry (Minor: French)

Research Experience

Dissertation, University of Illinois at Chicago, Chicago, IL **2016 – Present**

Advisor: Mike Stieff, PhD

- Cleaned and organized large registrar datasets and selected statistical models to analyze diversity representation and retention in STEM departments and courses over fourteen years of data
- Created and distributed a survey to analyze affective characteristics, based on responses, to understand the relationship between affective attributes of undergraduate students and their persistence in STEM
- Crafted an interview protocol, conducted semi-structured one-on-one interviews, and qualitatively analyzed transcripts to form narratives of participants to understand why marginalized students do not persist in STEM

University of Illinois at Chicago, Chicago, IL **2017 – Present**

Research Assistant, The Connected Chemistry Curriculum (IES), Mike Stieff, PhD

- Assisted in data collection via recording video and audio observations of high school chemistry teachers and administer consent and pre- and post-assessments to high school students to measure the efficacy of the CCC materials
- Coded observation videos using the RTOP to characterize teacher and classroom behavior
- Cleaned and analyzed large datasets to analyze self-efficacy survey data to determine the effect the curriculum had on affective characteristics
- Facilitated professional development workshops to aid researchers and teachers in improving curriculum planning and design
- Collaborated with teachers and other researchers within a workcircle to design, write, and produce a socio-scientific unit to introduce social and environmental justice into the chemistry classroom

University of Illinois at Chicago, Chicago, IL **2017**

Research Assistant, Mechanisms of Visuospatial Thinking in STEM (NSF), Mike Stieff, PhD

- Collaborated with PIs and other research assistants from multiple institutions to determine research plan, protocol, and experimental design
- Created molecular stimuli in Jmol, ran statistical analyses on experimental results, and reported findings to research team to assist in the writing and submission of research articles
- Administered consent, experimental protocol, and post-surveys to human subjects

University of Iowa, Iowa City, IA **2013 – 2015**

Undergraduate Research Assistant, Scott Shaw, PhD

- Created a path length calibration model for Teflon IR spacers used with various liquids in order to examine more efficient methods to quantify water content in ionic liquids (Bmim [TFSI]) using FTIR and GC (compared to Karl Fischer method)
- Became proficient with FTIR, basic e-beam, sputter coating techniques, and polishing and chemically cleaning silver
- Coordinated the making and set up the lab's Schlenk line with departmental personnel

Related Experience

University of Illinois at Chicago, Chicago, IL **2016 – Present**

Teaching Assistant, Preparatory Chemistry, General Chemistry I and II, and Inorganic Chemistry

- Facilitated discussion in recitation sections and office hours to improve student comprehension
- Supervised laboratory experiments and assisted students in the interpretation of their results and meaning
- Collaborated on exam development and substituted for main lecturer (Inorganic Chemistry)
- Provided constructive feedback and graded all lab reports, worksheets, and exams

University of Illinois at Chicago, Chicago, IL **2017 – 2020**

Graduate Assistant, Department of Chemistry

- Edited the laboratory manual for General Chemistry I and II to reflect changes in experimental procedures, materials available, and the focus of chemistry concepts to improve readability and support student understanding

3M Center, St. Paul, MN **2015 – 2016**

Health Safety & Environment Regulatory Analyst

- Assessed, updated, established, and monitored EHS systems for TSCA, GHS, Reach, and RoHS compliance of 3M raw materials
- Communicated with engineers and chemists from analytical, materials, and processing research labs within 3M on current and future projects to determine any federal or global restrictions on chemicals
- Prioritized projects and managed timelines to plan, lead, and execute with deliverables on multiple projects

Professional and Community Service

Science in Society (Boys and Girls Club), Chicago, IL 2018 – Present

Science Club Mentor

- Facilitated discussion and carried out various science experiments and independent research projects with middle school-aged children to increase their interest and participation in science

University of Illinois at Chicago, Chicago, IL 2018 – Present

Board Member, Graduate Women in Chemistry (gWiCh)

- Organized both formal and informal events for graduate students which included faculty panels, career panels, volunteer opportunities, professional development, and social events to further the cohesion of women in the graduate program and further their career goals

National Science Policy Network 2020 – Present

Member, Diversity. Equity, & Inclusion Division and Central Hub Division

- Participated in science policy memo writing competitions to strengthen technical skills and collaborate with other members on matters important to the scientific community to bring about policy change
- Discuss current science policy initiatives at the national and local level in monthly division meetings

University of Illinois at Chicago, Chicago, IL 2018 – 2019

Chemistry Education Research Division Representative & Member-at-Large, Chemistry Graduate Student Association (CGSA)

- Organized social events for the graduate students and department to build community amongst students and members of the departmental faculty and staff

Skills

Quantitative analysis:

- Parametric statistics (e.g., t-test, regression, binomial/multinomial logistic regression)
- Non-parametric statistics (e.g., Mann-Whitney, Kruskal-Wallis)
- One-way and factorial experimental design & analysis (e.g., ANOVA, ANCOVA, multiple regression)
- Confirmatory factor analysis (CFA)
- Hierarchical agglomerative clustering (HAC) analysis

Qualitative analysis:

- Constant comparison analysis
- RTOP

Technical Writing:

- Journal articles
- Policy memos
- Grant/funding proposals
- Applications for research involving human subjects (IRB)
- Chemistry curriculum content (secondary and undergraduate level)

Programs and Software: SPSS, SPSS AMOS, Qualtrics, Tableau, Wordpress, ChemDraw, Jmol, Microsoft Office, Slack, Box

Languages: JavaScript, Python

Publications

Stieff, M., **Werner, S. M.**, DeSutter, D., Franconeri, S., Hegarty, M. (2020). Visual chunking as a strategy for spatial thinking in STEM. *Cognitive Research: Principles and Implications.*

Stieff, M., **Werner, S. M.**, Fink, B., & Meador, D. (2018). Online Prelaboratory Videos Improve Student Performance in the General Chemistry Laboratory. *Journal of Chemical Education.* https://doi.org/10.1021/acs.jchemed.8b00109

Invited Talks and Symposia

Representation and Retention in the Sciences: Investigating Inequities at a Minority-serving Institution. Presentation at Science in Society, Winter Orientation, 2021

How diverse are the STEM disciplines? A comparative study of representation, retention, and attrition of underrepresented groups in Chemistry, Physics, and Biological Sciences, Presentation at the Diversity & Inclusion in Chemistry Education Symposium, ACS National Meeting in Philadelphia, 2020 (Cancelled due to COVID-19)

How diverse are the STEM disciplines? A comparative study of representation, retention, and attrition of underrepresented groups in Chemistry, Physics, and Biological Sciences, Presentation at the Chemistry Graduate Student Research Symposium, University of Illinois at Chicago, 2019

A comparison study of representation, retention, and attrition of underrepresented groups in chemistry compared to other science domains, Presentation at the Addressing Underrepresented Groups in STEM Symposium at the Biennial Conference on Chemical Education (ACS), University of Notre Dame, 2018

Poster Presentations

Werner, S. M. & Stieff, M. (2020) *How diverse are the STEM disciplines? A comparative study of representation, retention, and attrition of underrepresented groups in Chemistry, Physics, and Biological Sciences*. Sci-Mix, ACS National Meeting. Philadelphia, PA. (Cancelled due to COVID-19)

Werner, S. M. (2019) *Why are the leaving? Representation, retention, and attrition of underrepresented groups in chemistry compared to other science domains*. Graduate Student and Post-Doc Professional Development Conference at Miami University. Oxford, OH.

Werner, S. M. (2019) *Why are the leaving? Representation, retention, and attrition of underrepresented groups in chemistry compared to other science domains*. Gordon Research Conference on Chemistry Education Research and Practice at Bates College. Lewiston, ME.

Szuba, A., **Werner, S. M.,** & Stieff, M. (2019) *Visuospatial Thinking in Chemistry: Effects of spatial ability, domain knowledge, and task strategies*. Gordon Research Conference on Chemistry Education Research and Practice at Bates College. Lewiston, ME.

Werner, S. M. (2018) *A comparison study: Representation, retention, and attrition of underrepresented groups in chemistry compared to other science domains*. Chemistry Graduate Student Research Symposium, University of Illinois at Chicago. Chicago, IL.

Stieff, M., Hegarty, M., Franconeri, S., **Werner, S. M.,** DeSutter, D., Gunalop, P., Rathbun, Z., Jardine, N., & Meyerhoff, H. (2018) *Mechanisms of Visuospatial Thinking in STEM.* Spatial Cognition Conference. Tuebingen, Germany.

Werner, S. M., Szuba, A., DeSutter, D., & Stieff, M. (2017) *Improving high school and college chemistry through evidence-based interventions*. Chemistry Graduate Student Research Symposium, University of Illinois at Chicago. Chicago, IL.

Werner, S. M., & DeSutter, D. (2017) *Mechanisms of Visuospatial Thinking in STEM*. Visualization in Science and Education Gordon Research Conference, Bates College. Lewiston, ME.

Honors and Awards

UIC LAS Diversity Initiative Award	2019
UIC President's Research in Diversity Travel Award	2019
UIC Graduate Student Council Travel Award	2018
UIC Graduate College Student Presenter Award	2018
TRUSE Conference Graduate Student Travel & Registration Award	2017
Gordon Research Conference Graduate Student Travel Award	2017
University of Iowa National Scholars Award	2011 – 2015
University of Iowa Dean's List	2011

Professional Affiliations

American Chemical Society (ACS), 2015 – Present
National Science Policy Network (NSPN), 2020 – Present
American Association for the Advancement of Science (AAAS), 2020 – Present
American Education Research Association (AERA), 2020 – Present
Society for the Psychological Study of Social Issues (SPSSI), 2020 – Present