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A Holistic View of Student Success in Systemic Change: An Investigation of Student Identities and Experiences in Undergraduate Mathematics

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A Holistic View of Student Success in Systemic Change: An Investigation of Student Identities and Experiences in Undergraduate Mathematics

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Mathematics and Science Education

by

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2024

The Dissertation of Colin Thomas McGrane is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

Chair

University of California San Diego

San Diego State University

2024

DEDICATION

I dedicate this dissertation first to my beautiful, loving, funny, and caring wife Rachel Allison "Ray-Chuck" McGrane and our two children Neal Finnegan "Boogie" McGrane and Saoirse Odette "Sweet Pie" McGrane. Your presence in my life has had a profound influence on my sense of humor, my energy to play, my capacity for love, and my motivation to support you all through a career focused on helping others. I know that you all make this possible because as Robert Hunter once wrote, "without love in a dream, it will never come true."

I further dedicate this dissertation to my loving and supportive parents, Hugh Joseph "Pop-Pop" McGrane III and Teresa Marie "Oma" McGrane. Thanks for teaching me to be a good person and never doubting my path, as we all know it took a long time (and a few hiccups) to get to where we are now. Your dedication to our family and the love you share is an inspiration to me. Our relationship has always revolved around honesty, helping others, and our love of music. These values which you instilled in me continue to shape our daily lives and I look forward to the next family dinner (or concert) to spend time nurturing the wonderful bond we share.

Lastly, I dedicate this dissertation to all my cats, living and deceased: Sunshine, Scarlet Begonias, Pickles, Olive, and Mia. I provided you with a big, warm lap; you provided me with unconditional love, purrs, and cuddles. I forgive you for all the times you walked along my keyboard or scratched me. Extra shout-out to the mice we adopted that may or may not have survived the unintentional Tom and Jerry situation we put you in.

EPIGRAPH

"In the attics of my life, full of cloudy dreams unreal.

Full of tastes no tongue can know, and lights no eyes can see.

When there was no ear to hear, you sang to me.

I have spent my life seeking all that's still unsung.

Bent my ear to hear the tune, and closed my eyes to see.

When there was no strings to play, you played to me.

In the book of love's own dream, where all the print is blood.

Where all the pages are my days, and all the lights grow old.

When I had no wings to fly, you flew to me, you flew to me.

In the secret space of dreams, where I dreaming lay amazed.

When the secrets all are told, and the petals all unfold.

When there was no dream of mine, you dreamed of me."

Robert Hunter, "Attics of My Life"

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I also acknowledge the California Learning Lab for funding the grant that allowed me to implement the student and instructor supports that became the focus of my graduate research for the past two years. Some of the data I collected became the focus of this dissertation, so without their support this dissertation would also not be possible.

Lastly, I acknowledge the wonderful community of MSED members.

VITA

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ABSTRACT OF THE DISSERTATION

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San Diego State University, 2024

Professor Chris Rasmussen, Chair

Student success is an integral part of systemic change research. However, students' lived experiences and voices are often subdued in this programme, leaving the change that occurs to be evaluated upon measures that do not capture a holistic view of the experiences students and their shifting identities during the roll-out of those changes. These experiences could include not only the grades received and math course persistence, but also their perception of instructional practices, their attitudes towards mathematics, and their sense of belonging in math settings. In this dissertation, students' experiences and identities are investigated through a mixed-methods research design, with a critically inspired theoretical perspective of Figured Worlds interfaced with Critical Race Feminism.

A survey that included Likert scale and free-response items was administered to students enrolled in Precalculus, Calculus I, and Calculus II. Additionally, semi-structured interviews with several students were conducted. Through qualitative analysis, students' meaning of mathematics and their personal mathematical narratives are constructed. Additionally, emergent themes of identity-based struggles contextualize the diverse population of individuals that make up the survey population. Instructional practices that mediate these identities and support diverse student needs are identified and discussed. Through quantitative analysis, I make the argument for expanding the conceptualization of student success from grades and course persistence to become more holistic by analyzing these traditional measures as well as novel affective measures that paint a broader picture of students' identities and experiences. This argument is based in a demonstration of analyzing these factors comparing responses to a survey from students enrolled in a newly designed support course and students who did not enroll in the support course.

The results indicate that students in the support course overall were marginally more 'successful' than their peers in terms of grades received, positive shifts in confidence, and sense of belonging. These results suggest that not only is the support course we designed a viable option for supporting students, but also that systemic change research ought to consider students' voices, identities, and experiences when measuring student success.

Chapter 1

Identity development while enrolled in undergraduate mathematics courses is an important factor in the student's overall experience as budding scientists. In this chapter, I identify room for growth in the research in the field and provide rationale for investigating student experiences in these courses which includes their confidence, sense of belonging, and the mathematical community they perceive. To continue this thread of inquiry, I argue the broader conception of student success to include grades received and overall quality of life in terms of support and reported identity-related experiences while enrolled in mathematics courses. In this chapter, I will introduce my rationale for studying student experiences in undergraduate introductory math courses, with their voices and lived experience as a legitimate source of data that has the potential to help understand more about the experiences that are driving students out of STEM. Then, I speak to mathematical identity and the integral role student voices and lived experience ought to have in systemic change research. The chapter concludes with my research goals and hypotheses.

Rationale for Studying Student Experience in Undergraduate Introductory Mathematics Courses

Mathematics departments across the nation are taking action towards growing diversification and inclusivity of Science, Technology, Engineering, and Mathematics (STEM) fields with an eye towards equity and social justice. One goal is to increase the number of US STEM workers by promoting and investing in the diversification and inclusivity of students completing STEM degree programs. In December of 2022, the White House Office of Science and Technology Policy (OSTP) released their vision to address the mission of unprecedented investment into diversifying and making accessible the ecosystem that surrounds the fields of science and technology (OSTP, 2022). One year after their progress report on the implementation of the federal STEM education strategic plan (OSTP, 2021), the OSTP detailed several impactful barriers between the public and the pathways to STEMM (including an extra M for medicine) and produced action items that address the systemic biases, racism, sexism, ableism, and ageism that plagues US institutions.

One of these action items is to provide adequate support to all community members throughout their lifetimes, including universal design practices to increase access to labs, classrooms, and workspaces and addressing structural barriers from adolescence to adulthood. To do so, I argue that the pathway to STEMM is hinged on the transformative process on undergraduate mathematics that shifts towards inclusive, diverse, and provides equitable opportunity and access for all. The OSTP mission demonstrates considerable effort from the current political leaders of the US with the goal to produce enough scientifically literate STEMM graduates to meet growing domestic demand.

However, this is not a recent foray into STEM education reform. The calculus reform movement of the 90’s called for a reduction of rote memorization and algorithmic procedures to be replaced by active learning and student-centered focus of instruction with similar goals of making Calculus more accessible and relevant to an increasingly diverse body of potential scientists (Steen, 2000). Indeed, the 20 years between 1998 and 2018 saw over 300 bills produced by congress with words “Science Education” (Granovskiy, 2018); a considerable amount of attention that demonstrates that STEM education reform is a longstanding, thorny issue in the US with Calculus instruction showing a surprising resilience against change.

The 2022 report from the National Science Board shows that the current US STEM labor force makes up 23% of the total US labor force. This includes all education levels and still shows a higher proportion of men, Whites, Asians, and foreign-born workers than the proportions of these groups in the US population (NSB, 2022). This is evidence of a continuance of the underrepresentation of women, Blacks, Hispanics, and other people of color and historically oppressed individuals in the US. This report also shows that the attainment of a degree appears to affect how this representation changes in different fields. While the share of Blacks and Hispanics in the US STEM workforce without a bachelor's degree is similar to the share of the entire US workforce, they are underrepresented among students earning Science and Engineering degrees (NSF, 2022). If retention and attainment of a STEM degree is affecting how STEM workers are represented, then it is reasonable to focus on the undergraduate STEM pathways and how they are serving the populations attempting to become the next generation of US scientists.

In order to attain a STEM degree, potential scientists of all fields are required to take a mathematics course pathway from Precalculus through Calculus 2 (P2C2), with some majors requiring an additional course in multivariable calculus. Due to this requirement, the P2C2 pathway holds enormous significance for the retention and degree attainment of potential scientists, acting as an access-controlling mechanism to the sciences. While these courses are designed to offer the skills and critical thinking needed to become a successful problem solver and scientist, the reality is that these introductory mathematics courses continue to drive out women at 1.5 times the rate as compared to men (Ellis et al., 2016) and historically underrepresented STEM students through the access-controlling functionality of the introductory courses (Ellis et al, 2016; Thiry et al., 2019).

In their study of over 110,000 undergraduate student records, Hatfield et al. (2022) found that even when controlling for academic preparation in high school and STEM degree intent, underrepresented minority (URM) students' records show the strongest association between low performance in introductory mathematics courses and their failure to obtain a STEM degree when compared to their non-URM peers. While defining academic preparedness based on ACT (composite) scores and high school GPA is a notable point of discussion, this study counters a prevailing narrative that socio-economic related factors such as redlined neighborhoods and their public school systems are mostly to blame for the disproportionate preparedness of students leaving high school and entering four-year universities. Acknowledging that student experience in calculus appears to be a mitigating factor for switching out of calculus courses (Ellis et al, 2016), the results from Hatfield et al. (2022) further indicate that women and URM students are disproportionately affected and that there must be something about the experience in these mathematics courses that are driving these students out of STEM.

What Experiences in Mathematics are Driving People Out?

In their recent follow up of their influential book on STEM persistence and loss, Talking About Leaving Revisited, Thiry et al. (2019) explain that students are leaving STEM for predominantly the same reasons they were leaving 20 years ago. This is not to say that nothing has changed since then, but it does indicate that some level of attention should be paid to what has persisted: the racialized and gendered experience of American life (Bonna-Silva, 2014). Exacerbating the issue, students may actively resist instructors' attempts to discuss race and racism in their classes because of socialization into the dominant colorblind ideologies and myths of meritocracy (Eisen, 2020).

Mathematics is often touted as a race-free, gender-neutral, universal language, but these seemingly positive and affirming narratives insinuate that race, gender, and disability should not be taken into account when considering the student experience in mathematics classrooms and that instructors need not attend to them (McNeill et al., 2022). As Leyva et al. (2021) explains, these narratives serve to maintain Whiteness (Battey & Leyva, 2013) and Patriarchy (Leyva, 2021) which are two parallel frameworks for the gendered and racialized motivations for oppressing those who are non-white and non-male, particularly in modern society.

The widespread presence of racial narratives (Shah & Leonardo, 2017) and gender narratives (Esmonde, 2011) in mathematics highlights the need to dismantle familiar stereotypes and the implications they carry. Consider the harmful myth that Asian descent assumes mathematical proficiency. Even something as positive sounding as "being good at math" has the ability to manifest negative connotations, due to the implication that there is a hierarchy of ability in mathematics based on identity that harmfully places people below others. More examples of the way that narratives around mathematics can imply harmful ideologies are outlined by Su (2015), who was then the president of the MAA.

When innate ability of mathematics is assumed because of a stereotype, students can experience stereotype threat, which is the extra pressure an individual feels to perform a certain way to not perpetuate those stereotypes (Steele & Aronson, 1995). Stereotype threat has been shown to affect performance in women (Spencerl et al., 1999) and minority students (Maass & Cadinu, 2003) specifically in mathematics courses, which often occurs as an unseen burden on students in classrooms and universities that may have the best intentions for equity and inclusion. While some aspects of the mathematics experience for students are unseen, there are also areas that are all too visible for students.

Aside from everyday encounters with the way whiteness and patriarchy have shaped the institutions of society (such as housing, public education, healthcare, etc.), students are subject to the behaviors of the people in their classroom and the instructional practices they experience. These behaviors, whether they are intentional or not, can often translate into microaggressions, which are manifestations of everyday, automatic slights or indignities against race, sex, and/or ability that can appear in the form of bad jokes, prejudices, lowered expectations, off-hand comments, or improvised banter (Sue, 2010). While the term microaggression was coined by Pierce (1974) regarding the Black experience, they have been shown to be a part of the current university campus experience of Black students (Solorzano et al. 2000), women (Sue et al., 2007), Chicano/Chicana scholars (Solorzano, 1998), Asian (Sue et al., 2007), and multiracial people (Harris, 2017).

Along with the everyday racism, sexism, and ableism that many students experience, Leyva et al. (2021) detail three gendered and racialized mechanisms of instruction in undergraduate P2C2 courses which include, “(i) creating differential opportunities for participation and support, (ii) limiting support from same-race, same-gender peers to manage negativity in instruction, and (iii) activating exclusionary ideas about who belongs in STEM fields (p. 1).” Even with the best intentions, and despite efforts to increase diversity, equity, and inclusion in US universities, it is important to acknowledge that instructional practices and behaviors of classroom members can still promote and perpetuate the racialized and gendered narratives that continue to plague students in mathematics classes today.

Mathematical Identity and Student Voices in Systemic Change Research

Universities and systemic change researchers are deeply invested in determining what fosters STEM students’ success as measured by a variety of quantitative metrics: equity gaps in course grades, retention in STEM degrees, and placement data to name a few. Whichever way success is defined in terms of outcomes that benefit students, instructors, or the department, the way that researchers quantify and analyze the outcomes often leaves out an integral aspect of the student experience: their own voice. In order to build a sustainable vision for change in mathematics departments, the stories and lived experience of the students enrolled in courses targeted by change efforts would benefit by being captured and highlighted.

Additionally, there exists a need in the field for studies on the nuances of intersectional identities and their perception of instructional practices (Leyva et al, 2022). The use of the term intersectionality here is as coined in Crenshaw (1991), who describes it as a prism to view compounding pressures and barriers put on students because of the various identities they hold, such as black women who experience discrimination for their race as well as their gender.

In this dissertation, in the tradition of critical theory in mathematics education (Ladson-Billings &Tate, 1995; Lynn & Dixson, 2013), and more specifically Critical Race Feminism (CRF) where I will later detail in Chapter 2 how it can be interfaced with Figured Worlds Theory, I will believe and amplify real student voices to disrupt the racialized, gendered, and ableist status quo. I will also offer students a survey that allows them to report their own changing perceptions of themselves, their identity as it relates to mathematics, and their perception of instructional practices and university support structures. This critical research-inspired mixed-methods approach will highlight the perceptions of instruction and systemic change efforts with a focus on historically underrepresented student intersectionality and is expanded upon further in the third chapter of this dissertation.

An unavoidable aspect of studying student voices is their ever-adapting identity as they are adults growing, students learning, and budding mathematicians problem-solving. Acknowledging the fluid nature of identity and the amount of contemplation it takes for students to relate their identity (and all that entails including racial identity, gender identity, sexual orientation, and disability identity, etc.) to their ability to learn mathematics and their perception of instruction and student supports is an important step towards a critical understanding of the introductory mathematics experience, especially of the least represented and most often stereotyped populations. Between interviews and free response survey questions, students will have the opportunity to take time to consider what is most impactful to their experience.

Beyond the importance of broader identity theory set forth by researchers such as Gee (2000) who developed four types of identity (natural, structural, discourse, and affinity) there exists a more nuanced and specific identity framework that applies to how an individual sees themselves through a mathematical lens. Mathematical identity is defined by Martin (2006) as “dispositions and deeply held beliefs that individuals develop about their ability to participate and perform effectively in mathematical contexts and to use mathematics to change the conditions of their lives” (p. 206). Thus, mathematical identity development is important to this dissertation because of the impact it has on the sense of belonging in a mathematical space and the perception of how mathematics can be used to liberate students from oppression.

While some research focus specifically on black student experience and how whiteness and anti-blackness continue to harm students (e.g. Martin, 2019; Davis, 2022), the experiences of Latina students (e.g. Aguirre et al., 2020; Rinchiera, 2020; Rodriguez & Blaney, 2020), women (e.g. Jensen & Deemer, 2019; Bloodhart et al., 2020), APIDA students (e.g. Castro & Collins, 2021) and disabled students (e.g. Annamma, Connor, & Ferri, 2016; Lambert, 2019) in STEM fields have found their way into the literature base of identity in mathematics that will be expanded upon in my following literature review chapter.

Students’ voices and experience are integral to understanding how students perceive the supports provided by the university and the ways that these structures can be improved. I believe that fostering equitable experiences in mathematics and the support structures provided to students is one important factor towards social justice. Acknowledging that helping current students will not provide reconciliation for past injustices, attempts must be made to serve students in a way that aims to provide the future that students dream of and towards a future of the more diverse STEM field that has been promised.

One recent attempt at supporting students at the host-university for this dissertation, with assigned pseudonym Southwestern University (SWU), appears in one arm of a larger grant project that implemented multiple supports for students and instructors that a team of mathematics educators and I developed. The specific implementation that is integral to the students' experiences and data I collect and analyze for this dissertation is a support course that the team and I designed. This voluntary support course acts like a co-requisite, where students enroll in the course concurrently with their enrollment in either Precalculus or Calculus I. However, it stands apart from other co-requisite courses because instead of regular class meetings with a single instructor, our support course is housed entirely through an online learning management system run by a coordinated care provider. That means students do not meet the person who runs the online course shell weekly, but they are required to attend Supplemental Instruction (SI) sessions that occur throughout the week at various times of day and with several different SI leaders. More detail about this support course, including how SI leaders are chosen, the pedagogy that inspires SI sessions, the everyday format for a student enrolled in this course, and the design of the online component of the support course will be included in Chapter 3.

Research Questions and Hypotheses

I am interested to learn about mathematics students' evolving identity as it relates to their experiences in precalculus and calculus amidst the roll out of student support structures and change efforts. I broadly consider experiences to include identity development, in-class experiences, supplemental instruction experiences, study experiences, math and stat learning center experiences, and assessment experiences (which includes grades received). The students I want to learn about and will refer to in my research questions are STEM-Intending 4-year college students enrolled in Precalculus and Calculus, with the following foci: (1) historically underrepresented or underserved students, (2) students enrolled in a newly designed support course that runs concurrently with their enrollment to Precalculus or Calculus. As such, I will utilize the sociocultural theory of Figured Worlds through a Critical Race Feminism lens to highlight how identity is developed in these courses, how students perceive their own belonging in a mathematical space, and how their stories of success can be used to learn about and improve student support structures for undergraduate mathematics courses. Directly following from these threads of inquiry are the following two research goals and questions:

1. Investigate the connections between students' self-reported identity, what mathematics means to them, and the mathematical community they perceive.
    A. How do the interviewed students define mathematics and what it means to them?
    B. How are students' mathematical identities mediated by the instructional practices and the mathematical community they perceive?
2. Investigate student success of those enrolled in the support courses compared to those who are not.

A. In terms of external evaluation of success from the university, how are students succeeding by grades and retention?
B. How did their reported instructional experiences, confidence, and sense of belonging differ?

For this point on, I will refer to the research questions (RQ) with the shorthand RQ-1A, where ‘1’ represents the first research goal and ‘A’ represents the first research question. My hypothesis is that while not one particular intervention or effort will be able to conclude that it was the sole reason for success or failure in the closing of equity gaps in DFW rates and increasing STEM retention, there will be significant evidence from comparing my data to past department data that the proposed efforts have collective impact on the quantitative results of grades and retention, as well as other indicators of success. Since equity gaps will likely not close in the time frame of this study, I expect to reinvigorate discussion about how and why equity gaps persist. Acknowledging that while equity gaps and achievement gaps are important to identify and rectify, it is also important to me that my research design shy away from gap-gazing (Gutiérrez, 2008) or reinforcing prevailing narratives around ability and identity in mathematics. My hypothesis continues with how these equity gaps occur in alignment with how students relate their mathematical identities to their mathematics education experience.

Chapter 2

In this chapter, I review the literature of identity in mathematics education research and how this research became an increasingly important focus within the context of systemic change. This review fits within the context of broader systemic change research because of the shift in direction towards equity the field has taken and the influence this had on the primary goal for the student and instructor supports implemented locally: closing equity gaps in the Precalculus through Calculus II (P2C2) pathway. In particular, I am inspired by my involvement in a movement of local change in a math department focused on supporting students who fall into the categories of equity gaps in P2C2 courses at our university.

I begin this chapter demonstrating some evidence of the shift towards equity in systemic change research, how this shift brings student identity into focus, and continue with a deep exploration of the use of Figured Worlds as a theoretical framing that highlights changing identities. Then, I will fold in the use of Critical Race Feminism (CRF) as a lens that emphasizes connections between power, race, gender, and intersectionality which can be interfaced with Figured Worlds to create a holistic picture of identity development contextualized by the history of underrepresentation of women and people of color in the sciences. This chapter ends with the presentation of Figured Worlds interfaced with CRF as a potential candidate for a theoretical stance that aligns with the values of systemic change.

A Shift Towards Equity in Systemic Change Research

My time as a graduate student researcher in the field of systemic change research has provided me with a unique experience to view mathematics departments across the nation through a mathematics education researcher's lens. I am fortunate to have worked as a graduate researcher on two of the collaborative, multi-institutional efforts to learn about the current state of calculus in the US (Progress through Calculus (PtC)) and the way that active learning can be infused into P2C2 courses (Student Engagement in Mathematics through and Institutional Network for Active Learning, or SEMINAL) that subsequently followed the Characteristics of Successful Programs in College Calculus (CSPCC) team's investigation into identifying characteristics of successful calculus programs. It is within the timeframe of my involvement (since fall of 2019) that equity, diversity, and inclusion have become increasingly salient in the focus of the research. This aligns with a few major milestones of including equity as a focus in that same time.

The first I will discuss is the inclusion of the third and fourth pillars to round out the aspirational pillars of Inquiry Based Mathematics Education (IBME) put forth by Laursen & Rasmussen (2019). This work combines years of research on inquiry-based and inquiry-oriented mathematics education and culminates to four pillars that are focused half on what students do and half on what instructors do. The fourth of these revised pillars is an explicit focus of the instructor on attending to equitable experiences of their students, which is important to the shift towards student-centered, active learning pedagogies such as IBME. One way that student identity becomes salient in an active, inquiry-based classroom is an instructor who wants to highlight contributions from students with identities that are often underrepresented, lending ownership of mathematical ideas and mathematical authority in the classroom and creating opportunities for students to engage in other students' thinking. IBME is one pedagogical approach that allows instructors to trend away from traditional lecture, to actively engage students, and to allow for room to focus on fostering equitable experiences through attending to the unique identities of the class.

Simultaneous to the transformative mathematics reform that SEMINAL studied, research in the same time frame indicated that not only did active learning increase student performance in science, engineering, and mathematics (Freeman et al., 2014), but active learning also narrowed achievement gaps for underrepresented students in undergraduate STEM courses (Theobold et al., 2020). However, it is important to note (as Theobold et al. (2020) does in their discussion) that active learning is not a panacea, as some studies have found increased achievement gaps and disproportionate participation across gender. An understanding of how equitable experiences for students and active learning were connected and in support of one another assisted in the promotion of equity-driven change in mathematics departments, particularly as the culture around equity changed through tangible and actionable ways (Voigt, et al., 2020).

Another shift towards equity occurred in 2020, which was the three-armed phase III efforts of the SEMINAL project, one of which focused on equity. More specifically, members of the SEMINAL team united with other mathematics educators to embark on developing and researching a social-justice focused equity training for a professional learning community of instructors across different roles and multiple institutions, which has produced some publications recently (Machen et al., 2021; Martinez et al., 2021;Tremaine et al., 2022) and lessons learned from this endeavor are still currently being analyzed and disseminated (Voigt et al., 2023). This striving towards combatting racialized experiences in the classroom was timely, as the US experienced police brutality protests triggered by the murders of Brianna Taylor, George Floyd, and countless others in the first half of 2020 and the national conversation around modern-day systemic racism became commonplace.

A third recent development is the work of Ellis-Hagman (2021), one of the original authors of the seven characteristics of successful calculus programs (Rasmussen et al., 2014), that argues for an 8th characteristic: diversity, equity, and inclusion practices. This 8th characteristic comes seven years after their original work, inspired by much reflection and a determination to revisit data collected around 2010. While the original seven characteristics did indeed emerge from the analysis of successful programs, what was not accounted for was who these programs were largely successful for: White, Asian, and male populations. As Ellis-Hagman (2021) explains, this reflection on past data and what was potentially missing in their original analysis led to the discovery that equity, diversity, and inclusion must deserve a place in this list of characteristics.

More shifts toward equity in systemic change research were noticeable outside of the CSPCC, PtC, and SEMINAL lineage, as widely networked and influential as they are. As the NSF ADVANCE notes, their early years (beginning in 2001) focused on funding individuals who showed promise to promote gender equity but they learned that often these individuals were in environments that did not support their success, which led to a shift in funding towards groups who were able to help transform structures known to cause inequities and focus on the complexities of intersectionality (DeAro et al., 2019).

ADVANCE is one part of the NSF network of projects, scholars, subcommittees, and organizations called NSF INCLUDES, a national initiative with a focus on accessibility and inclusivity in the STEM fields through collaborative efforts of systemic change that advance equity and lead to sustainably expanded participation from historically underserved communities in STEM (NSF, 2022). The inclusion of a focus on equity in NSF's mission and the unprecedented funding they have achieved to secure from the US government, which will more than double in the next five years (NSF, 2022), is an indication that equity is an increasingly important aspect of transforming the nation's STEM ecosystem and the role that research on equitable experiences for students will play in the efforts for the systemic change necessary to reach our goals of racial and gender equity.

This shift towards outcomes that focus systemic change more on equity, diversity, and inclusion align with the sociopolitical turn in mathematics education. This turn is described by Gutiérrez (2013) as moving beyond the sociocultural perspectives of teaching and learning in order to build on a lens of how the structures and cultures around identity and power are often downplayed without the inclusion of sociopolitical perspectives. Another example of the encouragement of this turn towards sociopolitical shift in mathematics education is Adiredja and Anderews-Larson (2017) as they call for the need to attend to equity by using perspectives that focus on identity, power, and their interrelatedness with social discourses and ways of knowing.

Identity in Mathematics

As I acknowledge my own cisgender, white, male, researcher identity as it potentially fits within the progress towards a more inclusive and critically influenced research programme, I align my perception of identity with a post-structuralist approach, as in Collinson (2006) who describe it as dynamically designed by a variety of factors and always in flux. In addition to this position on identity, I also consider Martin's (2006) definition of mathematical identity an important supplement that narrows the focus specifically to the ways students enact their own identity as "doers" and "learners" of mathematics. Thus, mathematical identity is beyond the realm of natural, structural, affinity, or discourse identities as laid out by Gee (2000) but not without being intertwined among them.

Identity literature in education is dispersed across disciplines, creating different paradigms that utilize different definitions of identity that lend themselves to various situations. Gee (2000) reviewed the use of identity in education literature and compiled four ways to perceive identity: (1) natural identity, (2) institutional identity, (3) discourse identity, and (4) affinity identity. These four categories allow for discernment between different types of identity that a person holds, but it is important to recognize that everyone relates to each category differently and possesses the agency to accept or reject how they see themselves or how others see them through these lenses. While these four types of identity are not necessarily exhaustive, they form a foundation on which to layer more complex ideas.

Natural identity is shaped by forces beyond the individual's control, such as where they were born or who their parents are (Gee, 2000). Someone's natural identity is often difficult to change, however accents can be hidden and secrets can be kept. Institutional identity refers to an individual's place in an institutional system, often with power structures defined by explicit hierarchies such as the typical sales office or a position as an assistant professor at a college (Gee, 2000). Positions can change with experience, just as an employee might get fired for negligence or promoted for excellence. Discourse identity refers to individual traits, such as being recognized in class as being “the smart kid”, or being a professor that students say is “difficult to talk to”. Discourse identity is shaped by what people say about an individual, whether they are talking directly to them or about them while they are not present (Gee, 2000). Affinity identity affords the most amount of individual agency, with an identity that someone subscribes to as a member of a cultural group, a fan of a band, or a supporter of political ideologies. An example of affinity identity is a Grateful Dead fan who places a “steal your face” (Owsley, 2005) symbol on the back window of their car—this sticker does not define who that individual is but shows others that they enjoy the music and being a part of the counterculture that surrounds that particular group.

The concept of mathematical identity has been utilized in change research to leverage student experience as an important data collection point in the student version of the postsecondary instructional practices survey (S-PIPS) created and distributed by the PtC and SEMINAL teams (Apkarian, et al., 2019). These surveys include sections where students self-report their own confidence, enjoyment, and interest in mathematics alongside reports of their sense of belonging and sense of inclusivity in the mathematics classroom. The inclusion of such areas of focus, specifically on student experience, is integral in capturing student voices in efforts that focus largely on an equity-driven systems approach.

Mathematical identity fits within Gee’s broader framework of identity because of the narratives around mathematics and ability that specifically pertain to natural identities, such as the “Asians are good at math” narrative (Shah & Leonardo, 2017), or the lowered expectations that Black students perceive from their instructors (Martin, 2012). Since natural identities relate to the aspects of one’s identity that go unchanged throughout a lifetime such as race or ethnicity, narratives of innate mathematical ability are potentially the most difficult for students to avoid. These narratives are woven into the fabric of conversations about mathematical ability and affect students’ perception of themselves within the academic community.

Figured Worlds

Consistent with my research questions and participants, I will utilize Figured Worlds (Holland et al., 1998) interfaced with a critical lens. Figured Worlds is a theory of identity and self, as they relate to how identities are produced or subdued in educational spaces. They are defined by Holland et al. (1998) as, “socially and culturally constructed realms of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others” (p.52). This approach offers a view into how students’ identities in mathematics are influenced by their interactions with peers, instructors, and the institutional culture of mathematics education. This provides a contextual understanding of identity, where identities are shaped through participation in social worlds where cultural narratives and practices are enacted. For clarity, “Figured Worlds” (with capitalization) refers to the theoretical framework that examines how individuals interpret and navigate their identities within specific cultural contexts, while a “figured world” is one particular cultural setting or activity system, such as a mathematics classroom where students’ mathematical identities and social roles are shaped and negotiated. This section begins with a subsection that details my rationale for using Figured Worlds as opposed to other identity theories and continues with a subsection that focuses on providing examples of how Figured Worlds has been used in a Mathematics Education context.

Rationale for Using Figured Worlds

The utilization of Figured Worlds is important to my dissertation because I want to learn about how students relate their identity to the mathematics they are learning and the mathematical community they perceive. Using this theory of identity and self, I will be able to provide rich accounts of students' experiences in mathematics courses, including their identity development within the mathematical community they perceive, their perception of mathematics, and their success. The focus on student voices, as they act as counter-narratives to prevailing discourse and beliefs in mathematics, is emphasized in Figured Worlds. This can help uncover how students' stories about their experiences in mathematics courses reflect broader cultural narratives about who is capable of succeeding, and this is necessarily highlighted even more so through the weaving in of additional sociopolitical theories.

Based on my own experience as a Calculus I TA for five semesters, I have some idea of what to anticipate in terms of the types of worlds that are figured for students in undergraduate introductory mathematics courses. One way these figured worlds come naturally into conversation with students is their comparison of the world of mathematics in high school versus the world they perceive in college. While talking with students, they often compare their experiences from high school to their current experiences, because they differ in ways that they were not expecting and trigger self-evaluations about the "type of student" they are (e.g., the type of student that seeks tutoring, the type that needs help, etc.). Other worlds that I anticipate speaking with students about are the worlds around gender and racial identity. For example, there is the world of being a woman in America, more specifically the world of being a woman studying STEM at a university. The intersection of these figured worlds and the way that students are negotiating their identity within multiple worlds has the potential for rich analysis and discussion.

Sociocultural theories such as Figured Worlds can be interfaced with a theoretical lens through which to view sociopolitical aspects of the interconnectedness of identity, power, and knowledge (Esmonde & Booker, 2017). It is important that I utilize both Figured Worlds theory, as it pertains to how identity is developed among contextualized experiences in mathematics, and Critical Race Feminism (CRF) to reveal how instructional practices reinforce or challenge power relations and privileges that affect students' sense of belonging and confidence in mathematics. More detail about CRF, the critical tradition it is borne from, and how it aligns with the goals and values of systemic change is discussed in the following section.

Acknowledging that individuals are active agents who navigate and sometimes resist the roles and expectations imposed by the figured worlds they inhabit, it is important to my dissertation to have a framework that explores how students exercise agency in mathematics classrooms with the potential to challenge stereotypes or structural barriers. In investigating the research goals for this dissertation, I provide student-centered insights that create discourse about educational policy as it pertains to student supports in mathematics at this university and others. Through this work, I intend to promote social justice awareness and activism on whatever scale possible (e.g., student level, department level, university level).

This rationale for using Figured Worlds interfaced with CRF ties directly to following my research goals and answering my research questions. For RQ-1A, I analyze responses around the interview questions where I asked students about how they define mathematics, what it means to them, and their personal mathematics stories. Since mathematics experiences do not occur in a vacuum, the social influence of narratives around mathematics and power dynamics are likely to arise in their answers. For RQ-1B, I take a broader approach to our conversations that takes into account any utterance that is related to identity development, instructional practices they encountered, and the mathematical community they perceive at SWU. Utilizing Figured Worlds through a CRF lens assists in my interpretation of these conversations and how identities can be mediated by these student experiences. I do not expect Figured Worlds to tie into RQ-2A and RQ-2B as much because they mostly rely on quantitative data taken from course enrollment patterns, grades, and survey responses. However, this is where a CRF-inspired focus on quantitative analysis becomes useful to analyze the data in a way that acknowledges the pitfalls of many traditional statistical methods.

Reviewing Figured Worlds Literature

Research utilizing Figured Worlds in Mathematics Education highlights the significant role of classroom interactions and instructional approaches in shaping students' mathematical identities. Nasir and Hand (2006) explore how African American students' identities are shaped within the cultural and social practices of their learning environments. Highlighting students' participation in mathematics as a crucial aspect of identity formation, they show that it is not just influenced by their individuality or their personal traits but is shaped also by cultural narratives and the practices within their classroom communities. Thus, Figured Worlds is a tool that researchers have used to contextualize how the experiences of students in mathematics classes go beyond the individual because they are impacted by social and cultural factors at the classroom level as well as the societal level.

Boaler and Greeno (2000) further elaborate on this idea by investigating how different pedagogical approaches create distinct figured worlds that influence students' identities as mathematics learners. This study found that identity-focused pedagogical approaches, which emphasize active learning and collaboration, support more positive identity formation compared to traditional methods that often marginalize some students' ways of thinking and knowing. Similarly, Turner et al. (2013) focus on the figured worlds of Latina/o students in mathematics classrooms, where they found that culturally responsive teaching practices significantly enhance students' engagement in class as well as their mathematical identity formation. These studies collectively show that instructional practices and classroom culture play a crucial role in shaping students' mathematical identities, demonstrating the utility for a framework like Figured Worlds that takes into account the importance of focusing on students' perceptions of instructional practices.

The broader social implications of these findings point to the necessity of rethinking mathematics education to better support diverse student populations, with Figured Worlds being an integral tool to use in researching current student experiences in mathematics classes and their own narratives. Sfard and Prusak (2005) highlight the importance of personal narratives of students that focus on how their identity is shaped, suggesting that educators and researchers alike ought to pay attention to the stories that students tell about their experiences and their perceived abilities. Hand and Gresalfi (2015) adds to this by using Figured Worlds to examine the role of racial and cultural narratives in students' mathematical identities, furthering the argument that there is a need for instructional practices that regularly challenge stereotypes. These studies call for a shift towards more inclusive and equitable mathematics education practices, which I believe includes not only rethinking our own teaching practices as educators but also incorporating critical, sociopolitical perspectives into the research on students' identity formation in mathematics classrooms.

Interfacing sociopolitical perspectives to investigate figured worlds of mathematics education, such as CRF, removes the veil of the status quo and reveals deep-seated systemic inequities in US education institutions. Gutierrez (2017) discusses the concept of "political conocimiento" in the figured worlds of mathematics education, where she argues that educators must additionally attend to their politics as a form of teacher knowledge and build this necessary skill for teaching. Analogous to the harmful narratives and popular beliefs around the gender-free and race-free characterization of mathematics (Shah & Leonardo, 2017), this article persuades educators who believe that mathematics should be more straight-forward and politics-free should reconsider. This critically conscious perspective is crucial for understanding how educational practices can perpetuate or challenge societal inequities.

There are many researchers who use critical and sociopolitical theories to investigate how certain populations of students experience the figured world of mathematics education differently than others, in particular with regards to race and gender. Martin (2006) provides a comprehensive analysis of how Black students' identities are constructed within this context, demonstrating how racialized experiences and systemic inequities impact Black students' mathematical identities and success. Likewise, Battey and Leyva (2013) examine the influence of racial dynamics on Black students' participation and achievement in mathematics utilizing the perspective of Critical Race Theory within the figured world of mathematics education for Black learners. In addition, Spielman (2012) incorporate feminist theories to analyze how gender and other social identities influence students' experiences in mathematics, advocating for teaching practices that recognize and challenge gender biases. While these studies do not explicitly cite Figured Worlds, each call for educational practices that challenge the status quo, demonstrate how critical theories can be utilized in mathematics education research, and underscore the need for critical examination of how power, race, and gender intersect within educational settings to influence student outcomes.

There are also examples in the literature of utilizing Figured Worlds to understand the experience of special populations among university students, such as transfer students and commuter students that open discussion of intersectionality of race, gender, and being a part of one or more of these special populations of students. Heileman et al. (2022) examines the experiences of community college transfer students in mathematics at a four-year university. It utilizes Figured Worlds to analyze how these students reconstruct their mathematical identities in a new academic environment and this analysis reveals challenges transfer students face in adapting to new education settings and the promotes the importance of institutional support in their success. Hagedorn and Castro (1999) also utilize Figured Worlds to investigate the experiences of commuter students, who often rely on part-time faculty in particular. They discuss the implications of part-time faculty on commuter students' academic engagement and success, a factor of the 4-year university experience that is often overlooked.

Another special population of students important to this study are first-generation college students, who are the first of their immediate family to attend post-secondary education. First-generation students are faced with less privilege than their peers because of the fact that their parents did not attend college and are less likely to offer advice from personal experience. Jehangir (2010) is a book that explores the experiences of first-generation college students through the lens of Figured Worlds, examining how these students navigate their identities and find a sense of belonging in higher education. Cox (2011) also focus on first-generation students, with a focus on the challenges faced by these students and highlights the importance of understanding these cultural and identity-related challenges to inform supportive institutional practices. These studies both emphasize the importance of creating inclusive environments that recognize and support the unique experiences and identities of first-generation students, with a focus on practical ways that researchers and instructors alike are able to apply their newfound appreciation for these students' experience.

Identity Theory and Critical Theories Aligned Within Systemic Change

In a recent article in the Journal of Urban Mathematics Education, Davis (2022) recalls their own critical race theory in mathematics education (CRT(ME)) journey and argues that in order to avoid the misuse of CRT(ME), researchers must understand the history of how CRT was applied to law and in education. From the outset, CRT was brought forth as a response to the inability of critical legal studies (CLS) to address racism, albeit a step in the direction of analyzing social structures that are upheld by mechanisms such as discourse and legal ideology (Tate, 1997). Thus, the fundamental aspect of CRT is the belief that racism is ingrained in American society and just as alive today as it ever was.

As researchers in education recognized in the 90's that racism was also unaddressed and untheorized in their field, CRT was used to bring race to the forefront, where Tate (1994) was first to make a critical examination of the racist foundation of standardized testing in mathematics. Ladson-Billings and Tate (1995) followed with a formal introduction of CRT(ME), where they argue that inequities in education, and mathematics specifically, can be understood through pervasive inequitable social structures. As with the connection between property rights and race, intellectual property was theorized to be racialized as well, which led to a crucial understanding that education, intellectual property, and ways of knowing are all intertwined with the foundation of race in US society (Ladson-Billings & Tate, 1995). This influential paper set off a legacy of critical scholarship in education that was assisted by special issues of journals (e.g., Parker et al., 1999; Lynn et al. 2002) and further exploration into the way CRT(ME) can expand into applications across scholarship (Tate, 1997).

Delgado and Stefancic (2001) identify a number of tenets of CRT: (1) the belief that racism is part of the fabric of US society, (2) the convergence of interest is the driving motivation for dominating members of society to change, (3) race is believed to be a construct of society, (4) intersectionality as the retort to essentialism, (4) counter-narratives and voices of the oppressed are valued. Ladson-Billings (2013) argues that studying race or racial issues is necessary but not sufficient to make someone a critical theorist, rather they must subscribe to these tenets and infuse them into their research and practice throughout their scholarship. It is with this dissertation that I hope to demonstrate that my beliefs and values align with these tenets and continue to shape the way I perceive my place in a researcher's position of power. However, it is important that I also factor in the experiences of women, particularly women of color, into my analysis which is why I chose to interface Figured Worlds theory with a more specific theory, Critical Race Feminism (CRF).

CRF is an intellectual and activist movement that extends CRT by integrating feminist perspectives to address the intersecting dimensions of race and gender oppression. Originating from the foundational work of scholars like Kimberlé Crenshaw, CRF emphasizes the unique experiences of women of color that are often overlooked in both traditional feminist and antiracist discourses (Crenshaw, 1989). This theoretical framework critiques the monolithic approaches of mainstream critical theories by highlighting how the compounded effects of race and gender create distinct forms of marginalization.

Building upon the tenets of CRT, such as the centrality of race and the challenge to dominant ideologies, CRF incorporates feminist insights on patriarchy, sexuality, and social reproduction. Scholars who pioneered the utility and complexity of CRF such as Patricia Hill Collins and Bell Hooks enriched the framework by exploring how structures of power and domination are perpetrated through both racial and gendered lenses (Collins, 2000; Hooks 1981). By examining the lived realities of women of color, CRF advocates for a more inclusive and nuanced understanding of justice and equity. This approach not only broadens the analytical scope of CRT but also deepens the commitment to addressing complex systemic inequalities (Wing, 1997).

In their recent review of change theory literature, Reinholz et al (2020) systematically inspect change theory research in STEM higher education that not only reviews and categorizes extant literature by the change theory utilized, but also encourages discussion about what is necessary to add to the literature today. In particular, I contend that Change Theory research in STEM has focused on change without theoretical perspectives that ground the fundamental aspects of what they are changing within a critical framework. While Change Theory recognizes the need for systemic change to combat inequities and the need for research on how this change occurs and sustains, including a critical perspective in this research programme adds another lens through which to view how the status quo is so resistant to change. For example, if professors “stuck in their ways” and department cultures that “are less than inviting” are viewed through CRF lens, one might find that these resistances are consciously or unconsciously in service of maintaining Whiteness and Patriarchy.

Change efforts of the 24-year period between 1995 and 2019 primarily claim increased student success as their end goal, but common indicators of student success such as student grades or retention have implicit assumptions about what is valued

(Reinholz et al, 2020). Reinholz et al. (2020) continues to say that alternatively, students' mathematical identity, their sense of belonging, satisfaction with their education, and quality of life are all indicators of success that draw on students' lived experience and are noticeably absent from current journal publications on Change Theories in higher education STEM research.

While CRF promotes the discussion of the pervasive issues of patriarchy, whiteness, and racism in education, systemic change efforts (in research and in practice) rarely take the opportunity to borrow from this philosophy to inform their implementation. Through the combining of these perspectives, one can view an emergent image like the lenses of red and blue 3D glasses. Through one or the other, only two dimensions are overlaid and competing on a flat screen; through both, a clearer image that emulates three-dimensional life is formed. Analogously, how to view student grade outcomes, retention, or equity gaps as either data points to change-- or symptoms of colonial systems to disrupt-- would have a strong impact on the approach to implementation of change efforts and the research performed on them.

Solórzano and Yosso (2002) contend that CRT in education "is a framework or set of basic insights, perspectives, methods, and pedagogy that seeks to identify, analyze, and transform those structural and cultural aspects of education that maintain subordinate and dominant racial positions in and out the classroom" (p. 25). Building from this definition, critical theories including CRT and CRF are directly aligned with the values systemic change efforts, as the transformation of structures and cultural aspects of education are the same goals that some Change Theories have, including the Four Frames of Systemic Change in STEM departments (Reinholz & Apkarian, 2018).

Building from the multi-disciplinarity of the original multi-frame perspective of organizational change put forth by Bolman and Deal (1991), Reinholz and Apkarian (2018) produce their four frames in STEM departments: (1) structures, (2) symbols, (3) power, and (4) people. Through the inclusion of all four frames, culture is defined as, "a historical and evolving set of *structures* and *symbols* and the resulting *power* relationships between *people*" (Reinholz & Apkarian, 2018, p. 3). As Reinholz et al. (2020) notes in their review of the literature, the use of the four frames occurred the second-most often, with Communities of Practice (Wenger & Nuckles, 2015) ahead of it. However, due to the recency of the four frames and their focus on culture, which is often downplayed in systemic change literature, I believe their versatility and alignment with values held by critical theories creates a rich theoretical foundation to promote a shift of Change Theory research into the sociopolitical, critical realm.

In addition to promoting social justice and activism, I plan to contribute practical and theoretical contributions to the field in regard to institutional change and how learning about the student experience can inform future change efforts locally and beyond. It is my intention to describe more practical and sustainable ways of change through developing a better understanding of the experience of historically minoritized students, providing reasonable ways to attend to students' evolving identities to understand their level of engagement with various supports offered by the university. Furthermore, I intend to contribute theoretical contributions to the field of systemic change, where I can demonstrate the utility of weaving in CRF as the intersectional lens through which to analyze data through the figured worlds perspective. I aim to broaden the perception of how to believe and amplify student voices to invigorate and improve future systemic change studies.

Chapter 3

Designing the methodological approach for this study requires a careful amalgamation of quantitative and qualitative methods. This mixed-methods approach works to leverage affordances of multiple types of data and benefits from the acknowledgment that data and interpretations of data herein hold structural, societal, and relational power: the power to negate and dehumanize, as well as the power to liberate and enfranchise. This section describes my methodology, with focused attention to the way I collect and analyze data and how my positionality aims at the latter of this dichotomous power structure. I begin with a brief history on the local context of the university where data was collected, my own positionality as it relates to critical research, continue with the design of the research performed to answer these questions, the study setting, participants, and data sources, and lastly, the procedures and instruments that are used for data collection and analysis.

A Recent History of Local Change Efforts

The mathematics department at this large, masters-granting university in the southwest, given pseudonym SWU, has a history of a strong presence of mathematics education researchers. While the progressive pedagogical ideas around active learning and the shift away from traditional lecture format was present in the courses these math educators taught, it was relatively absent in the precalculus and calculus courses as recent as 10 years ago. Just as many mathematics departments across the country there was a collective decision, with encouragement from university administration, to take more responsibility of the mathematics department's role in the success of STEM-intending students in these crucial introductory courses.

With this decision, the chair of the department collaborated with mathematics education researchers and other mathematicians to implement sweeping changes to their Precalculus, Calculus I, and Calculus II course pathway (P2C2). This department-wide approach, inspired by the seven features of successful calculus programs (Rasmussen et al., 2014), included the development of a robust coordination system that unified exams and textbooks across sections, investment into the mathematics and science learning center on campus, changes to the placement system, and the adoption of worksheets that were designed to engage students in meaningful, collaborative, and rigorous mathematical tasks. There was also a redistribution of class-time dedication that created recitation sections taught by Graduate Teaching Assistants (GTAs) who participated in a new 3-day intensive professional development training for the GTAs to learn how to facilitate student-centered classrooms as well as a semester-long follow up course. While attending to their local data, another feature of successful calculus programs, the mathematics department made considerable strides in improving the student experience (Apkarian et al., 2018).

While these efforts show a significant dedication to changing the structures that were in place and promoting the sustainability of the changes made, a myriad of factors lead to the dampening of some of these features over time. In the last four years alone, alongside a global pandemic that closed schools and required education to occur over long distances through cameras and microphones on computers, the department has since also seen a change in the chair, decreased emphasis on coordinators and coordination, and less of a focus on student-centered facilitation of activities in recitation sections. This is not to say that this mathematics department is failing, but indeed struggling to find ways to boost the maintenance and sustainability of past efforts while focusing on the present.

Situating my dissertation within the brief history of this particular mathematics department is important because the students I recruited are currently experiencing the P2C2 courses as they are still the focus of various efforts of change in the mathematics department, with some of which I am directly involved. In the summer of 2022, I became involved as a graduate student researcher with an effort to implement a holistic approach to close equity gaps alongside the PI team which consisted of several seasoned mathematics educators, the new chair of the department, and the Associate Vice President of Faculty Advancement and Student Success. Our proposal laid out four main arms to our approach: addressing issues in placement, the use of near-peer STEM role models (Ko et al., 2020; Bjorkman et al., 2017), reinvigorating coordination through P2C2-wide professional development, and creating support courses for the P2C2 pathway. Being a part of this team inspired me to collect my dissertation data from the very students we were attempting to serve, with a focus on how their experience and voice can help us understand how we can meet their needs and narrow the equity gaps that women, people of color, and intersectional identities face.

The support course developed by this team is one of the main foci of this dissertation, so I describe it in more detail. Students enrolled in the course voluntarily, with recruitment for enrollment focused on incoming STEM-intending students. There was a designated coordinated care provider that ran multiple outreach programs around the county for students to learn more about the math requirements at SWU and the support systems in place for students, including the new support course. This designated point-person for the support course ran an online Canvas course dashboard that gave students a place to ask her questions and respond to intermittent opportunities to respond to prompts that focused on their college trajectory. This is the one-unit “course” that students actually enrolled in, which did not meet in person. However, enrollment in this course required frequent and regular attendance to supplemental instruction (SI) sessions.

SI is an already-existing university-funded academic support program designed to improve student performance and retention in historically challenging courses. Originating from the University of Missouri, Kansas City in the 1970’s, SI has been widely adopted across various education institutions to enhance learning outcomes. The fundamental aspect of the design of SI are regularly scheduled, peer-facilitated study sessions that are integrated in line with the pace of the courses they focus on. The sessions are led by SI leaders who are recruited as students who have recently succeeded in taking the course and are trained in effective learning strategies, such as active learning. SI leaders attend the course lectures, take notes, and at times collaborate with the course instructor to align their sessions with the course content. The SI sessions typically have anywhere between 1 and 10 students attend any given session, allowing for a more individualized approach to learning and reviewing current class content.

Students enrolled in the support course the team and I designed were able to choose one or two of the eight separate SI sessions that are held every week based on their individual schedules and required to attend at least once a week. Essentially, the support course is a way to provide students a structured approach towards seeking support from already existing SI sessions and creating another dedicated place where support, guidance, and answers to general questions could be offered by the coordinated care provider who ran the online course dashboard. The course is offered as credit/no-credit rather than a graded course since their grade would only depend on their regular engagement with SI sessions.

Since the support course was an integral aspect of the multi-pronged approach to student and instructor support being rolled out, data was collected across all students so that there may be some indications as to what supports were effective. This dissertation was borne from a deeper interest in understanding more about the students who enrolled in the support course and the inspiration I had to take a more complex, mixed methods approach towards collecting and analyzing students' experiences with mathematics overall.

Researcher Positionality

I am a cisgender white male with confidence in public speaking, multiple mathematics degrees, and a propensity to speak up for those whose voices are often disregarded. I acknowledge the privilege that I hold as a person born this way to college-educated parents who raised me to believe that good people do good for the sake of empathy and the benefit of others, not for personal gain or by threat of punishment. I learned from an early age that knowledge is power, but learned through experience and exposure to critical literature that power is also borne from identity and is intertwined with societal structures and the way knowledge exists today. Perhaps now I view myself as a critically informed and active member of resistance to society's ills, but it has not always been this way.

While I am also socioeconomically and geographically privileged as a coastal southern California resident for life, my journey through academia does not reflect a typical path. While many of my classmates from primary through secondary schools took the SATs, got four-year degrees, and began well-paying jobs before their mid-20's, I chose to spend my time after high school quite differently. I worked multiple minimum wage service jobs in food and retail industries while taking courses at a local community college and eventually transferred to a local state university to complete a mathematics degree. My natural inclination to help and teach those around me while at work and school lead to many conversations and friendships with a diverse set of individuals that helped shape who I am and the way I view society, knowledge, identity, and power.

Some aspects of continuing my degree in mathematics that initially appealed to me were the pedagogical tendency to rely on rote memorization, the reliably discrete and unambiguous nature of the algorithms and procedures, and the perception of mathematics as race-free and gender-invariant. It was not until I was introduced to socio-political theories of learning and professors with experience in critical theory in mathematics education that I began to understand how the very aspects of mathematics that appealed to me and helped me succeed in becoming a mathematician were actually some of the most problematic and harmful aspects of the prevailing narratives around ability, social mobility, and identity as they relate to mathematics and education in the US. I now recognize an equity-driven approach to instruction in mathematics akin to Inquiry-Based Mathematics Education (Lauren & Rasmussen, 2019) is aligned with the ways knowledge and learning ought to be theorized: through a lens of the students' role in social interaction and deep conceptual understanding, and the facilitating role of the instructor for equitable experiences and attention to and application of how students think and learn.

My conceptual change towards understanding the racialized, gendered, and ableist identity of mathematics and how knowledge and learning are defined as social and dynamic has taken years of experiential growth, and I recognize that I still have much to learn. Through this dissertation I plan to grow further as an individual who seeks to actively work towards righting the wrongs of centuries of oppressive mathematics education structures and narratives, continuing my history of helping and lifting up those around me who may or may not share my same privileges.

Research Design

In this dissertation, I construct my research design to explore ways that I can challenge the current research paradigm in systemic change research and complement my research questions. I believe my goals are best addressed through a transformative mixed methods approach, which is explained by Creswell et al. (2007) as explicitly utilizing the theoretical positionality of the researcher and aiming to effect positive change for the participants through its completion.

The philosophy of my research design is inspired by holism towards a mixed methods approach to data collection and analysis. A holistic approach views each student, instructor, class, department, and college as integrated parts of a complex system that are best studied as parts of a whole in relation to one another, acknowledging that mathematics education occurs exclusively with contextual, historical, and geographic importance (Miller et al, 2019). This philosophical position is opposed to the reductionist view of separating pieces from the whole and emphasizing their fundamental properties in a vacuum rather than being contextualized in cultural significance. Holism in education, as Miller and Corsini (1990) discuss, extends beyond the acknowledgement of context and history by being inspired by the awe of the naturally chaotic unfolding of life. This deeper, creative, spiritual, all-encompassing wholeness highlights human nature and perception, which aligns with the goal to help re-humanize a field with a history rife with de-humanizing efforts (Paris & Winn, 2013).

My critical, holistic approach to mixed methods research design, in turn, captures the voices and stories of students as they relate their identity to mathematics in tandem with their evolving experience with all the cultural and historical implications in the education system and society have on their lives. This data exists as a snapshot of a relatively small operation among a larger and incredibly more complex system of what our society has produced around mathematics: racialized and gendered narratives, hierarchies of ability and status, stereotypes and stereotype threat, societal and mathematical norms, and decades of narrowly focused pedagogy and problematic education systems. By naming and discussing the pervasive, systemic issues of racism and sexism within the context of our data collection in this way, I follow just one way to operationalize CRF interfaced with Figured Worlds into my research design.

Another manifestation of CRF interfaced with Figured Worlds in my research design is the purposeful legitimization and promotion of historically oppressed voices, creating an opportunity for listening and believing the narratives of women, people of color, and historically stereotyped groups. This is what inspires me to use narrative as a critique against the dominant social order, which is important to the design of my research because I want to use my position of power as a white, male mathematics education researcher to amplify their stories as I seek to become a more involved and engaging ally and advocate for social change. Narratives of students are formed through the conversations I hold with students during semi-structured interviews. Creswell et al. (2007) describes the use of narrative in mixed methods approach as a reflexive relationship between the researcher and their subjects, as they learn from each other and change throughout the research process.

There is a problematic history of colonizing ways of knowing, including the ways research is executed and what kind of data is valued. As Paris and Winn (2013) state in their book, the history of critical research across the 19th century through today demonstrates how researchers' intentions, at their best, are the capitalization and growth of the researcher without reciprocity to the community. My research design recognizes this history and combats it with opportunities for growth and social justice for the participants of my research with fair compensation for their time, valuing and highlighting their lived experience, and playing a part in advocating for their needs through social justice work in the university.

To investigate the questions of both research goals, I interview and survey students, with the intent to ask potentially uncomfortable questions that have potential to unearth the complex system of inequitable experiences and the barriers they may face. While I collect quantitative data that is typical of education research such as grades received and course persistence, I also broaden my collection to include survey items that focus on the perception of the inclusivity of instructor behavior, students attitudes towards mathematics, their sense of belonging, and a wide range of demographic indicators that include non-binary gender choices, over a dozen race and ethnicities, LGBTQIA+ inclusive sexual orientations, and several special populations that include students with a disability and first-generation college status. The decision to choose a survey that casts such a wide net was deliberate in recognition of the philosophy of my research design.

There are also free-response items on the survey that allow students to voice their opinions through text, which were included to allow a starting point for me to construct themes or potential narratives of student experience that are beyond what the survey may include. The inclusion of these themes and potential narratives is necessary in my critically inspired research design, yet insufficient to capture the rich and complex stories of individual students. Thus, the semi-structured interviews align with my goal of constructing narratives around not only the inequities and barriers that individual students may face, but also what mathematics means to them and their personal mathematical story that carries many potential inflection points in its trajectory. As Reinholz (2018) describes, I measure what I value rather than value what others typically measure.

As can sometimes be the case with equity-focused research, I intentionally refrain from gap-gazing (Gutiérrez, 2008) of typical success metrics comparing unrepresented groups against the dominant group. Rather, I use comparisons across support course enrollment and emergent identity groups to paint a broader picture of the reality of student experiences, inspired by their personal reports. This is where Figured Worlds interfaced with CRF inspires constructing narratives around students who detail their perception of the differences between figured worlds they, and potentially myself, are acting members in. The roles, values, and interwoven cultural norms and practices become the aspects of identity-related student experiences that I bring to light through careful construction of survey items and interview questions to include.

In an effort to humanize the analysis of “gap” data and supplement quantitative analysis with lived experience and stories of marginalized students, the critical qualitative aspects of my research design are further inspired by a reconceptualization of the ‘interview data’ I am gathering. This reconceptualization is described by Jackson and Mazzei (2022) to use the term *performative accounts* from interviews with students. Inspired by philosopher Butler’s ideas of performativity, the language they choose to adopt refers to what is traditionally called *interview data* reconceptualized as accounts that are theorized to be representative of only one individual’s unique telling. Jackson and Mazzei (2022) explain that the accounts are *performative* because they refuse the idea that the storyteller is representing the complete picture of their existence through the limited context of an interview, acknowledging that interviews themselves occur within the dynamics of gendered and racialized power structures.

Through the intentional use of a widely subjective theoretical methodology in this dissertation, I continue to explore the directions students’ stories and responses to survey items takes me. That is, there are emergent themes from experiencing this snapshot of time in students’ lives that I might not expect, so I retain some flexibility as to what specific identities and experiences I could learn about through my analysis. In Koro-Ljungberg’s (2015) book Reconceptualizing Qualitative Research: Methodologies without Methodology, she breaks traditional norms and structures by pushing against rigid methodologies, expanding the conceptualization of data and possibilities of data interactions, and reveling in the uncertainty that a data set can provide. In her chapter about data, Koro-Ljungburg (2015) speaks to this uncertainty as the inspiration to work within and without traditional approaches of data collection and analysis.

My methodology grounded in Figured Worlds theory interfaced with CRF, using counter narratives to push back against the prevailing social order is integral. However, Koro-Ljungburg (2015) reminds us that collecting these kinds of performative accounts can often lead to issues with the researcher's own biases and tendency to want to control the data, rather than letting students speak for themselves. For example, due to a number of reasons including an overwhelming amount of data, researchers may find themselves after analysis with what appears to be a list of themes and some selected quotes. To avoid my self-projection and control of the data, I continue to shape my perception of the qualitative data I collect through my own fluid, growing knowledge. This includes requiring some aspect of testing the reliability of my narrative construction as well as revisiting the methodologies and analytic frameworks throughout the research process. As Koro-Ljungburg (2015) describes, this allows for the perception of research progress as somewhere in *the middle* rather than a beginning or an end.

Procedures and Instruments

Investigating the two questions of my first research goal involved constructing an interview protocol that encompasses many aspects of the student experience in mathematics currently as well questions that assist me constructing personal mathematical narratives for each student interviewed. This interview protocol is in Appendix I, along with the main questions and potential probes for more detailed information based on students' responses.

The questions and probes from the interview protocol were designed to start conversations around various aspects of students' mathematical experiences, with reference to the identity as it impacts their experience in particular. The intent of these conversations was to unearth responses that would assist in responding to my research goals. For example, questions 1 and 6 were designed to have students reflect on their definition of mathematics, what it means to them, and their personal mathematics stories, where the responses of those questions were used to form narrative vignettes for each student. Some questions were also designed to elicit further detail of questions that appeared on the survey in the form of free-response items. For example, questions 2 and 5 were inspired by questions on the survey that asked about how their identity has affected the way they do or learn mathematics and how their attitudes towards mathematics have changed. However, they were paired with probes and additional questions about their experiences with mathematics and the impact on their identity to elicit more rich detail and explanation about their responses.

The interview protocol is designed to not only elicit performative accounts from these students but to engage with their experiences, learn from them with emergent probes, and grow with them as we attempt to recall the past, reconcile the present, and envision the future of their experience with mathematics education. Crafting narratives from these performative accounts, as well as the answers to the free-response items on the surveys, requires the trust and consent of the individuals to whom I speak and listen, which I plan to gain through the genuine engagement and empathy that is required to do such a task. I am the conduit through which their stories can be lifted into the sphere of research in mathematics education and I accept the responsibility to capture their meaning and dignity. In RQ-1B, I supplement the narratives with some of the responses around instructional practices from a survey I administered, which is the main focus of analysis in the second research goal.

Investigating my second research goal utilizes one large survey that was created as the combination of two surveys that was administered to students in weeks 12-14 of Spring 2023 and Fall 2023. I chose near the end of the semester for survey distribution so that students have enough experience with the class to form an opinion on the teaching practices, but not too late in the semester that the pressure of end-of semester exams and projects are enough to disregard a survey sent to them.

The first of these surveys is the student version of the modified Postsecondary Instructional Practice Survey (S-PIPS) developed by Apkarian et al. (2017). The dimensions of student experience this survey aims to illuminate are important to my data collection because they obtain information about how students are engaging with mathematics in the classroom, how the local mathematics community might be marginalizing, and the degree to which students' contributions are valued. This survey offers a combination of 5-point Likert scale questions that measure the degree to which students agree with statements around confidence, interest, and enjoyment of mathematics and multiple free response questions that give an opportunity for students to share in their own words what they found helpful, what they found unhelpful, and how their identity affected the way they do or learn mathematics.

Supplemental to these factors of student experience, a second survey developed by Nate Brown and colleagues at Penn State University called the Inclusive Instructor Behaviors (IIB) survey was incorporated into the large survey administered to students.

These survey questions leverage student experience to determine various aspects of the perceived inclusivity of teaching behaviors, which were qualitatively different from the aspects of identity and experience that the S-PIPS offered. This survey includes dozens of 5-point Likert scale items, some of which are characterized by multiple themes that measure the degree to which students perceive of their instructor's: 1) willingness to help, 2) engagement or disinterest in the content of the course, 3) complexity of instruction, 4) facilitation of group work, 5) attention given to students and use of time, and 6) negativity or criticism. These six themes were confirmed to collect into statistically significant factors, developed by a factor analysis and confirmatory factor analysis performed by Nate Brown and colleagues on multiple data sets. The broad results of these analyses have only been shared internally and the specific results have not been shared or published as of the writing of this dissertation. There is also a considerable portion of the survey that focuses on students' sense of belonging in mathematics, the items of which have not yet been grouped into factors. The exact items of the entire survey, including all S-PIPS questions, IIB questions, and sense of belonging questions as they are presented to students are listed in Appendix I.

These aspects of the student experience are useful to my analysis because they complement the student perceptions of instructional practices from the S-PIPS by focusing on specific behaviors of the instructor within their general practices. For example, students can measure their perception of their instructor's enthusiasm for teaching, classroom time management, or the degree to which teachers are perceived to care about the success of their students. Behaviors like these that are not present in the S-PIPS help me build a broader picture of how students experience their courses.

These surveys together require significant labor from students, as the two surveys combined can take up to 45 minutes. To mitigate this, instructors incentivized students to complete the surveys with nominal course credit in both semesters the survey was administered.

Methods of Data Analysis

Quantitative data for research goals is analyzed using R and SPSS for running statistical analyses and generating visualizations of the results. My quantitative approach to analysis recognizes that the vast majority of the survey responses come in the form of Likert scale items. These items offer ordinal data, which is when responses such as the ones from my survey exist in discrete ordered categories of 1-5 or 1-6, depending on if there is a neutral option available. Unlike categorical or scale data, with ordinal data there is an assumption of an inherent meaningful order of the responses, such as levels of agreement to a statement or T-shirt sizes (S, M, L, XL).

In the figured world of educational research, ordinal data is often treated as numeric or scale data (such as a ratio or any real number between 0-100) with the assumption that the distances between each of the ordinal categories is consistent. There is a long-standing debate that this is not an appropriate assumption, which influences the types of statistical tests one may use depending on which camp a researcher finds themselves in. Treating ordinal data as scale data essentially means that researchers may utilize statistical tests that compare the means of responses, which affords powerful results that are valued in educational research, and this practice has become a norm in this world.

However, in this dissertation, I mostly refuse to treat my ordinal data as scale data because it is impossible to quantify the distance between “slightly agree” and “agree”, and I cannot make the assumption this distance is consistent across the 6-point Likert scale. Furthermore, there are many statistical tests that are analogous to the ones that compare means used with scale data that are designed with the inherent assumption of the ordinal data involved. These tests include descriptive statistics, chi-squared tests for independence, two-sample proportions Z-tests, non-linear statistical tools to determine effect sizes such as Mann-Whitney U test, and providing confidence intervals for the effect sizes to determine a reasonable interpretation of the result.

When I saw that I mostly refuse to treat my ordinal data as scale data, that is because I do extend my quantitative data analysis into performing a principal component analysis (PCA) which is not typically meant for ordinal data. The reason I include this statistical test that contradicts my stance against utilizing tests that assume numeric data is being used is that I incorrectly identified the PCA test as a reasonable test to use, without realizing there exists a non-linear version of PCA tests that utilize kernel methods to map data into higher-dimensional spaces. I still included this portion of the analysis to convey the potentially useful information it reveals, as well as to demonstrate my evolving knowledge of the assumptions that must be met before utilizing a statistical test.

I perform statistics with the knowledge that my data is one collection of data in a pool of infinitely many different snapshots of potential data, inspired by the meta-analytic mindset that urges highlighting both what is and what is not statistically significant. My philosophy of quantitative data analysis comes from a critical tradition pioneered by Cohen (1989) that pushes back against the generations of misinterpretations and misrepresentations of crucial data. This is why I report findings that are inconclusive as well as findings that may not align with my hypotheses. The collective interpretation of all results must include the ones I may not find appealing so that a holistic, critical perspective can be applied to my discussion of those results.

I also analyze the qualitative aspects of my data collection, which include both the conversations I have with students in semi-structured interviews as well as the text-based free-responses to items of the survey. Transcripts of these conversations and verbatim copies of the free-response text are uploaded to a qualitative data analysis program MAXQDA, where open and axial coding are implemented through a theoretically driven approach of constant comparison and grounding thematic codes contextually as the data demands (Miles, et al, 2014). While this process is antithetical to a purely narrative approach I could have taken to lift marginalized voices as performative accounts, I believe a thematic analysis emboldens those narratives with lessons to learn that span the experience of many unique students.

The reliability of my coding and subsequent narrative construction based on that coding was tested against another graduate students' use of a subset of the performative accounts from interviews. This coding reliability process enhances the dependability and trustworthiness of the narratives and themes I present, with the knowledge that another graduate researcher with years of experience of coding, particularly through a Figured Worlds perspective, developed a reasonably similar result when applying the codes I developed to a blank version of excerpts of the interview accounts.

While this process could have been made more valid through a complete re-coding and comparison across all student interview accounts, time and labor was a factor in the determination of how to design this coding reliability test. Thus, two students' interviews were randomly chosen and select subsets of those interviews were chosen based on the interview questions they were responding to. Since the majority of importance of the reliability and trustworthiness of this coding is in the construction of narratives, the excerpts selected were around students responding to the questions about how they define mathematics and what it means to them and their personal mathematics stories. These questions are numbers 1 and 6 in the interview protocol found in Appendix I.

Through the process of data analysis, I expect to uncover aspects of the student experience I may not anticipate. So, as I *analyze data*, as a traditional approach would expect, I am simultaneously *thinking with theory* to develop what Jackson and Mazzei (2022) call *becoming-questions.* These questions are not set out from the beginning, or used to wrap up ideas at the end, but exist in the middle as emergent ponderings that take advantage of the newness and uncertainty of my experience as a researcher learning from students, growing with their perceptions and my own, and gaining insight into a world that may be familiar to me, but not viewed through my eyes. The precise steps I take in the process of analysis is described in detail in Table 3.1, where the source of data and the steps taken to analyze it is paired with each research goal.

I repeat the research goals and questions here to allow for careful comparison between the steps of analysis taken in Table 3.1 and the questions I aimed to answer. The research goals with their research questions are as follows:

1. Investigate the connections between students' self-reported identity, what mathematics means to them, and the mathematical community they perceive.
    A. How do the interviewed students define mathematics and what it means to them?
    B. How are students' mathematical identities mediated by the instructional practices and the mathematical community they perceive?
2. Investigate student success of those enrolled in the support courses compared to those who are not.
    A. In terms of external evaluation of success from the university, how are students succeeding by grades and retention?
    B. How did their reported instructional experiences, confidence, and sense of belonging differ?

Table 3.1: Data collection and method of analysis for each research question. RQ-1A refers to the first of two research questions under my first research goal.

Research Question	Data Collected	Specific Steps of Analysis
RQ-1A and RQ-1B	Interview Transcripts and Free-Response Survey Items	1. Interview transcripts and collected answers to free-response items are cleaned and uploaded to MAXQDA. 2. Multiple rounds of open coding on transcripts and the text of survey responses. 3. Axial coding to determine sub-categories and super-categories of codes. 4. Identify salient themes to focus on in the reporting of results. 5. Identify quotes that have potential for highlighting the selected emergent themes. 6. Create narratives for each student interviewed based on their performative accounts about the meaning of mathematics and their identity-related accounts of experiences with mathematics. 7. Interpret emergent themes of identity groups (e.g. women in STEM, first-generation college students) and analyze through lens of Figured Worlds interfaced with CRF. 8. Supplement emergent themes of identity-based experience with comparison of survey data responses.
RQ-2A and RQ-2B	Survey Data	1. Export survey data from Qualtrics into Excel. 2. Identify incomplete and potentially unreliable responses (e.g. duplicates, unreasonable completion time) 3. Clean data and prepare for R and SPSS analysis, including removal of identifying data, consistency across responses, and simplifying variable names. 4. Perform exploratory data analysis to run descriptive analysis of populations and observe distributions across responses. 5. Make hypothesis, run appropriate statistical tests and report results. 6. Determine additional appropriate statistical tests based on emergent *becoming questions* while analyzing. 7. Run additional tests and report results. Create charts, figures, and tables of data to visually display and interpret results. 8. Accept or reject hypothesis based on results.

Study Setting and Participants

The setting of my study is SWU: a pseudonym for a large, masters granting public university in the southwest, which is a Hispanic Serving Institution, has a large commuter and transfer population from multiple local community colleges, and holds a population of approximately 32,000 undergraduate students. Out of this population, 28% were enrolled in STEM degrees.

The survey was administered to all students of Precalculus, Calculus I, and Calculus II in the semesters of Spring 2023 and Fall 2023. While students were incentivized to complete the survey, the level of response rates varied across the two semesters. In Spring 2023, there was a ~80% response rate and a lower but a reasonable response rate of ~70% in Fall 2023. These numbers are approximate due to the nature of counting responses that were not completed to a satisfactory amount. This resulted in a total of 1,131 unique responses across the two semesters with just 34 students who completed the survey both semesters. Of those 34, six repeated a course with five repeating Precalculus and one repeating Calculus I, nine had Precalculus as the first course, thirteen had Calculus I as the first course, and six took Calculus I over the summer resulting in responses from Precalculus and Calculus II only. Due to the small number of students who filled out the survey both semesters, my analysis will not focus on longitudinal data, rather all responses from both semesters will be taken into account as one large data set. Tables 3.2, 3.3, 3.4, and 3.5 provide the frequency of each demographic category and percentage of the survey population followed by Table 3.6 which shows the frequency and percentage of students in each course level.

Table 3.2: Gender frequency across entire survey population.

Category	Count	Percentage
Man	658	58.18%
Woman	429	37.93%
Prefer Not to Say	15	1.33%
Transgender	8	0.71%
Not Listed	4	0.35%

Table 3.3: Race or Ethnicity frequency across entire survey population.

Category	Count	Percentage
White	505	44.65%
Hispanic or Latinx	343	30.33%
Southeast Asian	160	14.15%
East Asian	77	6.81%
Black or African American	59	5.22%
South Asian	49	4.33%
Middle Eastern or North African	43	3.80%
Native Hawaiian or Pacific Islander	39	3.45%
Prefer Not to Disclose	19	1.68%
Alaskan Native or Native American	8	0.71%
Central Asian	8	0.71%
Not Listed	6	0.53%

Table 3.4: Sexual orientation frequency across entire survey population.

Category	Count	Percentage
Straight (Heterosexual)	905	80.02%
Bisexual	79	6.98%
Prefer Not to Disclose	42	3.71%
Asexual	23	2.03%
Queer	20	1.77%
Gay	16	1.41%
Lesbian	13	1.15%
Not Listed	8	0.71%

Table 3.5: Special populations frequency across entire survey population.

Category	Count	Percentage
Commuter Student	397	35.10%
First Generation	310	27.41%
Prefer Not to Disclose	116	10.26%
ELL	87	7.69%
International Student	52	4.60%
Student Athlete	34	3.01%
Student with a Disability	32	2.83%
Transfer Student	21	1.86%
Parent or Guardian	2	0.18%

Table 3.6: Course level frequency across entire survey population.

Course Level	Count	Percentage
Precalculus	408	36.07%
Calculus I	399	35.28%
Calculus II	324.	28.65%

Individual interviews took place in person on or near campus as well as through audio/video calls using internet-based platforms when in-person meetings were not possible. I invited all students enrolled in the support course, focusing on students with intersectional or underrepresented identities, have reported disabilities, or replied to free response survey items with experiences that have potential for elaboration. Even with offering $50 for an hour-long interview and contacting students multiple times, it was difficult to develop a diverse group of students to interview. This unexpected difficulty in data collection influenced my choice of students to interview, because it was a struggle to reach ten interviews total.

The final group of interviewees consisted of five women and two men, three of which I was able to interview twice across varying lengths of time for a total of ten interviews. Four students were international students, two from Mexico, one from Italy, and one from Spain. One student identified as having a disability. Two of the students identified as being commuter students. Four of the students identified as being first generation college students. All of the students were enrolled in the newly created support course. Table 3.7 summarizes the demographic information of these students as well as the dates of their first and second interview (when applicable).

Table 3.7: A summary of the diversity of demographics among the 7 students interviewed.

Pseudonym	First Interview	Second Interview	Ethnicity or Race	Gender	Special Population
Silvia	4/28/2023	11/16/2023	White, Italian	Woman	First Gen
Amy	11/14/2023	2/29/2024	Asian American	Woman	Commuter
Belinda	5/11/2023	3/11/2024	Mexican / Latina	Woman	First Gen, International
Santiago	4/28/2023	N/A	Mexican / Latino	Man	First Gen, International
Adeline	2/15/2024	N/A	White, American	Woman	First Gen, Commuter
Micah	2/29/2024	N/A	White, American	Man	With a Disability
Carina	3/19/2024	N/A	White, Spanish	Woman	International Student, Athlete

Learning and Growing from Data Analysis

Through the transformative approach of my research, I intend to utilize the results of what I learn from conversations I have, survey responses I read, and analysis I conduct for a greater purpose than to report in this dissertation. I expect what I gain from the students who trust me with their experiences to be leveraged towards helping those same students as well as future students at our university and others. It is with great honor that I conduct this research with the intent to help others as well as help redefine what my dissertation can do, rather than what it can be. My goals for this research reach beyond answering my research questions and developing more questions to answer; I also plan to build agency among students with intersectional identities, advocate for justice in the students' communities, and add a critical perspective and opportunity for growth to the broader field of systemic change research.

Chapter 4

My first research goal is to investigate connections between students' self-reported identity and the mathematical community they perceive. This chapter is split into two sections, each focusing on one of the two research questions associated with this research goal. The research questions are: (1) How do the interviewed students define mathematics and what it means to them?; and (2) How are students' mathematical identities mediated by the instructional practices and the mathematical community they perceive? The first section highlights each of the seven students that were interviewed at least once, whereas the second section is informed by both the interviewed students' performative accounts as well as the broader student population's responses to the survey.

The Meaning of Mathematics

Students interviewed were asked the question, "what does mathematics mean to you?" The reason why I included this question in my interviews is to get a broad idea of students' perceptions of mathematics as a whole, how they believe they will use it in the future, and the shape mathematics takes in their perception based on their experiences thus far. While this question seemed to challenge students in complexity, students were open and honest about their perception of mathematics. Later in our interview conversations, I asked students to reflect on the arch or their own "mathematics story" which begins somewhere in the past, treats the present as the middle of that arch, and poses the question, "what does the future hold for this story?" This section is broken into vignettes that include each interviewed students' narrative around what mathematics means to them and their personal mathematics story that describes the beginning, middle, and end of their individualized arch.

Carina's Vignette

Carina is a woman who is a microbiology major, a student athlete, and an international student who grew up and went to primary and secondary schools in Spain. Between her full-time schedule as a student, her many practices and games as a water polo player, and attempting to sustain a social life, there are multiple figured worlds salient to her everyday experience that she must navigate to remain successful and on top of all her responsibilities. Even so, she made time to interview with me about her experiences with mathematics and what mathematics means to her.

Carina contrasts her high school experience with her current college experience, noting that relearning some of the math concepts that were already presented to her in high school boosted her confidence and deepened her understanding. This shift highlights the importance of the impact on educational transitions and instructional practices on students' identities, particularly those who do not share a common US high school experience. She says that, "relearning all this stuff has taught me to like actually learn everything that's going on and like understand everything", which highlights the importance of continued engagement with material leading to conceptual understanding.

When asked to define mathematics, Carina's narrative suggests a pragmatic approach that emphasizes utility over passion. She said that she, "would describe it as a useful tool for my future", which aligns with the figured world of science and research where math is a crucial skill that is often considered to be one tool on a toolbelt that scientists need to be successful.

Carina's mathematics story arch began in Spain, where she received a rigorous education that included extensive training in mathematical concepts. She learned relatively advanced topics such as limits, derivatives, and integration techniques during high school. However, she encountered a more inclusive teaching style and an increased focus on topics she had already seen in the curriculum when she moved to the US for college. Despite the differences she found that her solid foundation in math from Spain helped her adapt to the new system.

The middle of Carina's mathematics story arch includes the present experiences she is navigating as a calculus student who is also a student-athlete majoring in microbiology. Finding balance between her role of a student in the figured world of college academics and her commitments to her role as a position on the water polo team creates tension in her everyday life. She is currently enrolled in Calculus I, where she has had mixed experiences. That is, she is encouraged by her preparation from her experiences with math in high school in Spain, but she also feels bored and uninterested due to the repetition of content. Carina appreciates teaching methods that involve a combination of lectures and lab sessions. The lab sessions in particular offer opportunities to work in groups, which she finds beneficial for understanding and retaining mathematical concepts.

Looking forward, Carina sees herself continuing to use mathematics in her career, particularly in research. She recognizes that math will be an integral part of her work, especially in data collection and analysis. Carina is determined to maintain her proficiency in math and plans to continue leveraging the support systems she can make time to attend, as well as utilizing collaborative learning to achieve her goals.

Amy's Vignette

Amy is an Asian American commuter student who chose to be a biochemistry major because she would like to become a medical doctor in her future. Despite finding math challenging, Amy enjoys the problem-solving process. One salient quote that encapsulated her feelings towards mathematics from Amy was that, “sometimes it makes me cry, but like I really enjoy math!” Amy's simultaneous conflict and connection with mathematics is relatable because her struggle reflects broader issues of the need for supportive instructional practices that address diverse learning needs and honors this nuanced view of the complicated relationship students have with mathematics.

Aligning with the figured world of STEM, Amy recognizes that the math she learns in college is essential for her understanding of concepts in biochemistry. Though she feels that it is cliché, Amy said about mathematics that, “like what everyone says, it's basically like the language of all the sciences.” It is understandable and relatable that she feels this way about mathematics. While the sciences are humans' way of observing, evaluating, categorizing, and making hypotheses about worldly phenomena in order to better understand our place in the history of the universe, mathematics is the language used across those sciences to quantify and model those phenomena.

Amy recalls struggling with mathematics from a young age, often feeling pressured by the stereotype that Asians are inherently good at math. This stereotype created a burden for her, especially when she did not meet others' expectations.

Despite the pressure of stereotype threat, Amy remained determined to fit into this stereotype, which motivated her to improve her math skills.

Currently, Amy is enrolled in Calculus I, where she has had mixed experiences. On the one hand, she appreciates the support structures available, such as the Supplemental Instruction (SI) sessions she attended by way of enrollment in the support course and the free tutoring she received at the MSLC, which have helped her reinforce her understanding and specific areas that need improvement. On the other hand, Amy faces challenges in group settings, especially when her contributions are overlooked by her male peers. This experience of being ignored, despite having the correct solution, has been disheartening and continues to irritate her.

Amy envisions using mathematics extensively in her future career. She has even considered switching her major to physical chemistry due to her growing interest in math. Her experiences have increased her confidence, especially after performing well on exams she thought she would fail. Amy aims to continue overcoming stereotypes, contributing significantly to the scientific community, and enter a career that aligns with her ideal of working towards a social good.

Adeline's Vignette

Adeline is a White American woman, who is a first-generation college student who commutes to school rather than living on campus. Adeline defines mathematics as a structured discipline with definitive answers. She appreciates the logical, step-by-step nature of solving problems, which she contrasted with more subjective disciplines. Her response to the meaning of mathematics also focused on the role of mathematics in her confidence as a student of environmental engineering. She said that, "back in high school, freshman or sophomore year before the pandemic hit, math was easily my best course, my favorite course. And then in college it just is completely different— math is what I struggle in the most." Adeline's transition from excelling in math in high school to struggling in college highlights her experience transitioning between the figured worlds of high school math and college math.

Later in this chapter, I provide additional analysis of this transition as it applies to students more broadly, but Adeline's experience reflects the challenges many students face when transitioning to higher education, where the conceptual and cognitive demands of math and their other classes increase. What sets Adeline's narrative apart is the depth that I was able to speak to her about her individual experience, which revealed a strong desire to regain her confidence and enjoyment in math. She said, "I have to learn to love it again because I used to love it in the past and I was able to excel in it and do my best." This emotional and identity-related struggle is compounded by the shift from rote memorization to conceptual understanding, emphasizing her need for instructional methods that support this transition.

Adeline excelled in mathematics during high school, where it was her favorite subject. She consistently received high grades and found the material easy to understand. Her confidence in math was high, and she enjoyed the clear, definite nature of mathematical problems and solutions. She feels now that she prefers a more algorithmic and memory-dependent approach rather than the more abstract and conceptual nature of the math she has experienced in college. Adeline did not include any specific story of mathematics in her past other than her general success as a student in math courses leading up to college.

Upon entering college as a first-generation student majoring in environmental engineering, Adeline's relationship with mathematics changed drastically. She found college-level math significantly harder, particularly due to its more conceptual nature. Adeline initially struggled with Calculus I, receiving a C- and having to retake the course. Despite these challenges, she utilized various support systems including SI sessions, tutoring, and practice problems from an online homework program called ALEKS. These resources helped her improve, but she still finds the material difficult and feels less confident than she did in high school.

Looking forward, Adeline aims to rekindle her love for mathematics. She recognizes the importance of math in her field of study and future career in environmental engineering. Although she currently finds math challenging, she is committed to improving her understanding and performance. Adeline plans to continue using support systems and hopes to find ways to make learning math more enjoyable and less stressful.

Belinda's Vignette

Belinda is a Mexican American woman who identifies as Latina who is a first-generation college student majoring in biology with aspirations of becoming an anesthesiologist. Belinda's response to the meaning of mathematics focused more on how she perceived that it is used, viewing math as essential for preparedness in the world and applicable across various domains including not only the sciences but also art and everyday life. She challenges the narrative that math is only for certain careers when she says, "I mean you need to use it for everything and for every career… it's a very important thing you need to know because it is useful for your future." She continues to challenge more narratives around math when she said later that, “sometimes people say that mathematics is useless and you don’t need to learn it because you don’t get to use it, but you get to use it for everything.” Her narrative counters the common perception that the math taught in school is not useful, suggesting a broader understanding of its relevance.

Belinda’s early experiences with mathematics were marked by significant challenges. As an aspiring first-generation college student whose first language is Spanish, she faced difficulties understanding mathematical terminology in English. In high school, she struggled with Precalculus, receiving a C grade and relying heavily on friends for help. Her lack of confidence was compounded by what she perceived as ineffective teaching methods, where instructors made mistakes that confused her further.

Currently at the university level, Belinda initially failed her first math class but decided to retake it, demonstrating her resilience. This time, she utilized SI sessions by way of the support course for Precalculus which she found extremely helpful in improving her understanding and performance on quizzes and exams. She also specifically mentioned how she benefited from the ALEKS program, which provided extensive practice problems and clear explanations. However, Belinda encountered difficulties in group work settings due to her reserved nature and language barriers, which made communication and collaboration challenging. Despite these hurdles, she noticed a significant improvement in her confidence and performance in math, attributing this to better instructional methods and support systems in college.

Thinking about the future, Belinda plans to continue her studies in mathematics with the goal of becoming an anesthesiologist. She recognizes the importance of math in her future career, particularly mentioning calculating dosages for patients. Her motivation for persistence is based in her belief in the social mobility that a college degree promises, knowing what it is like to grow up in a family that struggled to pay for food. Although she anticipates challenges in her upcoming calculus course, she feels more prepared and confident thanks to the support course she enrolled in and the other resources she has utilized. Belinda also aims to improve her communication skills to better engage in group work and develop stronger relationships with her peers.

Micah's Vignette

Micah is a White American male who identifies as having a learning disability. When asked to define what mathematics means to him, Micah likens math to "cheat codes" that help achieve goals more efficiently in his aspirations of an automotive career. He said that, "math is different cheat codes I guess. To get to that answer faster or like however I need to find that out." This metaphor reflects a pragmatic and goal-oriented mindset alluding to his allegiance to the figured world of the working class that values practicality and utility, where his experience with math in college is a means to an end. His view suggests a need for instructional approaches that connect math to real-world applications, where students that perceive math like Micah does can have the utility of the mathematics they are learning demonstrated to them.

Micah's journey with mathematics began in elementary school in Washington State, where he participated in a program called Math Olympiad. This program involved early morning sessions to solve math problems and compete in math tournaments.

Despite not enjoying the intense testing, these early experiences fostered a foundational interest in math. In high school, Micah was consistently ahead in math classes, culminating in taking AP Calculus during his senior year. However, he struggled to connect the material to his interests, leading to mixed performance and a realization of the need to revisit the fundamental concepts in college.

As a first-year mechanical engineering student, Micah has now enrolled in Calculus I after successfully completing Precalculus. His experiences have been shaped significantly by his disability, Attention-Deficit/Hyperactivity Disorder (ADHD), which impacts his learning. Micah identifies as a hands-on learner and finds the online nature of many assignments challenging to complete. Despite these hurdles, he actively participates in smaller group activities and prefers working on whiteboards to visualize problem solving techniques. He has utilized resources like the MSLC and has accommodations through Student Disability Services, such as extended time on tests and note-taking assistance. These supports have been crucial to helping him manage his coursework and improve his confidence in math.

Looking ahead to the future, Micah envisions using mathematics extensively in his career, particularly in mechanical engineering and automotive design. He is motivated by his involvement in the university's Electric Racing Team, where he anticipates applying his problem-solving skills developed in math classes in designing and building electric race cars. Micah's passion for motorsports and engineering drives his commitment to mastering math, seeing it as integral to his future success. He plans to continue leveraging support systems and accommodations from the university to achieve his academic and career goals.

Silvia's Vignette

Silvia is an Italian woman who is a first-generation college student majoring in biology with an aspiration to become a medical doctor. When asked to define what mathematics means to her, Silvia's response focused on describing what she perceives math to be useful for. She said,

> I think that math can applied to like an everyday use. Like when you go to the store, you have to do like basic calculations. You know, in your life you have to use it for like the bank and like money and things like that.

Silvia also defines math as involving logic and reasoning along with everyday tasks like banking and shopping. This narrative aligns with the figured world of everyday life, highlighting the pervasive and practical nature of math and the value of the practicality of what is learned in school as applied to life's everyday tasks.

Silvia's early experiences with mathematics were shaped by the Italian education system. She recalls that math was taught rigorously and systematically, which provided her with a strong foundation but also came with its challenges. She described educators there as "old school", in terms of their perception of mathematics as an elite field and how women students did not hold as much value to a field historically dominated by men. Her high school experience was marked by a particularly strict and unmotivated math teacher, which significantly affected her confidence and interest in the subject.

Currently, Silvia is enrolled in Calculus I and the connected support course, having chosen it over the life sciences calculus course offered because of her interest in understanding math deeply and her perception that the traditional Calculus I course offers a more rigorous approach. Despite initially starting her college math trajectory at College Algebra due to placement test timing issues, she has progressed to this higher-level course. Silvia has found that the teaching methods in the US are different and typically more engaging than those in Italy. She appreciates her professor's use of traditional chalkboard teaching over PowerPoints, which she says helps her follow and understand the material better. From her experience in SI sessions that were required by enrollment in the support course, Silvia discovered a new-found confidence in her mathematics ability. She was so inspired by this experience that she became an SI leader for previous classes she was successful in, changing her self-view from someone who does not belong in mathematics towards someone who is now helping teach it to her peers. However, she has faced challenges in group settings, often being the only woman among male engineering students, which sometimes makes her feel intimidated.

In the future, Silvia envisions continuing to use mathematics in her career, possibly incorporating it into her aspirations of working in neuroscience and biopsychology. Her unexpected discovery for a passion for teaching math has led her to consider more opportunities to tutor or assist in teaching math, which demonstrates her recognition of the value of making math accessible and enjoyable for others.

Santiago's Vignette

Santiago is a Mexican man who identifies as Latino and is a first-generation college student majoring in computer science. When asked to define what mathematics means to him, Santiago focused on how math is used and where he perceives math to emerge in daily life. He said that, "math is like the foundation of how everything's developing and like how everything has been", which suggests an interpretation of math as foundational to understanding and developing various fields, from computer science to natural phenomena. He goes on to say that, “math is living in so mundane things that you don’t think about,” appreciating the presence of math in everyday and natural contexts that emphasizes a more holistic and integrated view of math’s role in the world.

Santiago grew up in Mexico, where his early education in mathematics was not strongly supported by his family or community, as they had limited formal education. This lack of early support meant Santiago had to rely heavily on school resources to develop his math skills. Upon moving to the US in 10^{th} grade, he faced challenges in adapting to a new educational system and language, but he remained determined to succeed.

Currently, as a first-generation college student majoring in computer science, Santiago has found both challenges and support at the university level. He values the mentorship he has received from professors and TA’s, particularly those who have been approachable and communicative. Santiago emphasized the importance of resources like the Math and Science Learning Center (MSLC), required SI sessions from enrollment in the support course, and the university’s Educational Opportunity Program (EOP). These supports have been crucial in helping him understand complex mathematical concepts and improve his performance. Santiago also mentions the significance of having mentors who share similar backgrounds, as they can provide relatable guidance and encouragement.

Santiago envisions using mathematics extensively in his future career in computer science. He recognizes the importance of math in areas like algorithms, graphing, and optimization problems, even if he does not foresee using every single concept learned in his classes. Santiago aims to represent his community by becoming a successful professional in a field where he currently sees little representation. He is motivated to continue his studies and contribute what he can to creating a more inclusive environment for future generations of students.

Threads of Continuity Through Students' Mathematics Narratives

While honoring each individual's experience and narrative is an important aspect of how results of analysis are presented in this dissertation, examining and analyzing across narratives promotes a deeper understanding of the complex and varied definitions of mathematics provided by these students as well as the shared experiences these students have with mathematics. First, I compare the definitions of mathematics given by the interviewed students and that is followed by the results from thematically organizing experiences from each vignette.

Comparing Definitions of Mathematics

The definitions of mathematics provided by the students reveal several common themes that were identified through open coding. Many students emphasized the interdisciplinary nature of math, recognizing its crucial role in fields such as science, engineering, and computer science. Amy, Santiago, and Carina, for instance, highlighted how math serves as a foundational tool and language across various scientific disciplines. Others, like Silvia and Belinda, noted its practical applications in everyday life emphasizing logic and reasoning as central to understanding and solving real-world problems. Adeline appreciated the structured nature of mathematics, valuing its ability to provide clear, definitive answers, while Micah saw it as a set of tools for efficiently solving practical engineering challenges. Collectively, these perspectives underscore students' understanding of math's importance as both a versatile and essential discipline that is integral to academic success and everyday functionality.

However, the way students relate to and engage with mathematics is deeply influenced by their unique identities and the systemic barriers they encounter. For example, Amy's experience as an Asian American woman involves navigating the pressures of cultural stereotypes, while Belinda and Santiago, both first-generation Mexican American students, grapple with language barriers and the lack of representation in STEM fields.

Intersection of Identity and Academic Performance

Across the conversations around what mathematics means to students and their personal mathematics story arch, students' identities as first-generation college students, gender, race, language, and learning styles all influenced the shaping of their academic journey in mathematics. Each of these aspects of individual's identity intersect and complicate navigating college mathematics, with some focusing more on the roles, values, and practices of some figured worlds over others. Through analyzing across our conversations, it was clear that support systems from the university played an integral role in students' ability to demonstrate incredible resilience and dedication to their education despite having to face challenges that were tuned specifically to each unique identity.

Multiple supports that students mentioned, such as the support course that requires attendance to SI sessions, tutoring at the MSLC, and online homework programs like ALEKS, were crucial for their perceived success and confidence in mathematics. Five out of the seven students interviewed specifically mentioned the SI sessions as having a positive effect on their performance in math. Silvia mentioned the effect that the coordinated care provider who ran the Canvas course had on her while when she described her as, "… like, not like a math professor, but she worked more as a mentor…" and continued to describe the support course as, "… more like a class to support myself, like 360 degree, like a total thing. Not just within my math, but also be like enrolling into classes, understanding what to do next, [and] what classes to take." In addition to Silvia's mathematics story including a shift in confidence, there was also a theme of evolving confidence across other students' experiences in math.

Several students discussed changes in their confidence regarding mathematics throughout their educational journeys, with enrollment in the support course as a common aspect of their experience. Amy mentioned that performing well on midterms, attributed to her utilization of the support course's SI sessions, boosted her confidence significantly, which challenged her own self-doubt. Belinda experienced a notable improvement in confidence after utilizing SI sessions and the ALEKS program, which helped her overcome language barriers and shyness. Santiago entered college with insecurity but felt more confident after receiving support from the MSLC and engaging with supportive professors and mentors. Adeline's confidence decreased upon transitioning from high school to college math due to increased difficulty, but she remained determined to rebuild her confidence through the support systems available to her. Micah's confidence grew as he adapted his learning strategies and leveraged support systems to manage his ADHD and preference for hands-on learning.

Altogether, these narratives highlight how structures like the support course that requires attendance to SI sessions, tutoring at the MSLC, and mentorship can significantly impact students' confidence in their mathematical abilities. More analysis on students' changes in mathematical attitudes, including confidence, is included in the next chapter. For the next section, I widen the scope to include both changes in attitude and confidence.

Inclusivity and Respect in STEM

Santiago and Adeline both spoke directly to the idea of representation of their own identities in the people in positions of power in math and their respective major disciplines was important to them. While Santiago said, "I don't know of many Mexican faculty… I wanna bring representation to that", Adeline shared that her experience with having a woman instructor for an environmental engineering course was, "comforting and just like cool to have a woman be able to teach me a field like that." Belinda spoke to her motivation to demonstrate her worth in STEM when she said, "as a Latina, it's important to me to prove that we can excel in math and science."

In addition to this idea that Belinda feels she must prove herself as a Mexican woman, Silvia and Amy both mentioned different experiences of being a woman in math class where representation of women in math was lacking. Silvia recalled that she, "often finds [herself] the only female in the class… [and] sometimes it's tricky to speak up". Amy, on the other hand, felt confident in speaking up in her group despite being underrepresented but explained that, "when we tried to explain the solution, we were ignored because we were the only two women there." Viewing these intersecting and overlapping figured worlds of cultural backgrounds, what is valued in educational and non-educational environments, and their personal aspirations reveal the way students relate to mathematics is deeply influenced by their unique identities and the systemic barriers they encounter. Furthermore, through a Critical Race Feminism (CRF) lens there is an emergent theme of how power dynamics and intersectional identities shape each student's mathematical journey.

Within the conversations I had with these students about what mathematics means to them and how they define it, identity-related aspects of their experience became increasingly important in the service of explaining their reasoning. While the differences in definitions of mathematics and what mathematics means to these students reflected the individuality of each student interviewed, the shared experiences among them emerged as principal to their own identity development. The next section explores which instructional practices that they perceived as attending to their various experiences of being under-represented, intersecting, and compounding identities and how the mathematical community they perceived influenced a shift in the identity-specific ways they experience mathematics.

Identities in Transition: The Role of Mathematical Community and Instructional Practices

The following results delve further into the theme of identity formation in mathematics through multiple life transitions for not only the students who were interviewed, but also the entirety of the group of 1,131 students who responded to the survey. Through analysis of this data through the lens of Figured Worlds interfaced with CRF, the connection between students' identity navigation and reformation, the mathematical community they perceive, and the instructional practices they experienced becomes more salient. In this section, I answer the second research question of my first research goal: How are students' mathematical identities mediated by the instructional practices and the mathematical communities they perceive?

To contextualize where in the arch of time in academia and life these students are currently residing, it is important to recognize that the average age of the students responding to the survey is 18.76 years old, an age where they just recently finished high school and by US society's cultural standards are at the infancy of their adulthood. Along with all the opportunities and freedoms assumed from this transition there are also significant struggles and barriers to overcome, particularly for these students who continue their academic studies at a four-year college. One all-encompassing aspect of this transition is the negotiation of identity, dynamically shifting and forming in the face of the wide scope of the present reality and the future they envision inhabiting.

The figured worlds that these students operate within are socially constructed realms of interpretation, which are shaped by culture, norms, and shared meanings that reach back into everyone's personal experience. While each unique individual has their own interpretation of reality, there are shared experiences that form commonalities among their experiences as they begin their adult lives. For college students, the transition into adulthood involves navigating multiple figured worlds simultaneously, each with its own set of expectations, cultural practices, roles, and values that must be learned to be understood and integrated into their sense of self. For example, these worlds include the broad societal norms, family expectations, different social circles, and their academic environment.

Transitioning Between the Figured Worlds of High School and College

One theme of the students' experiences voiced through free responses on the survey as well as the interviews was a focus on the change of academic environments. Living in a time of their lives marked by a search for personal meaning and direction, identity formation is an integral aspect of their daily experience. Analyzing academic struggles through the lens of Figured Worlds, provides insights into how students perceive their identities and experiences through this transition from the figured world of high school math to the figured world of college math.

Through qualitative analysis of student responses to question "Is there anything about your identity or who you are that has affected the way you do or learn mathematics here at SWU?", there was a clear theme of academic struggles involving the differences they perceived between high school math and college math. This question was asked both in free-response form on the survey as well as included in the interview protocol. The combination of these two sources for student utterances resulted in over 60 unique instances of students speaking to this transition, including at least one mention from each interviewee. After coding these responses for the larger theme of "high school vs. college", another round of open coding and constant comparison revealed five sub-themes: positioning and power, cultural norms and expectations, sense of belonging and agency, support and resources, and psychological or emotional impact.

Summarizing these themes, it was clear that college math is perceived as more demanding, requiring higher levels of critical thinking and independent study compared to high school. Students struggled with the faster pace and increased complexity of college math courses, often noting a feeling of being unprepared by their high school experiences. Their high school teachers were seen as more supportive (despite some mentioning support from their professors as well), while college math was perceived to require more self-reliance and self-election to utilize available resources. Finally, the navigation of this new academic and mathematical landscape lead to stress, anxiety, and a sense of inadequacy. Delving into these themes through a Figured Worlds perspective in the following paragraphs widens the scope of how this transition is so closely tied to their sense of self.

Positioning and Power

In high school, students spoke to the idea that they often occupy a more passive role, relying on teacher support and structured learning environments. The figured world of high school math is one where success is more predictable and controlled, whereas in college, students are thrust into a figured world where they must take on more active and independent roles. Many students agreed with the perspective of one student who said, “High school math was easier than college”, which is not a surprising sentiment but is underscored by a quote from another student who said, “in high school, the teacher would guide us through everything, but in college we’re expected to figure things out on our own.” There are two shifts of positioning occurring in this theme: one positions high school math as easier, underneath the position of college math and the other positions the students themselves in a place of more responsibility.

Students who were interviewed were able to delve more deeply into the ideas of positioning and power dynamics. Silvia, the Italian woman, characterized her high school math as, “very strict… especially in the south, it’s very male-oriented for science." Her experience in Italy was marked by a rigid, male-dominated educational context, positioning her as less-than in a challenging, sexist environment. However, her transition into college at SWU, she was surprised by the positive and supportive experience she had, particularly how she positioned herself before and after. She shared that,

> Like professor are like very different in here. Everything is more open here. Like in south of Europe is more like male oriented for science. So they were not really open to like teaching like female in the STEM environment. So I always like was very limited about it and thinking that math was not for me. So when I came here and I got a job for math, I was like really shocked, you know? It was like, oh wow. It was not what I expected honestly, since moving here.

Silvia describes here that the way she positioned herself in the mathematical community changed because she was accepted as an equally important student of mathematics who was recognized by people in positions of power that offered her a job specifically teaching math to her peers.

Adeline, the white woman who is a first-generation college student had an entirely different experience. The figured world of high school math, with its support and consistent structure, had her position herself as a confident and successful math student. During this transition into college, Adeline's self-positioning went from someone who, "used to love math… [and] always got high grades," to someone who's, "confidence has definitely gone down… struggling so much in the subject that I've never experienced this type of struggle in." This shift in positioning from the role of a high-achieving high school student to struggling in college highlights the impact of growing into a more challenging academic environment.

Whether they are positive like Silvia's or negative like Adeline's, the shifts of positioning and power that students are navigating are inextricably tied to the cultural practices and norms between these two figured worlds, which is the focus of the next section.

Cultural Practices and Norms

Students voiced their opinions and perceptions around the norms and practices of college math, which they described as valuing self-directed learning, critical thinking, and resilience. There, students are expected to engage with material more critically and independently, which reflects a figured world that values intellectual rigor and self-sufficiency. Several students shared the idea of one student who mentioned, "the pace of college math is much faster", which indicates the increased demands and expectations in college. Students noted that collaboration with others, engagement in the material, and the comprehensiveness of the courses all characterized their experience with college math.

On the other hand, high school math classrooms were characterized by more guided instruction and immediate feedback, aligning with a figured world that emphasizes supportive learning. This is highlighted by one student who said, "high school teachers were more supportive" and another student who said, "high school math was less demanding." Another student mentioned that, "high school math didn't prepare me for college", which underscores the feelings they have of the changes they perceive between the two worlds.

In the interviews with both Mexican students, our conversations explored more deeply the cultural differences of their high school math versus their experiences in the world of college math, with a focus on the support they received for the language barrier they faced. Belinda, the first-generation college Latina woman, “struggled a lot with precalculus in high school because of the language barrier.” Her high school experience was influenced by cultural and linguistic norms that created barriers to understanding mathematical terminology and concepts. As Spanish-speakers in an English-dominated environment, she and Santiago, the first-generation college Latino man, both separately faced additional challenges accessing and engaging with the curriculum sharing a similar story of moving to the US while they were in high school. Santiago said that when, “[he] moved to the US in 10th grade, it was hard to adapt to the new educational system and language.”

However, their transition into the figured world of college math was quite different than what other students were saying. While many students categorized the norms of high school to be more supportive, they both found that it was finally in college when they were able to access the support they needed to help overcome struggles that they had from lack of support in high school. Belinda said that, “the SI sessions and tutoring really helped me with my math class” and Santiago said that, “meeting with my professor in their office hours has been huge, honestly.” In college, Santiago benefited from the cultural norms of accessible and supportive faculty in addition to the cultural practice of providing support systems such as SI sessions and free tutoring that Belinda benefited from. They both spoke positively of the supportive environment that contrasted with the challenges they faced in high school, improving their confidence and performance.

The stark contrast between how some students felt regarding the cultural norms and practices of high school versus those in college reveal another layer of complexity of all students' transitions into college. From some points of view, college was less supportive and more demanding and from others, the demand was similar but the support offered in college math was actually much better. This incongruity across all students' responses suggests that the cultural norms and practices are only one level of analysis and that additional aspects of their experience, such as their sense of belonging and agency should also be considered.

Sense of Belonging and Agency

Students touched on this feeling of a loss of agency as they transitioned to college, struggling to find their place in the more intellectually challenging and less supportive environment. As one student from the survey mentioned, "I feel like an outsider in [college] math classes", highlighting the idea that this transition between worlds can lead to a sense of not belonging or feeling inadequate. However, there was a duality of inclusion and exclusion that students felt directly related to this change between high school math and college math.

This duality is punctuated by the fact that while some students shared feelings of exclusion, nearly the identical number of students surveyed shared the exact opposite. For example, one student shared they, "feel accepted in the math department", while another shared that they, "feel unwelcome in the math department." Another student shared that, "instructors make me feel included", while another student said they were, "not welcomed by instructors." The duality continues with students who shared that they, "feel welcomed by peers" and that they felt, "included in group activities", while other students said they, “feel isolated in math classes” or that they, “feel ignored by peers.”

Analyzing the student interviews confirmed that there were mixed feelings around sense of belonging and agency. For instance, Amy, the Asian American, first-generation college student, expressed appreciation for her college instructors, stating, “my professor and TA have been really cool… I don’t think they marginalize any students,” highlighting an inclusive environment. Conversely, a lack of representation of women and minorities in the mathematical community they perceive can exacerbate feelings of exclusion. Amy’s experience with gender-based marginalization within a group setting and Santiago’s note of the scarcity of Mexican American faculty illustrate how systemic barriers and underrepresentation could contribute to the sense of isolation that many other students reported.

Yet another layer of complexity to the transition between these two figured worlds emerged as an indicator of students’ success navigating the tension between the roles that they inhabit, which supplements this analysis with more explanation as to why so many students felt so differently about their experience during this hectic transitionary period of their lives.

Resource Identification and Utilization

The figured world of high school provides more direct support, which students may or may not take for granted. In college, the expectation is to seek out resources proactively, which was noted as a difficult adjustment. Highlighting the direct support they received, one student from the survey mentioned that, “high school math was less resource intensive.” Another student corroborated this difference between figured worlds when they said, “in college, I have to seek out help on my own.” Some of the resources students identified were those that are already built into the college class itself, while others required engagement outside of class.

One of the resources that students had to take time out of their schedule to make use of was the MSLC in the library on campus. Some students in the survey said that the MSLC, “provided the resources I needed” and that it, “really helped me get through [this college] course.” Many surveyed students agreed with the sentiment of one student who said that, “the [MSLC] was a key resource” and another student who said that, “the [MSLC]’s resources were invaluable.”

One aspect of student resources for support that comes along with enrollment in SWU’s math courses is the use of teaching assistants (TA’s) in required recitation courses. Some students mentioned their TA’s in college math, “made a big difference”, “were essential for my learning”, and that, “[their] support was crucial for understanding the material.” TA’s as a resource in college math is something that high school math does not offer, and the transition to a college course where there is an often more approachable TA that runs the recitation course that meets twice a week was something that students agreed was a resource that was invaluable to them.

Amy spoke to the difference she perceived between the support that was offered between her experiences in the figured worlds of high school and college math. She said that, “in high school, I didn’t have much access to extra help. There were some after-school tutoring sessions, but they weren’t very effective…” which she later described as “really stressful.” However, comparing the two figured worlds, she said, “in college, I discovered the Supplemental Instruction sessions and tutoring. My professor and TA also hold regular office hours." While access to support is important, access does not always mean that students are identifying those supports and utilizing them. Amy, Santiago, and Micah all mentioned specifically that they had to "search for" or they "discovered" or "found" the supports, which emphasizes the idea that students had to seek out the support they needed. For Adeline, who's college math experience was perceived as negative compared to high school math, she reiterates this idea when she says, "this has been a humbling experience and has made me realize the importance of seeking help." Seeking help on your own aligns with the practices and norms of the figured world of college math because independence and self-advocacy are valued in that space. While students may be directly or passively informed about resources available to them, it is up to students themselves to "find" those resources.

Another interesting theme that emerged from analyzing responses from the survey as well as the interview questions around resources from students is that they either were not aware of, or they very rarely (if ever) utilized the psychological and therapeutic services that SWU offers. Even though students said they could use it and that they might use it in the future, these resources were often nonexistent in their responses to the emotional and mental strain students they aware of experiencing. The next section focuses on the emotional and psychological struggles students were facing in reference to their adjustment to the figured world of college math.

Emotional and Psychological Adjustment

The transition to college math can be emotionally taxing, as students adjust to new expectations and the pressure to perform independently. This can result in stress and anxiety, which are common themes in the responses from students regarding this transition between figured worlds of math. Reflecting their stress and frustration with this transition, one student said that “high school [math] prepared me poorly for college math.” The emotional toll of adjusting to college-level math is highlighted by another student who said that, “college math is much harder, and it stresses me out.”

From the students I interviewed, Amy talked in detail of the differences in pressure, stress, and anxiety she experienced while comparing the figured worlds of high school and college math which is different than the students that responded from the survey. She said that, “being Asian, there’s always this stereotype that we are naturally good at math… in high school, this stereotype really affected me.” She continued later to say that she, “felt pressured to meet everyone’s expectations and it often made [her] anxious.” In college, she found the environment to be more inclusive and supportive, that the Asians are good at math narrative was less salient to her experience, and that, “this change made me … less anxious about my math abilities.”

Santiago’s experience also speaks to the positive results of his transition from high school to college. When he moved to the US in 10th grade and was having a difficult time adapting to the cultural and linguistic barriers, he said, “it was a very isolating experience, and I didn’t know where to turn for help.” However, after seeking out the help from professors, TAs, SI sessions from enrollment in the support course, and tutoring in the MSLC he said that, “having access to these resources has made me feel more capable and supported, and less isolated in my math journey.” While Amy and Santiago both credit their success to the supports they had to seek out to engage with, their stories of resilience and determination should be an inspiration to all students. However, the fact that students overall are dealing with significant emotional and psychological issues throughout this transition should not be overshadowed by these two students' success stories.

Summary of Transition Between High School and College Math

Viewing the transition into college math through the lens of Figured Worlds Theory as I have in these previous sections highlights the complexity and multiplicity of this developmental stage in their lives. This in demonstrated in the several dualities that emerge when synthesizing the results reported in this chapter, causing a lapse in the ability to conclude unequivocally the students' experiences. The overarching theme of the duality that students presented in their experiences is visualized in Figure 4.1.

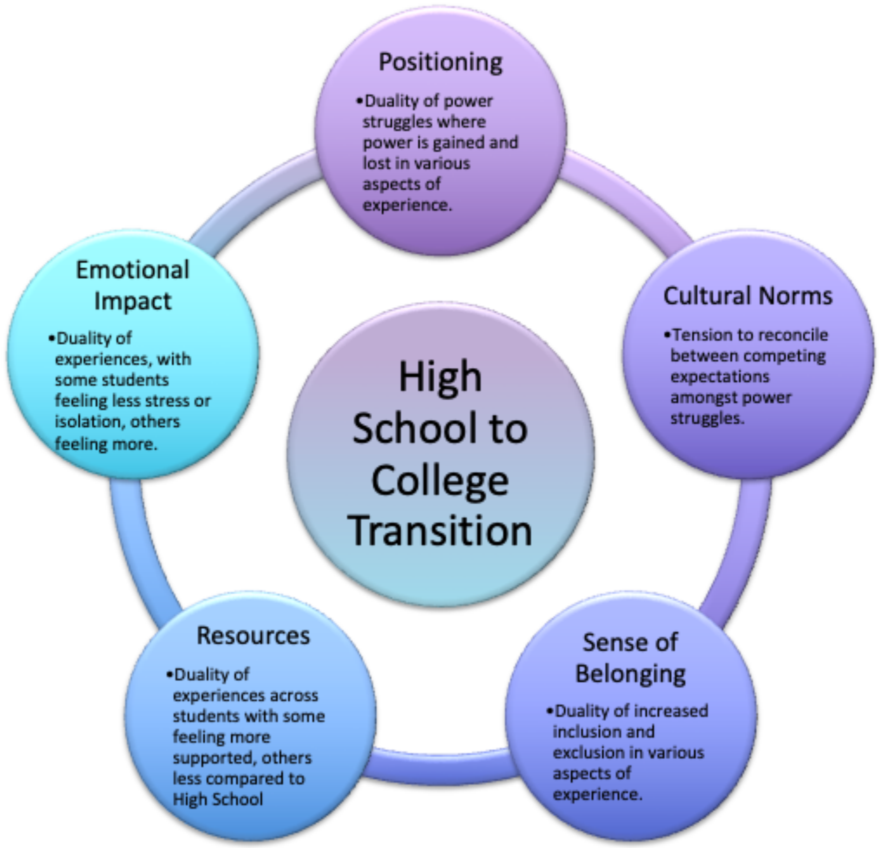

Figure 4.1: A diagram that places the transition from high school math to college math at the center of interconnected themes gained from analyzing students' voiced experiences.

Transition Into Adulthood and the Student-Workforce

Acknowledging that humans navigate multiple figured worlds simultaneously, it is important to contextualize these students' experiences as they voiced not only issues of identity related to college, social circles, and adulthood, but also balancing their budding identity as a member of what I call the student-workforce in the US. In this section, the term "student-workforce" is introduced to define a specific figured world characterized by the necessity of balancing academic responsibilities with external employment. The creation of this term is an effort to delineate students who must engage in paid work outside of their studies to support themselves financially, distinct from the politically- and sociologically loaded term, “working class”, which often refers to socioeconomic background based on family income and occupation.

One assumption I make about these student-workers based on a lack of specific data on their individual reasons to be members of this figured world is the economic necessity of having to work outside their academic commitments to afford basic living expenses, tuition, and other costs associated with their education. The term acknowledges the social identity through these economic activities that students conjured themselves, which recognizes that the need to work while studying shapes their college experience and perspectives. Defining the student-workforce in this manner aims to highlight the structural and experiential distinctions of students who must work to support themselves while in school without making assumptions about their familial socioeconomic background or the nature of the job they are working.

Since each overlapping figured world has its own set of norms, expectations, and practices, the introduction of the figured world of the student-workforce became necessary in this dissertation because of the way that students responded to the identity-related free response question on the survey and the approximate number of hours per week they worked at a job during that semester. Since this was an emergent theme from the survey responses and reference to working outside of school was not a topic of the interview protocol, this section focuses entirely on the student responses from the survey.

A significant 393 student-workers out of the entire survey population of 1,031 responded that they worked at least 1 hour per week at a job, making up just over a third of all respondents. Of those 393 student-workers, 51% of them worked 16 or more hours per week at a job during the term they responded to the survey. Since being a student-worker emerged as an integral aspect of such a large portion of the sample, this section focuses on the experience of these students as they attempt to succeed in both the figured world of college math and the figured world of the student-workforce.

To extend the grounded nature of this section in terms of a Figured Worlds lens, there are some similarities between these two figured worlds that I have personally surmised based on my experience as a student-worker in the past. Since I do not have information about the types of jobs and the roles students inhabit at those jobs, I cannot make assumptions about the level of cognitive load or the relevance of their job to their academic life. However, I can anecdotally describe from personal experience the competing expectations of responsibility, persistence and hard work, and skill development. Both worlds expect individuals to adhere to certain cultural practices, like taking responsibility for their roles, whether in completing academic assignments or fulfilling job duties. Some characteristics that students and workers are both expected to demonstrate and are valued in both figured worlds are reliability, punctuality, and the perseverance that is required to continuously improve.

While it is certainly possible to thrive and succeed in both worlds simultaneously, students must inevitably allocate more of their finite time, emotions, cognitive capacity, and motivation towards one or the other. Of the students who responded to the identity related free response question, 81 unique responses were thematically organized under the theme of Work Responsibilities. These responses were then open coded and four sub-themes emerged: balancing multiple roles, emotional or psychological impact, time management challenges, and impact on academic performance.

Balancing Multiple Roles

Two major roles that students responding to the survey mentioned were the role of student and the role of employee and the tension they felt between the two. The tension students experience between these worlds creates significant challenges for student-workers, which includes the idea of balancing the two worlds where they feel the pressure of responsibility simultaneously. One student mentioned that, “balancing work and study is challenging”, while another said that they were, “struggling to manage job and study workload”. These sentiments reflect the struggle of balancing the roles of student and employee. In the figured world of math, students are expected to dedicate their focus on intellectual and academic improvement, while in the working world, they must fulfill their job responsibilities.

Navigating conflicting roles, such as being a student and a worker, can lead to a fractured sense of self as individuals struggle to reconcile the divergent expectations and values of the two worlds that are at odds with one another. This tension, as described by Burke & Stets (2009), can result in identity fragmentation, where the demands of each role pull individuals in different directions. This fragmentation can lead to stress, anxiety, and a sense of inadequacy, which is the next theme from the student-worker responses.

Emotional or Psychological Impact

Some of the student-workers responses spoke to the struggle or stress they experience because of their concurrent roles as student and worker in these two figured worlds. Two students mentioned stress specifically in their responses, and both were tied to their success in their role of a student. One of these students said that, "work-related stress affects my studies" and the other statement was nearly identical by stating, "job stress impacts my academic performance." Another student said that they were, "struggling while I try to manage work hours and classes", which does not specifically call-out what that struggle was but the generic struggle itself is worth noting as something that influenced this student and likely others. Not only was there a struggle of mental nature, but there was also an aspect of time management in this quote, and the aspect of impact on academic performance from the first two student-workers, which leads into the next two themes from student responses.

Time Management Challenges

Effective time management is crucial in balancing the demands of multiple figured worlds that student-workers are invested in. One student spoke to the confines of school and work when they said that, "managing work schedule around classes" was affecting their ability to learn or do math at SWU. Another student tried to, "find time to study while working", which demonstrates that they may be trying to use down-time at their job to make up for time lost towards their academics. Another student who may not be able to find down-time to study while at work said that, "work responsibilities limit my study hours."

These responses reflect the ongoing struggle to manage time effectively for student-workers who must allocate limited hours to fulfill the demands of both work and school, often sacrificing leisure or sleep. This constant juggling act is a defining feature of their transition into adulthood, where they must learn to prioritize and manage their time. However, their academic performance can become impacted while they are still finding ways to balance their multiple roles and learn to cope with the struggles they experience.

Impact on Academic Performance

The working world often places demands on student-workers that can conflict with the academic figured world, leading to a potential decrease in academic performance. One student said that their, “full-time job affects [their] studies”, which speaks to the general decrease in academic performance if their studies are affected. Another student shared a similar sentiment when they said their, “job responsibilities reduce study hours”, referencing the idea that a reduction in study hours affects their ability to learn or do math. Another student mentioned that their, “work hours conflict with [their] class schedule”, which references the idea that varying work schedules week to week can be a constant struggle that forces a student-worker to choose schedule over the other.

When schedules conflict and a choice is made to attend to responsibilities in one world over the other world, that choice leads to either a reprimand at work for missing a scheduled shift or a loss of valuable class-time or study time and the potential for a loss of points towards a final grade. While there are no data available from these student-workers that provide evidence of their academic responsibilities had on their job, this section has demonstrated the salient aspects of the tensions of the competing role and responsibilities attached to being a member of the student-workforce.

Summary of Transition in Adulthood and the Student-Workforce

The results of qualitative analysis of the experiences of members of the student-workforce reported in this section shown in Figure 4.2 report the barriers that these students face as they continue to attempt to cope with their transition into adulthood.

While some students spoke to the general struggle to balance the competing roles the inhabit simultaneously, others focused their input on the emotional or academic impacts these barriers have. Another compounding factor that feeds into all of these barriers is the struggle of time management, where prioritizing class and work schedules and demands requires students to make difficult decisions that have potential to affect their status in one or both of the positions within the figured worlds they are interpreting.

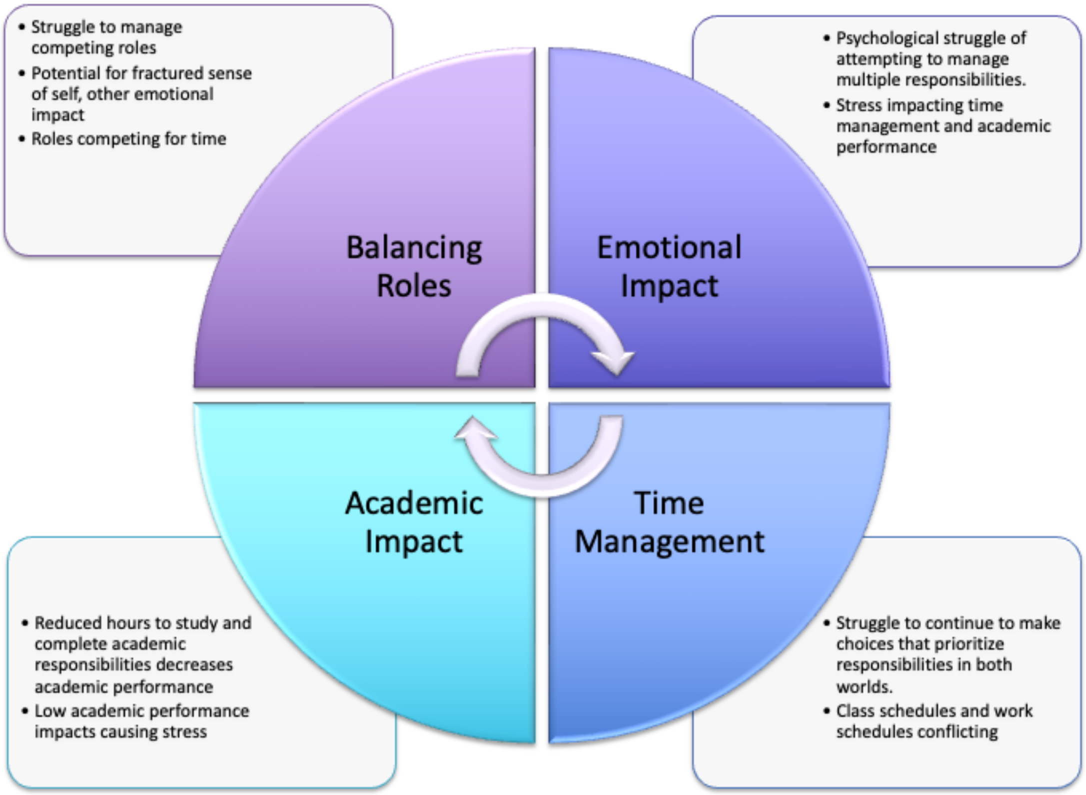

Figure 4.2: Four themes of the tensions students spoke to when discussing the impact of different aspects of their identity, specifically between the roles they inhabit in the figured world of college math and the figured world of the student-workforce.

Figure 4.2 is not only a summary of the four themes gained from analyzing student responses of this section, but the directional arrows symbolize how each of these tensions causes a repeating cycle of compounding issues students are experiencing. If the tension commences in any one of those these quadrants, for example the struggle to balance roles and responsibilities, then there is often emotional impact which can cause distraction and inefficient time management, which could impact academic performance, which then returns to compounded tensions on balancing roles which now have more weight because of the impact on academic performance.

Instructional Practices and Identity Development

In this section, I respond to the second research question of my first research goal which is, “how are students’ mathematical identities mediated by the instructional practices and the mathematical community they perceive? In this section I present results of analysis that produced emergent themes from investigating both the free response identity question on the survey as well as the related conversations during the student interviews. This qualitative analysis provides motivation for making hypotheses about the proportions of agreement across different populations to specific survey items and those results are reported as well. This quantitative analysis is pulled from the entire data set of all students who responded to questions on the survey regarding particular items that involve instructional practices (from SPIPS), the perceived inclusivity of instructor behavior (IIB), and the climate in their math course. While there are many different identities that emerged as salient throughout the entirety of data collection, this section highlights two broad aspects of identity that are significant portions of the surveyed and interviewed population: women and first-generation college students.

Intersecting Identities of Women in STEM

Since five of the seven students I talked with were women, and the sample contains 429 women making up 37.93% of the population, the data represents a wide variety of the experiences of women and their intersectional identities in mathematics and STEM more broadly. The focus for this section is specifically on instructional practices that mediate their intersectional identities as women in mathematics, where some themes emerged through analysis of the interviews as well as the identity-based free response item on the survey.

Qualitative Analysis of Women's Identity-Related Experiences

Specifically in response to the survey question that asks if there is something about their identity or who they are that affects the way they do or learn math, several surveyed women shared the sentiment of one woman's response which said, "Being a woman in a male-dominated major is tough." Another woman spoke to the challenge of underrepresentation in math specifically when they said, "being a woman in math is isolating." These two responses, and the several other women who responded to that survey question with nearly identical statements, demonstrate the prominence of gender and the patriarchy in mathematical experiences and set the stage for the analysis of women's experiences in math at SWU.

Silvia, the Italian woman who is a first-generation college student, has been featured already for the difference in her high school and college experiences but the insight she shared on her experience as a woman in STEM reveals how the residual systemic sexism in Southern Europe affected her identity as an aspiring STEM student. She described the focus of the sciences in the school system in Italy as strict and male-oriented, which resulted in a feeling that she had to prove herself as worthy of the sciences just because she was a woman. Commenting on how this part of her identity was in the forefront of her mind, she said that, "this constant need to prove myself made math a source of anxiety." So even though she was a smart and successful student, she felt extra pressure to prove herself as a woman in a version of the figured world of the sciences that still maintains that women do not belong.

However, the feeling of exclusion from math and STEM because of her identity as a woman was mediated by a specific instructional practice in the figured world of college math. Silvia had no reason to think things would be any different than her high school experience, where she said that her group projects were, “very hierarchical, and as one of the few girls, it was hard to have my ideas taken seriously.” But fortunately, she said that the TA in her recitation course as well as the SI-leaders, “encourage participation from everyone, and I don’t feel like I have to constantly prove my worth as a female student in STEM.” She continues to say that this instructional practice of encouraging everyone to participate, “helped [her] to participate more actively in class and to enjoy learning math again.” This instructional practice of soliciting answers from a diverse group of students, rather than just a few who typically speak up, made Silvia feel that, “the atmosphere is more inclusive, and my contributions are valued more.” In a figured worlds perspective, the perception that her contributions from the role of student having an increase in value among her peers helped promote a change in an aspect of her identity. She said that the more inclusive atmosphere that was generated by the instructional practice of encouraging every student to participate, “encouraged [her] to speak up more and to be more confident in [her] ideas.” While this one instructional practice is certainly not the only driving force for Silvia’s change of self-perception, she spoke specifically to this practice having an influence on her success.

Amy, one of the students that was interviewed, shared some psychologically and emotionally harmful interactions in math spaces that she attributed to be directly related to her identity as an Asian American woman. While she shared that the Asians are good at math narrative was salient to her experience while in high school, her experiences with that narrative affecting her did not end there. She was surprised that of all people, one of her friends she made at college reignited those issues and decided to tell that story as an example of an aspect of her identity that affects the way she learns or does math in college:

> So I was working on a problem with my friend and she just goes, 'Well, of course, you got it right. You're Asian, you're supposed to be good at math.' It really hit me because it's like, yeah, there's this stereotype, but it also feels like I have to live up to it. And when I don't, I feel like I've let people down or like I'm not good enough. It's just a lot of pressure, and sometimes I question my own abilities because of it.

This quote highlights the impact of stereotype threat on Amy. The casual remark from her friend reinforces the societal expectation that Asians inherently maintain proficiency in math, which places pressure on Amy. This microaggression she experienced not only affects her self-esteem but also her confidence in her mathematical abilities contributing to anxiety and self-doubt and emphasizes the reality that systemic racism remains to affect students in the present day.

Amy's negative mathematics experiences were compounded by one particularly harmful experience in a group setting that reminded her of the casual sexism that also continues to occur in mathematics and STEM settings. Instigated by my solicitation of any marginalization she may have experienced around math, Amy shared this story:

> There was this one time we were working on a group project, and I suggested an answer. The guys in the group just ignored me and went with another answer that ended up being wrong. It was really frustrating because I felt like they didn't take me seriously just because I was a woman. It made me doubt myself and whether I should speak up in group settings.

Amy was one of the students that was interviewed twice, and it is important to note that she brought this story up both times I spoke with her; an indication that this experience not only bothered her at the time but continued to stay on her mind for months. Amy's interaction with gender bias in group work illustrates how being overlooked can undermine confidence and participation. The dismissal of her correct answer by male peers not only invalidates her contribution but also reinforces the sexist perception that women's input is less valuable, impacting her willingness to engage in future group activities.

However, my conversations with Amy demonstrated her resiliency and determination to succeed despite her personal sexist and racist experiences around mathematics while in college. There were multiple instructional practices that mediated changes in the negative effects of these experiences with mathematics. First, she spoke about the support she received from her TA who teaches the recitation section for Calculus I:

> One of the things that really helped me was my TA. He was always there during office hours, and he explained things in a way that made sense to me. He never made me feel stupid for asking questions, and he encouraged me to keep trying even when I was struggling. It was a huge boost to my confidence.

The encouraging interactions and support from Amy's TA signifies the significant role of personalized in fostering a positive learning environment. She also spoke about impactful instructional practices of the professor for the lecture section:

> In one of my classes, the professor always made sure everyone had a chance to speak. He would go around the room and ask each person for their input. It made me feel valued and like my opinion mattered. It was a stark contrast to some of my other experiences, and it really changed how I viewed myself in the classroom.

Facilitating an inclusive classroom environment where the instructor actively seeks input from all students helped Amy combat feelings of marginalization. For her, this practice validated her contributions and fostered a sense of belonging, positively influencing her identity by changing her self-perception and her place in the math classroom. One last specific instructional practice that Amy brought up in our conversation was one that she found to combat the gender bias she experienced in group work: "There was this one class where the professor structured group work really well. He gave us clear roles and made sure we rotated them each week. It meant that everyone had a chance to lead and contribute, which was great because it ensured that no one was left out or ignored." Structured group work with rotating roles promotes equitable participation and prevents dominant voices from overshadowing others. This instructional practice specific to group work facilitation fostered a collaborative and respecting learning environment that ensured her contributions were acknowledged and valued.

Adeline, the white American woman who was interviewed, mentioned negative experiences she had with the overbearing presence of certain men in her class. She described a group of them as being loud when they entered class, often not on-time, and that they were over-confident and over-represented in class discussions. While this experience did not have much effect on her identity as a woman in her math class, it was interesting to note that this male presence was something that she was used to dealing with. However, she did share a story of one specific male presence in her class that understandably caused her significant discomfort:

> There would be a certain peer who was a man who would somehow always... No matter where I sat, no matter what time, would always just find a way to sit right next to me. And, you know, I'm not a super confrontational person, so I never said anything but it just always seemed to be that it was this man who would sit right next to me. And, you know, I... it was just like... I guess my thing is like not the fear of being perceived, but I'm like I just want to focus right now and I don't want to think about why this person is sitting right next to me all the time.

This quote highlights Adeline's discomfort with a male peer who intruded on her personal space in class and her inability to take action to stop it, something that extends to the experience of many women in today's society.

Unfortunately, there was not an instructional practice that prevented these uncomfortable situations to occur in every meeting of her lecture section, but Adeline did share one story of a how change in how groups were chosen by her TA in her recitation section that is tangential to this idea of fostering a space that feels safe for women in class:

> In my [recitation course] specifically we would just be put into groups like, '1234-1234, You're part of a group. You're part of a group.' Now it's just like, 'okay group together.' And obviously there's that like awkward tension where people are just like, 'wherever should I go?'

In Adeline's case, structured group work with randomly assigned groups such as how her TA facilitated at the beginning of the semester could help mitigate tension, awkwardness, and exclusion that can occur in unstructured group settings. In particular, considering the hypothetical case that her lecture instructor would utilize groups based on proximity, Adeline would be forced to engage with the man who purposefully chose to sit immediately next to her in every class. With a randomized selection of group members, the person sitting right next to her would likely not be placed in the same group as her which demonstrates how consistently attending to group selection is an instructional practice that could relieve students of awkward choices forced upon them that could realistically cause uncomfortable or even dangerous interactions with an unstable (or at the least, unpredictable) peer.

Another student from the interviews who spoke to a specific instructional practice that mediated a shift in aspects of her identity was Belinda, the Mexican Latina first-generation college student who described herself as an introvert. Belinda came out of high school with feelings of exclusion from engaging in mathematics and she shared that, “in high school, group work was difficult because of the language barrier. I often felt left out because I couldn’t communicate my ideas effectively.” However, she shared multiple instructional practices that helped mediate a change in how she saw herself as a math student. In her experience,

> College group work is still a challenge, but having more support from SI sessions helps. It makes collaboration more effective. In SI, we often work in small groups to solve problems together, and the leader encourages us to explain our thinking, which helps me practice my English and math skills at the same time.

In this quote, Belinda explains that the small group work and encouragement for students to explain their thinking, instructional practices that are common in SI sessions, allowed her to feel that she was developing positively in both verbal communication and her math studies. She continues later to say that, “SI sessions really helped me with my math class. They break down the problems step-by-step, and the SI leader makes sure everyone understands before moving on.” This quote brings up two more instructional practices that helped Belinda, where complex problems are broken down into more manageable pieces and the practice of attending to the groups’ consensus of understanding before starting the next topic. Collectively, these instructional practices mediated a positive change of Belinda’s identity of being shy and nervous about her communication skills because as she puts it, “the supportive environment in SI sessions makes me feel more comfortable asking questions and participating… and this has made a huge difference in my overall confidence and willingness to engage in class.”

Belinda’s experiences underscore the profound impact that specific instructional practices within SI sessions can have on a student’s identity and confidence in math. The step-by-step problem breakdowns, small group dynamics, encouragement of peer explanations, and supportive, interactive environment provided in SI sessions have transformed Belinda’s relationship with math in the classroom. These practices have helped her overcome language barriers, reduce feelings of isolation, and build her confidence and competence in both math and English.

Silvia, Belinda, and Amy were all required to attend SI sessions because of their enrollment in the support course for their math course and they all said they would have most likely not attended SI sessions if they had not enrolled in that support course. It is reasonable to presume that the SI sessions, and to a lesser extent the recitation courses, are the only place where these specific instructional practices are occurring based on the noticeable absence of mentioning the lecture section to any degree when speaking about instructional practices that helped them.

Quantitative Analysis of Women’s Responses to Survey Questions

Influenced by that presumption and the fact that multiple women interviewed described the presence and behavior of men in their class to be overbearing, my hypothesis is that the proportion of students who are women who responded to the survey that agree or strongly agree to the statement about their lecture class experience, “my math instructor pays more attention to some students than others” would be greater than proportion of men who agree or strongly agree to that statement with statistical significance.

When comparing women and men's agreement, a two-sample proportions test of this statement returned a z-statistic of 0.27 (p = 0.78). This result indicates that there is no significant difference among women and men in agreement with this statement. This result prompted me to check a difference in disagreement, in the case that more students responded in disagreement. This two-sample proportions test of disagreement to the same statement returned a z-statistic of 1.57 (p = 0.12). In both cases, there was no significant difference between women and men in either agreement or disagreement to the statement, "my math instructor pays more attention to some students than others." Thus, I cannot reject the null hypothesis for both agreement or disagreement to the statements.

My next hypothesis is that there is a statistical difference in the proportions of agreement or disagreement between women and men across the statement, "How much opportunity do you get to contribute to class discussions?" regarding the recitation sections as well as the lecture sections. In this case, based on the scale provided to students and the wording of the question on the survey, agreement means that the student feels they get more opportunities to contribute compared to other students in the class and disagreement means that the student feels they get less opportunities to contribute compared to other students in the class. I conducted a two-sample proportions Z-test to examine the differences between women and men regarding their agreement and disagreement with statements about opportunities to contribute to class discussions. The results indicate that there were no significant differences between women and men for both agreement ($Z = -0.86$, $p = 0.39$) and disagreement ($Z = -0.26$, $p = 0.80$) within the recitation section meetings. Similarly, the results indicate that there were no significant differences between women and men for both agreement (Z = -0.27, p = 0.79) and disagreement (Z = -0.015, p = 0.99) within the lecture meetings as well. These results suggest that gender did not have a significant influence in how students responded to these questions on the survey and I cannot reject the null hypothesis.

Discussion of the interpretation of the quantitative results presented here is addressed in Chapter 6, along with discussion of the results of analysis that detail the women's experiences in mathematics. Next, I shift the focus to another significant population of students who were surveyed and interviewed in the following section.

First-Generation College Students

There were 310 self-identified first-generation students that responded to the survey making up 27.41% of the sample, where 8 of them found that aspect of their identity salient enough to comment on its effect on their ability to do or learn mathematics. Those students collectively shared that in comparison to their peers, they felt their first-generation status reflected increased obstacles, a lack of resources, a lack of confidence, or feeling unprepared for college. In addition, two of the interviewed students shed more light on their unique experiences as first-generation college students and the instructional practices that mediated this aspect of their complex identities.

Qualitative Analysis of First-Generation Students Experiences

Santiago, the first-generation Mexican Latino student, demonstrated an incredible attitude and resilient spirit. He shared that his parents only completed school through primaria, which is equivalent to 6^{th} grade in the US, and did not have the knowledge or ability to help him prepare for his experiences or the content in his classes in high school or college. Santiago explains his heartfelt motivation for enrolling as a computer science major in college as someone who is aware that his ability to attain a degree could lift himself, as well as his family, out of the struggles of a life of missed opportunities in education and hard labor:

> I want to succeed and get a good job so that I can help my family. My parents didn't have the chance to go to college, so I want to make them proud and show that their hard work was worth it.

Santiago's determination to succeed academically is deeply tied to his desire to support his family and make them proud, illustrating the value of family background and responsibility in his role as a son in the figured world of his family.

While his determination with the presence of family in mind is undeniable, this did not ameliorate his self-doubt and comparing the perception of himself to other students in his classes. Regarding this feeling he was having at the beginning of this journey of becoming a computer scientist, he mentioned specific instructional practices that helped him along the way:

> At the beginning, I was like, 'well maybe I shouldn't stay in this major 'cause I am not as good as other people in this major.' But like then I talked to my professor and my TA and they were like, 'no you are good enough you can do this.' And they helped me with extra resources and just talking to them gave me a boost of confidence.

The encouragement and additional resource identification provided by Santiago's lecture instructor and TA were crucial in boosting his confidence and helping him persevere in his major. The specific teaching practice alluded to by Santiago in this quote is being approachable and positive during office hours or other times when students can speak one on one with their instructors. In Santiago's case, instructors or TAs recognizing when a student needs encouragement and help finding more resources on campus helped mediate the aspects of his identity challenged by the effects of his first-generation status.

Another first-generation student who spoke directly about the barriers she faces with this complicating layer of her intersectional identity-related experiences was Adeline. When speaking directly about her experience with trying to elicit advice for college from her mom, she shared that, “I don't really talk about it with my mom. She isn’t really good for that. Not in a bad way, but she never went to college, so it's like talking to someone that, you know, just doesn't get it.” This quote highlights the disconnect Adeline feels with her mother regarding college experiences, which was compounded with feelings of uncertainty about her choice to attend college herself. As a first-generation college student, she lacks parental guidance in navigating the academic, social, or cultural challenges she faces that are specific to her role as a student in the figured world of college math.

As for instructional practices that addressed some of the challenges she faces as a first-generation student, Adeline spoke about two different experiences she had with professors or instructors in not only her math classes but across the sciences. First, she talks about the impact one professor’s encouragement made on her self-confidence as a first-generation woman majoring in environmental engineering: “I've had a professor who always encouraged me to keep pushing myself. He would say things like, 'You have the potential to do great things in this field,' and that really boosted my confidence. Knowing that someone believes in you can make a huge difference.” In Adeline’s case, hearing words of encouragement from a professor who inhabits a role ascribed with power, authority, and experience in the figured world of academia certainly mediated the uncertainty and self-doubt she feels navigating this figured world in the role of a student who has less access to resources of advice from her mom. The other instructional practice that she mentioned was beneficial to her was presented as an amalgamation of experiences from other professors or instructors she has had while in college so far: “In some of my classes, the professors make sure to create a supportive environment where everyone feels included. They are approachable and always willing to help, which makes it easier to ask questions and seek guidance.” Fostering a supportive environment and presenting an attitude and demeanor that conveys approachability and a willingness to help is an instructional practice that significantly impacted the learning experience of this first-generation student.

Quantitative Analysis of First-Generation Students Responses to Survey

Considering the significant struggles that first-generation students described, regardless of their ability to receive or access resources that helped mitigate some of those struggles, I hypothesize about the surveyed students’ perception of the academic rigor of their math course. The survey question I can use to test my hypothesis asked students to rate on a scale from 1 – 5 how rigorous they perceive the climate in the math their math class, with a 1 being academically easy and a 5 being academically rigorous. My hypothesis is that with the lack of family resources and experience in college, the proportion of first-generation students from the survey that responded a 4 or a 5 on the Likert scale would be greater than the proportion of non-first-generation students who responded a 4 or a 5. To perform the two-sample proportions test, I use another Z-test for proportions. The result of this test came back inconclusive ($Z = -0.38$, $p = 0.65$), which means this means there is no statistically significant evidence from the survey responses that the proportion of first-generation students who perceive their math course content as academically rigorous is greater than the proportion of non-first-generation students who perceive the same.

This result brought on pondering about the distribution of the responses for this survey item, in case they are skewed in a way that the proportions test I ran would not catch. In Figure 4.3, there are two bar chats adjacent to each other, with one showing the distribution of responses to the academically rigorous climate survey item across first-generation and non-first-generation students.

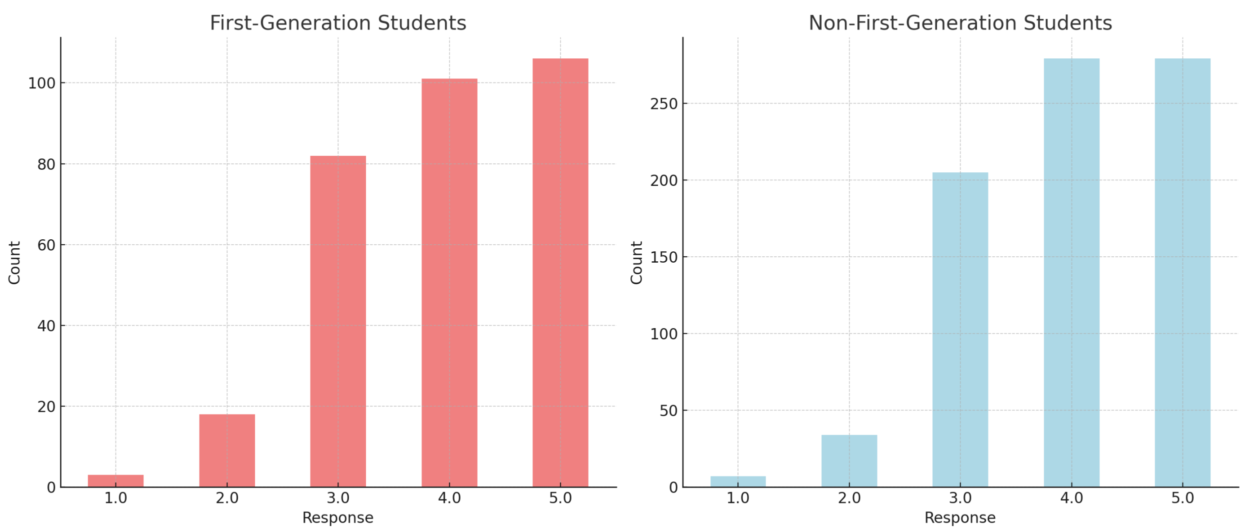

Figure 4.3: Response distributions of first-generation college students and non-first-generation college students to the 5-point Likert-scale question on the survey that asked to rate their perception of their math course from academically easy (1) to academically rigorous (5).

While they appear to be very similar distributions heavily skewed towards responses of 3, 4, or 5, I create another hypothesis about this data to see if I can investigate this question with more nuance. My hypothesis is that the proportion of students who are first-generation that responded with 4 to the proportion of students who are first-generation that responded with a 5 are is higher compared against non-first-generation students.

The results for this Z-test also came back inconclusive, with the proportion of 4-respones to 5- responses for first-generation students compared to non-first-generation students ($Z = -0.3$, $p = 0.77$). Since the p-value is much larger than 0.5, that is indicative of there being no statistical difference between these two proportions of student responses that lean towards academically rigorous climate.

Summary of Instructional Practices Identified in Analysis

Collectively, the instructional practices identified to help mediate identity-related barriers to engagement and increased self-confidence in women and first-generation students should appear familiar to an educator focused on equitable experiences for their students, as noted by multiple pedagogical frameworks in the field of mathematics education. For example, inquiry-based mathematics education promotes instruction that emphasize a focus on equity and engagement in one of its four pillars of implementation. A diagram summarizing the instructional practices found in this analysis can be found in Figure 4.4.

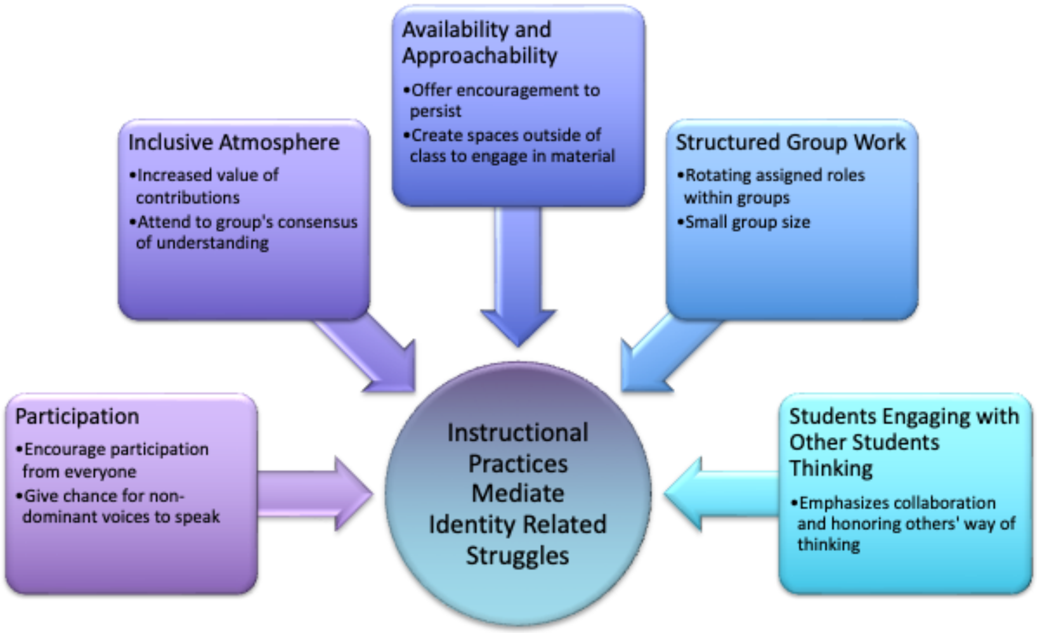

Figure 4.4: Characteristics of instructional practices found to help mediate identity-related barriers to equitable engagement and self-confidence.

These results from analysis of real students' voices and lived experience in Figure 4.4 gives concrete examples of how to attend to equity and lends support to the positive effect these instructional practices can have students sense of selves.

Chapter 5

In this chapter, I focus on my second research goal, which is to investigate student success of those enrolled in the support courses compared to those who are not. Primarily, student success is defined as what a university or math department might typically view success as for their students: the proportions of grades received (grades and DFW rates) and whether students plan to take the next course in the series (persistence in the course series). Then, I broaden the definition of student success to also consider students' perception of the inclusivity of teaching behaviors, their confidence, and their sense of belonging. The goal of this chapter is to demonstrate how taking into account a more holistic perception of student success offers a more complete picture of how students are experiencing introductory math courses.

Success as Grades and Course Taking Patterns

The support course my team and I designed was implemented for both Precalculus and Calculus I courses for the entirety of the data collection process, which spanned from the Spring 2023 semester through the Fall 2023 semester. Thus, this chapter comparing student success across support course enrollment only includes data from students in Precalculus or Calculus I. While enrollment in the support course was relatively low, there were a total of 60 students who completed this survey who were enrolled in a support course. Of those 60, 41 students were enrolled in Precalculus and the other 19 were enrolled in Calculus I. The 747 students who make up the rest of the data set are split by 367 enrolled in Precalculus and 380 enrolled in Calculus.

Demographic Comparison Across Support Course Enrollment

Since there are not enough Calculus I students enrolled in the support course to have statistical power, this chapter focuses on the difference between all students enrolled in the support course (those enrolled in support course for both Precalculus and Calculus I) and those who were not. The demographic tables comparing the frequency of gender, race or ethnicity, sexual orientation, and special populations between the two groups of enrolled and not enrolled in the support course are given in Tables 5.1 through 5.4. Note that not every student responded to each demographic item and students were allowed to choose more than one race or ethnicity, so the totals may vary slightly.

Table 5.1: Gender Demographic Comparison for Precalculus and Calculus I students, split by enrollment in the support course.

	Enrolled in Support Course	Not Enrolled in Support Course
Man	34 (56.67%)	414 (55.42%)
Transgender	0 (0.00%)	5 (0.67%)
Woman	24 (40.00%)	303 (40.56%)
Not Listed	0 (0.00%)	4 (0.54%)
Prefer Not to Disclose	1 (1.67%)	7 (0.94%)

Table 5.2: Race or Ethnicity Demographic Comparison for Precalculus and Calculus I students, split by enrollment in the support course.

	Enrolled in Support Course	Not Enrolled in Support Course
Alaskan Native or Native American	1 (1.67%)	6 (0.80%)
Black or African American	3 (5.00%)	45 (6.02%)
Central Asian	0 (0.00%)	4 (0.54%)
East Asian	4 (6.67%)	45 (6.02%)
Hispanic or Latinx	19 (31.67%)	245 (32.80%)
Middle Eastern or North African	1 (1.67%)	30 (4.02%)
Native Hawaiian or Pacific Islander	1 (1.67%)	29 (3.88%)
Southeast Asian	10 (16.67%)	94 (12.58%)
South Asian	1 (1.67%)	26 (3.48%)
White	24 (40.00%)	331 (44.31%)
Not Listed	0 (0.00%)	4 (0.54%)
Prefer not to disclose	1 (1.67%)	10 (1.34%)

Table 5.3: Sexual Orientation Demographic Comparison for Precalculus and Calculus I students, split by enrollment in the support course.

	Enrolled in Support Course	Not Enrolled in Support Course
Asexual	1 (1.67%)	15 (2.01%)
Bisexual	2 (3.33%)	57 (7.63%)
Gay	0 (0.00%)	11 (1.47%)
Lesbian	0 (0.00%)	11 (1.47%)
Queer	2 (3.33%)	13 (1.74%)
Straight (Heterosexual)	48 (80.00%)	589 (78.85%)
Not listed	0 (0.00%)	6 (0.80%)
Prefer not to disclose	3 (5.00%)	28 (3.75%)

Table 5.4: Special Population Demographic Comparison for students enrolled in Precalculus or Calculus I, split by support course enrollment.

	Enrolled in Support Course	Not Enrolled in Support Course
International student	5 (8.33%)	23 (3.08%)
First-Generation	16 (26.67%)	222 (29.72%)
Commuter student	21 (35.00%)	265 (35.48%)
Transfer student	0 (0.00%)	19 (2.54%)
Student with a disability	2 (3.33%)	24 (3.21%)
Student athlete	3 (5.00%)	23 (3.08%)
ELL	4 (6.67%)	56 (7.50%)
Parent or Guardian	0 (0.00%)	2 (0.27%)
Prefer not to disclose	8 (13.33%)	79 (10.58%)

To determine whether the distribution of demographics across these groups is statistically similar, a series of chi-square tests of independence were performed to examine the relationships between each demographic factor (gender, race or ethnicity, sexual orientation, and special population status) and enrollment in the support course. The results indicated no significant associations of support course enrollment in any of the categories eligible for a chi-squared test. Specifically, for gender, the test yielded $\chi^2 (5) = 0.812$, $p = 0.976$. Similarly, the test for race or ethnicity showed $\chi^2 (12) = 5.231$, $p = 0.950$, while the test for sexual orientation resulted in $\chi^2 (8) = 7.629$, $p = 0.470$. Lastly, the test for special population status (including first-generation, commuter student, etc.) indicated $\chi^2 (8) = 7.221$, $p = 0.513$. These findings suggest that the distribution of these demographic factors is not significantly different between students enrolled in the support course and those who are not.

Grade Distributions Across Support Course Enrollment

In this section I analyze the grade distribution across the two courses. My hypothesis is that students enrolled in the support course are favored in statistically significant differences of A, B, and C grades. To explore the impact of support course enrollment on student grades, I first visualized the grade distributions for the two groups in Figure 5.1. The side-by-side bar charts show the counts of each grade (A, B, C, D, F, WU) for students not enrolled in the support course (left) and those enrolled (right).

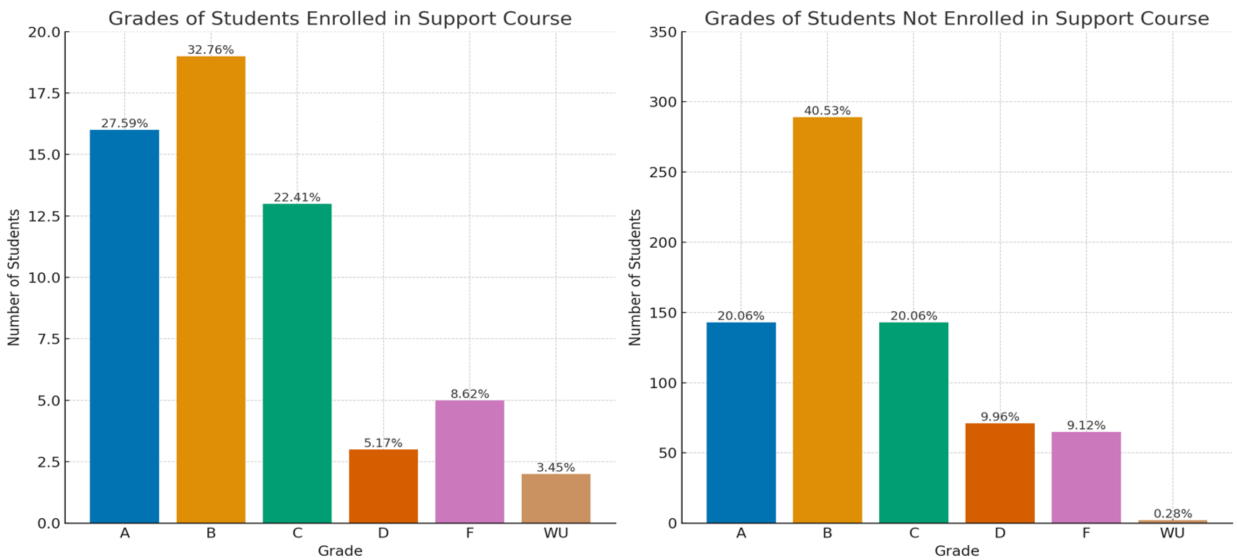

Figure 5.1: Grade distributions for students from both enrolled and not enrolled in the support course.

The decision to bin the +/- grades (e.g., A-, B+, C-) into their respective whole grade categories (e.g., A, B, C) was made to simplify the analysis and enhance interpretability. Grades of a C- were converted to D since a final grade of C- is not sufficient to fulfill the prerequisite requirements and move on to the next course. A grade of WU means “Withdrawal Unauthorized” which indicates that a student did not withdraw themselves from the course, but failed to complete course requirements and this grade is calculated into a student’s grade point average as an F. Binning the grades reduces the complexity of the data and allows for a clearer comparison of grade distributions between groups. This approach is particularly useful in the case of this analysis, where the sample sizes for the individual +/- categories are small, which could lead to unstable estimates and reduced statistical power. By aggregating the grades into broader categories, I ensure more robust and meaningful statistical comparisons, while still capturing the overall trends in student performance.

One metric that universities and math departments typically investigate is the DFW rate, which is the percentage of students who received a D, F, or WU in the course. For students enrolled in the support course and not enrolled in the support course, the DFW rates are 17.24% and 19.36%, respectively. A two-sample proportions Z-test was conducted to determine if there is a significant difference between these two DFW rates and the results indicate there is no statistically significant difference between them ($Z = -.401$, $p = 0.688$).

A chi-square test of independence was conducted to statistically compare the distributions of all grades across both groups. The results revealed a significant difference in the grade distributions between the two groups, $\chi^2\,(5) = 14.102$, $p = 0.015$. This indicates that the distribution of grades for students enrolled in the support course differs significantly from those not enrolled, suggesting an association between support course enrollment and student grades.

To understand the nature of this difference, adjusted residuals were examined to identify which specific grades contributed most to the significant result. Table 5.5 presents the adjusted residuals for each grade category.

Table 5.5: Adjusted Residuals for Grade Distributions.

Grade	Not Enrolled	Enrolled
A	-0.370	1.177
B	0.311	-0.880
C	-0.117	0.372
D	0.325	-1.092
F	0.035	-0.116
WU	-0.886	3.098

Typically, adjusted residuals with an absolute value greater than 2 are considered significant contributors to the chi-square statistic, but for the sake of this analysis, I take into consideration adjusted residuals with an absolute value greater than 1. The residual for Grade A (1.177) indicates that more students in the support course received an 'A' than expected, whereas the residuals for Grade D (-1.092) suggest fewer students in the support course received a 'D' than expected. The residual for Grade WU (3.098) is highly significant, indicating that significantly more students in the support course received a 'WU' than expected. These findings suggest that while students in the support course are more likely to receive an 'A' and less likely to receive a ‘D’, they are also significantly more likely to receive a 'WU'. This dual trend highlights the complexity and uncertainty of the impact of the support course on student performance based on these analyses, with some students performing exceptionally well and others struggling significantly. Thus, I must reject my hypothesis on basis of these results.

I am interested to dig deeper into grade distribution across different demographic categories specific to this dissertation, such as women or first-generation college students enrolled in the support course. However, the small population size of each of those groups that enrolled in the support course prevent statistical tests from having much power, since the typical cutoff for a population size should be 30 students to ensure the tests can be interpreted in a meaningful way. That being considered, there are other steps I can take to investigate support course enrollment and the grades received.

To further explore the impact of support course enrollment on student grades, I performed an ordinal logistic regression analysis. The results (Table 5.6) indicate that the effect of support course enrollment on grades was not statistically significant, $\beta = -0.148$, $p = 0.563$, with an odds ratio of 0.863, 95% CI [0.523, 1.423]. This suggests that, after accounting for the ordinal nature of the grades, enrollment in the support course does not significantly influence the likelihood of receiving higher grades.

Table 5.6: Ordinal Logistic Regression Results for impact of support course enrollment on grades.

Predictor	Coefficient	Std. Error	Z-value	P-value	Odds Ratio	CI Lower	CI Upper
Support Course Enrollment	-0.148	0.255	-0.579	0.563	0.863	0.523	1.423

Therefore, the analysis so far shows that while there is a significant difference in the distribution of grades between the two groups as indicated by the chi-square test, the support course enrollment itself does not significantly predict higher grades when treated as an ordinal outcome. Since I have more quantitative data from the survey that provides information about students' habits around attendance and seeking tutoring, it is appropriate to test these variables for correlation with the adjusted grades, shown in Table 5.7, to investigate if I can build a more complex regression model.

Table 5.7: Correlation coefficients between grades and various potential predictors.

Potential Predictor	Correlation Coefficient with Grades
Supplemental Inst	0.025
Recitation	0.045
Missing Lecture Class	-0.037
Missing Recitation Class	-0.079
MSLC	-0.059
Office Hours	0.091
Friends	0.022
Private Tutor	-0.119
Extra Course Sessions	-0.066
Review Sessions	-0.044

Table 5.7 shows the correlation coefficients for various potential predictors, including support supplemental instruction, recitation attendance, frequency of missing lecture or recitation course meetings, and various tutoring sources (e.g., MSLC, Office Hours, Friends, Private Tutor, Extra Course Sessions, Review Sessions) against the binned grades. When interpreting the values in this Table 5.7, higher absolute values of the correlation coefficients (closer to ±1) indicate stronger linear relationships. A common threshold to consider a variable for inclusion in a more complex regression model is an absolute correlation value of 0.3 or higher. However, depending on the specific research question and the sample size, a lower cutoff (e.g., 0.2) could also be justifiable. In this analysis, none of the variables show a strong correlation with students' grades (all correlations are below 0.12), suggesting that individually these predictors do

not strongly influence grades and are also not likely to have a combined effect either. Therefore, I will not attempt at designing a more complex ordinal linear regression model based on these variables.

Student Persistence Across Support Course Enrollment

Another important metric that indicates a successful student for universities and math departments is one that indicates persistence in enrollment. That is in this case, whether the student plans to enroll in the next logical course in the sequence. First, I consider the size of each population of students in the support course and the course they are currently enrolled in. Of the 60 total students enrolled in the support course, 41 were enrolled in Precalculus and 19 were enrolled in Calculus I. For the first subsection, I focus on all students that were enrolled in the support course and analyze their persistence to the next logical course, which is Calculus I for Precalculus students and Calculus II for Calculus I students. In the following subsection I run a similar analysis, but for only the Precalculus students since they form a population size appropriate for statistical tests.

Persistence of Precalculus and Calculus I Students

For this section, I continue to focus on students enrolled in Precalculus and Calculus I and their respective support courses. Based on the extra support in terms of encouragement and identity-related mediation that students enrolled in the support course experienced, my hypothesis is that students enrolled in the support course has higher persistence rates, that is a higher proportion of students planning to enroll in the next logical course in the series, than the students not enrolled in the support course.

First, I present a visualization of the data that represents three categories of persistence: students who plan to take the next logical course, students who plan to take the same course, and students who do not plan to enroll in another math course shown in Figure 5.2.

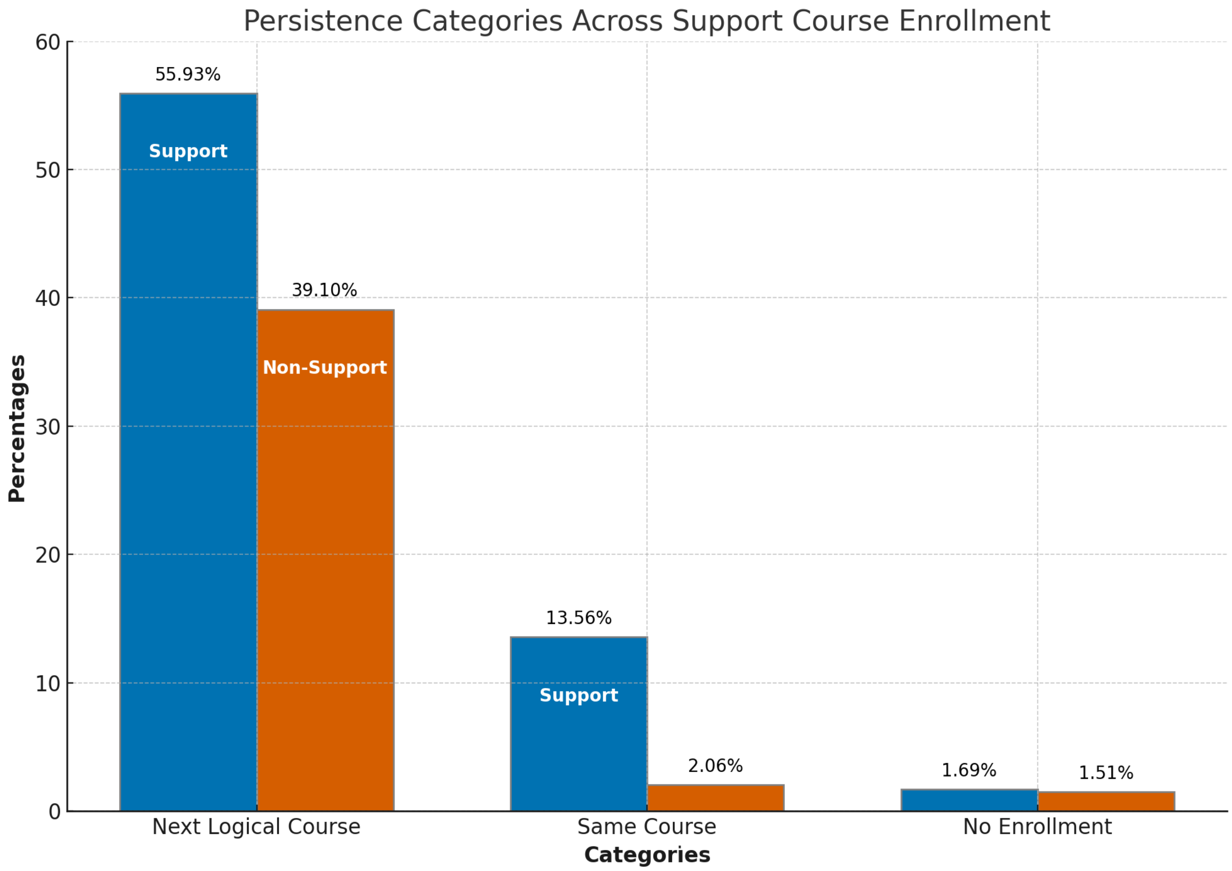

Figure 5.2: A bar chart that shows the percentages of the persistence categories for students enrolled in the support course (labeled Support in blue) and the students not enrolled in the support course (labeled Non-Support in orange).

Next, I conducted a series of chi-square tests of independence to compare the persistence rates between students enrolled in the support course and those not enrolled, across the three categories of interest. The results showed no statistically significant differences in the rates of students planning to enroll in the next logical course ($\chi^2 = 0.026$, $p = 0.871$), retake the same course ($\chi^2 = 2.010$, $p = 0.156$), or not enroll in another math course ($\chi^2 = 0.029$, $p = 0.864$). Although some of the observed differences in percentages were notable, with 55.93% of support course students and 39.10% of non-support course students planning to enroll in the next logical course, the chi-squared tests indicate that these differences could be due to chance. Similarly, the rates for retaking the same course (13.56% vs. 2.06%) and not enrolling in another math course (1.69% vs. 1.51%) did not show significant differences, suggesting that the variations in observed counts are not statistically significant.

Another test that can help corroborate these results is a two-sample proportions Z-test across enrollment in the support course. For the category "Next Logical Course," the results showed no statistically significant difference in the proportions of students planning to enroll in the next logical course between the two groups ($Z = 1.355$, $p = 0.175$). However, for the category "Same Course," there was a statistically significant difference ($Z = 4.814$, $p < 0.001$), indicating that a higher proportion of support course students plan to retake the same course compared to non-support course students. Lastly, for the category "No Enrollment," the results indicated no significant difference in the proportions of students not planning to enroll in another math course ($Z = -0.061$, $p = 0.951$).

With the discrepancy between these two statistical tests regarding the significant difference in the “Same Course” category, the Cochran-Mantel-Haenszel (CMH) test was chosen to assess the association between support course enrollment and persistence categories while controlling for gender. While there are only 24 women enrolled, I thought it was worth investigating despite the marginally appropriate populations sizes to stratify by. The results showed no statistically significant differences between support course and non-support course groups across all three categories: the odds ratios (OR) of planning to enroll in the next logical course (OR = 0.90, $\chi^2 = 0.002$, $p = 0.962$), retaking the same course (OR = 1.18, $\chi^2 = 0.011$, $p = 0.917$), and not enrolling in another math course (OR = 0.63, $\chi^2 = 0.095$, $p = 0.758$). These findings indicate that support course enrollment does not significantly influence these persistence outcomes when accounting for gender. While I considered also running a CMH test controlling for race or ethnicity, the test would result in invalid results due to insufficient sample sizes in the stratified group to effectively apply this statistical test.

Collectively, the results of these tests show that there is inconclusive statistical evidence that students enrolled in the support course persist in the course sequence, enroll in the same course again, or have no plans to enroll in the next course. Thus, I cannot reject the null hypothesis based on these results. However, based on the size of the populations of students only enrolled in Precalculus, I can investigate if there are any significant differences in persistence categories for this subgroup.

Persistence of Precalculus Students

For this section, I focus only on students that were enrolled in Precalculus, since they form an appropriately sized population to compare proportions of persistence. My hypothesis is that students enrolled in the support course have higher persistence rates based on the qualitative data analysis from Chapter 4 that showed the increased encouragement and support students received.

For this more specific analysis on persistence to the next logical course, I focus on only Precalculus students that responded in one of three ways: enrolling in the next logical course of Calculus I, enrolling in Precalculus again, or they indicated they are not planning to enroll in another math course. Figure 5.3 shows two bar charts side by side that show the percentage of students that chose each category across enrollment in the support course.

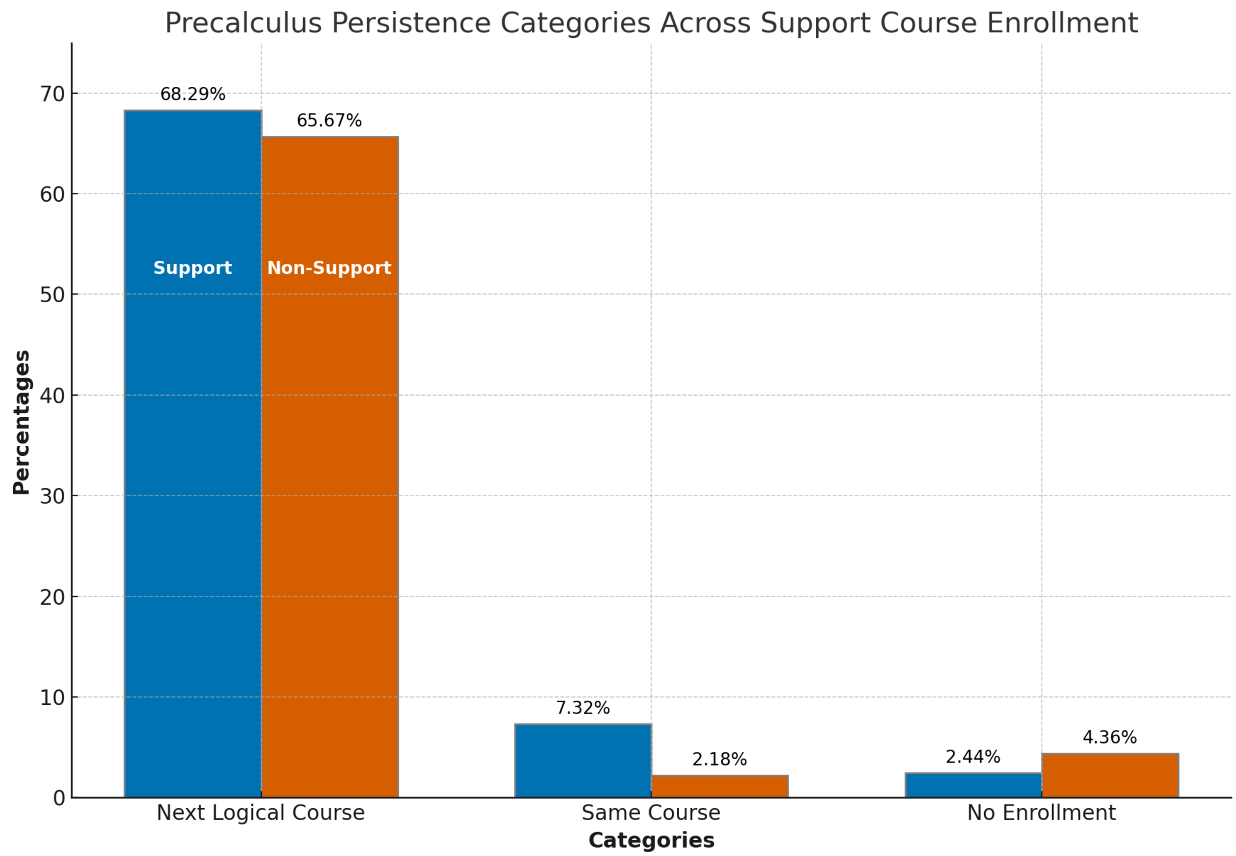

Figure 5.3: A bar chart that shows the percentages of the persistence categories for only Precalculus students enrolled in the support course (labeled Support in blue) and the students not enrolled in the support course (labeled Non-Support in orange).

A series of chi-square tests of independence were conducted to compare the persistence rates between students enrolled in the support course and those not enrolled, across the three categories of interest. The results showed no statistically significant differences in the rates of students planning to enroll in Calculus I (χ^2 = 0.026, p = 0.871), retake Precalculus (χ^2 = 2.010, p = 0.156), or not enroll in another math course (χ^2 = 0.029, p = 0.864). Specifically, 68.29% of enrolled students and

65.67% of non-enrolled students planned to continue to Calculus I; 7.32% of enrolled and 2.18% of non-enrolled students planned to retake Precalculus; and 2.44% of enrolled and 4.36% of non-enrolled students did not plan to enroll in another math course.

To corroborate these results with another statistical test, a series of two-sample proportions Z-tests were conducted to compare the persistence rates between students enrolled in the support course and those not enrolled. The results showed no statistically significant differences in the rates of students planning to enroll in Calculus I ($Z = 0.336$, $p = 0.737$) or not planning to enroll in another math course ($Z = -0.584$, $p = 0.559$). The test for retaking Precalculus was close to the significance threshold ($Z = 1.926$, $p = 0.054$), suggesting a potential difference, with 7.32% of enrolled students and 2.18% of non-enrolled students planning to retake Precalculus.

The results of these two tests together indicate that I should not reject the null hypothesis, since there are no statistically significant differences in persistence, repeating the course, or no plan of enrollment in the next course. While I would prefer to run more tests on persistence of specific subgroups of the Precalculus population, I cannot due to the lack of statistical power from populations of size under 30.

Holistic Interpretation of Success

In this section, I continue to compare the experience of students enrolled in the support course versus those not enrolled. Moving forward, I broaden the definition of student success beyond grades received and persistence rates to include results of analysis of items on the survey that ask students to self-report perceptions of instructional practices, changes in attitudes towards mathematics, and their sense of belonging. Each of the following sections include a hypothesis grounded in qualitative results from Chapter 4, a collection of appropriate statistical tools that test that hypothesis, and a report of the results.

Perceptions of Instructional Practices

Students in the support course were required to engage with supplemental instruction (SI) sessions on a regular basis (around once or more per week), whereas students who did not enroll in the support course were able to attend SI sessions voluntarily but had no structure in place requiring them to attend. Thus, based on the results from Chapter 4, students enrolled in the support course typically experienced instructional practices that occurred more often in SI such as active group work on white boards, small class sizes that allowed for each voice to be heard, and general encouragement from their SI leader. However, the questions on the survey that focus on the perception of the inclusivity of instructor behaviors ask specifically about the instructor of their large lecture section. Thus, when I compare students’ experiences across support course enrollment, I am attending to the effect the support course has on students’ perception of their lecture instructor’s behaviors.

In this section, I begin with a subsection that compares three individual items, each with their own hypothesis and result between students enrolled in the support course and not enrolled. In the following subsection, I compare multiple factors of items grouped together based on a previous factor analysis performed by Nate Brown, one of the designers of the IIB survey.

Individual Item Analysis

One item on the survey asks students to rate their level of agreement on a 5-point Likert scale to the statement, “my math instructor has little or no interest in students’ success.” My hypothesis is that students in the support course agree more with the perception that their instructor has little or no interest in students’ success. This hypothesis is grounded in the results from Chapter 4, where students in the support course received positive encouragement and genuine interest in student success from their SI leaders and TA’s, which could lead them to perceive their instructor’s behavior differently than those who did not enroll in the support course and experience as many SI sessions.

Based on the distribution of responses to this statement, I consolidated the results to this question to three categories: disagreement, Neutral, and agreement. The distribution of these three categories is displayed in Figure 5.4, where there exists a substantial skew towards disagreement in both populations. However, there are apparent differences in the proportions of students who fall into each level of agreement, so I next run a series of statistical tests to determine whether there is a significant difference in agreement to align with testing my hypothesis.

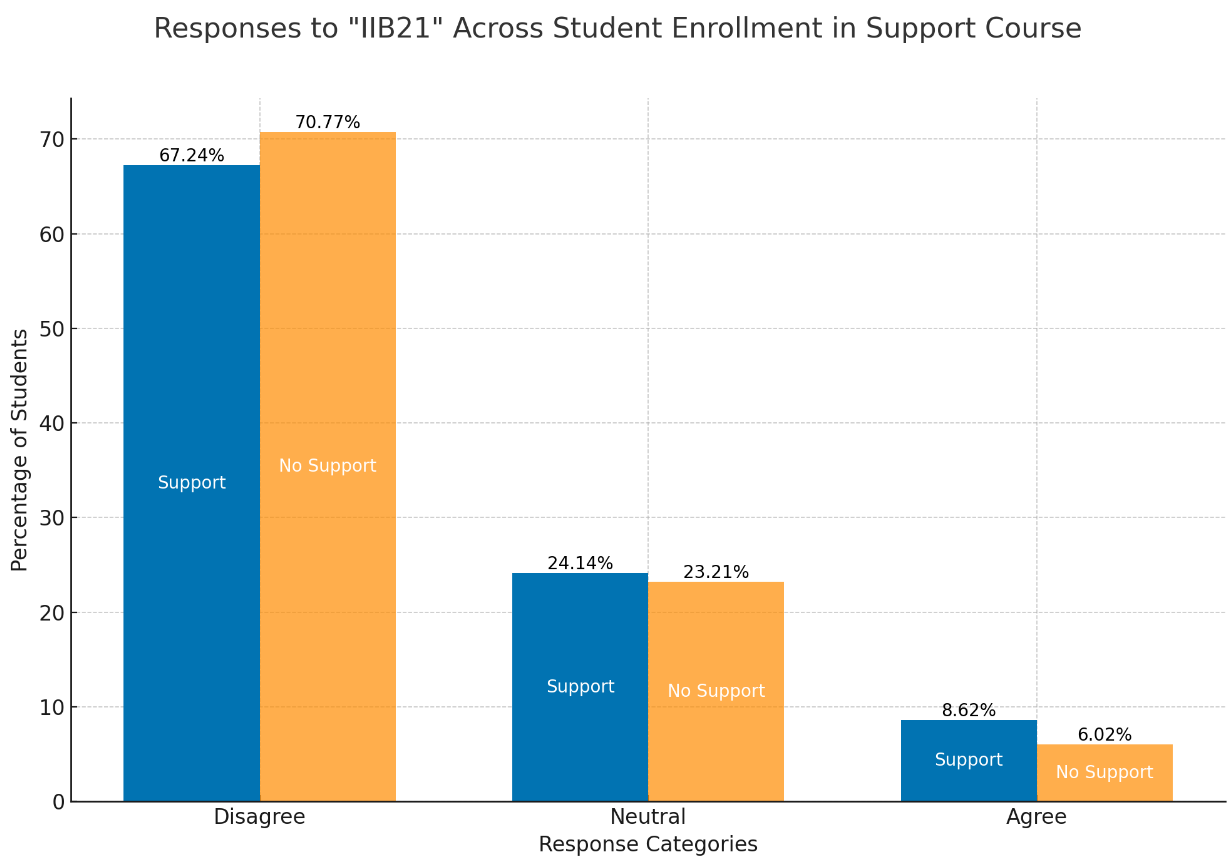

Figure 5.4: Distribution of adjusted agreement levels to the survey item IIB21, which reads “my math instructor has little or no interest in students’ success” across support course enrollment.

I conducted a Chi-squared test to examine the association between enrollment in the support course and categories of agreement levels to this survey item. The test did not reveal a significant association between support course enrollment and agreement with the statement, χ^2 (1) = 0.256, p = 0.613. The result of this test suggests that students’ agreement with the statement regarding their instructors’ interest in their success is not significantly influenced by enrollment in the support course. To further investigate the difference in the level of agreement across support course enrollment, a 2-sample proportions test was conducted. The z-statistic for the agreement category showed no significant differences between the two groups (Z = 0.789, p = 0.43). These tests collectively indicate that there is no significant difference of agreement level between the two groups.

The next item in the survey I analyze focuses on the perceived inclusivity of the lecture instructor behavior. Specifically, the 5-point Likert scale item says, “My math instructor teaches too fast” and directs students to reply on a scale from 1 being strongly disagree to 5 being strongly agree. Based on the fact that students in the support course self-selected into the course, they likely perceive the instructor to teach too fast. However, I also make the assumption that most students feel that the instructor teaches too fast based on personal experience. Thus, my hypothesis is that students in the support course reported statistically significant differences in the pace of the teaching in their lecture course, specifically they disagreed less with the statement than students not enrolled in the support course.

First, I once again consolidated the responses from students to consider all students who responded as “strongly disagree” and “disagree” as well as “strongly agree” and “agree” to achieve reasonably sized proportions of the groups to compare. The distribution of the responses as three categories of agreement are found in Figure 5.5.

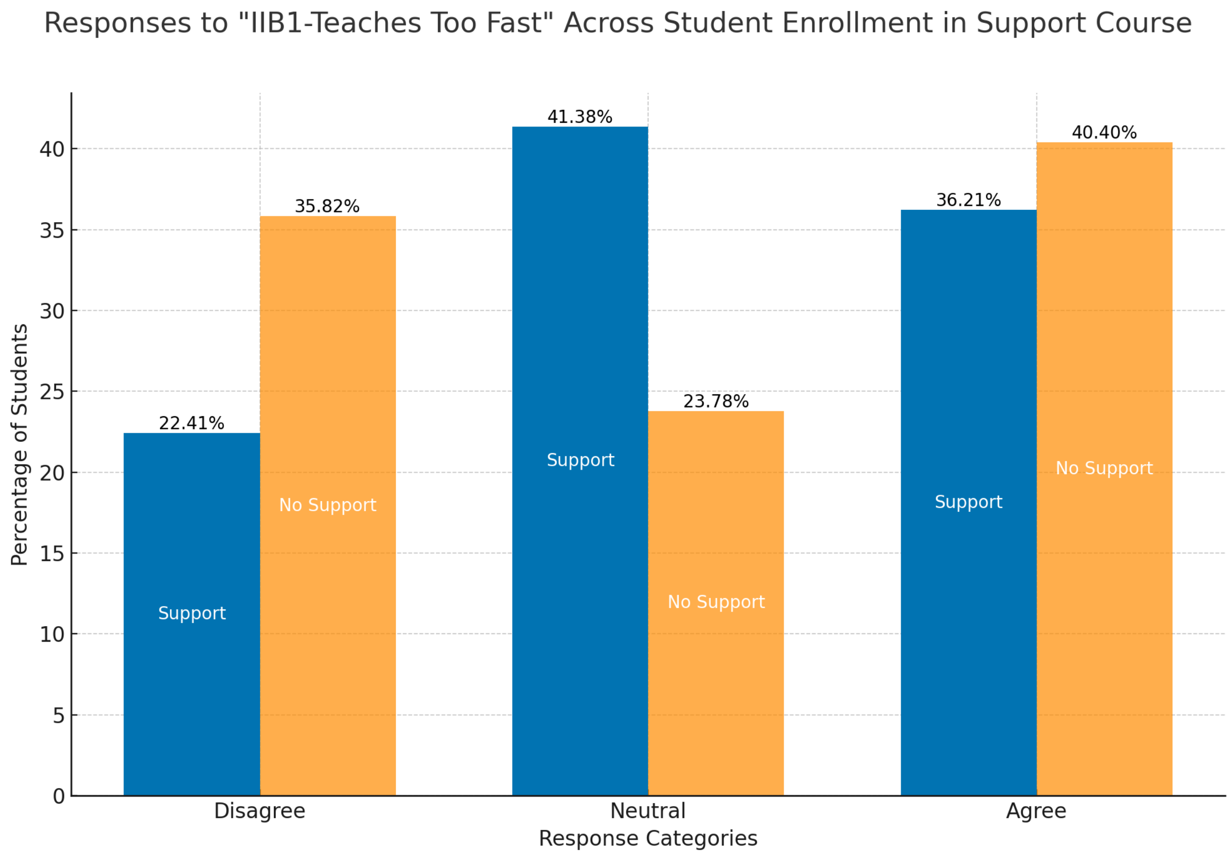

Figure 5.5: A bar chart that compares the distribution of categories of agreement across support course enrollment to the statement, “My math instructor teaches too fast”.

A chi-squared test was conducted to compare the proportion of students who disagreed with the statement "My math teacher teaches too fast" across support course enrollment. The results indicated a marginal difference between the two groups, $\chi^2(1, N = 756) = 3.670$, $p = .055$. A follow-up two-sample proportions test revealed a statistically significant difference, $Z = -2.059$, $p = .039$, suggesting that students enrolled in the support course were less likely to disagree with the statement compared to those enrolled. Thus, my I can reject the null hypothesis and accept there was a statistically significant difference.

However, based on the distribution of responses, I also performed a chi-squared test to compare the proportion of students who were neutral about the statement "my math instructor teaches too fast" across support course enrollment. The results showed a significant difference between the groups, $\chi^2(1, N = 756) = 7.902$, $p = .005$. Additionally, a two-sample proportions test confirmed this significant difference, $Z = 2.969$, $p = .003$, indicating that students enrolled in the support course were more likely to be neutral about the statement compared to those not enrolled. This result combined with the result on disagreement demonstrates that while students in the support course were less likely to disagree with the statement "my math instructor teaches too fast", they were also more likely to be neutral about the statement.

The next item I investigate is responses across support course enrollment to the statement, "my math instructor pays more attention to some students than others." The distribution of consolidated response categories that bin agreement, disagreement, and neutral is displayed in Figure 5.6. Based on the experiences of students studied in Chapter 4 that mentioned some students' overbearing presence in lecture courses, I hypothesize that the proportion of students enrolled in the support course that agreed with this statement was significantly greater than those who are not enrolled in the support course.

A chi-squared test was performed to determine if there was a significant difference in the distribution of responses to the statement, "my math instructor pays more attention to some students than others" between students enrolled in the support course and those not enrolled. The chi-squared test revealed no statistically significant difference in distribution, χ^2 $(2) = 3.699$, $p = 0.157$.

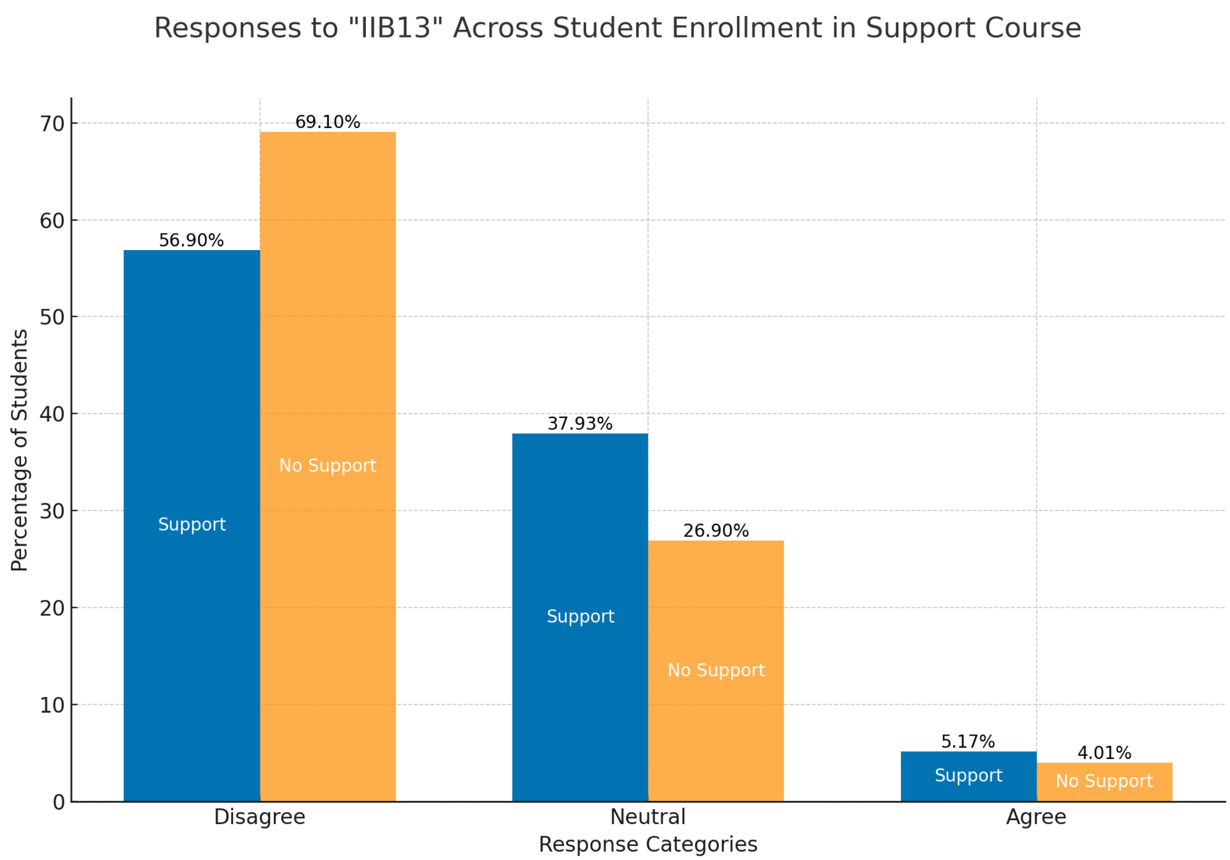

Figure 5.6: Distribution of response categories to the survey item IIB13, which reads "my math instructor pays more attention to some students than others" across support course enrollment.

To further investigate the apparent differences in proportions from each population, a series of two-sample proportion tests were performed on each response category to determine which response categories had significant differences. While agreement (Z = 0.431, *p* = 0.667) and neutral (Z = 1.804, *p* = 0.071) responses show no statistically significant differences, there was a marginally significant difference in disagreement (Z = -1.917, *p* = 0.055) with support course students disagreeing slightly less. These responses indicate that the I cannot reject the null hypothesis as there was no statistically significant difference of responses across support course enrollment.

The final item I investigate is responses across support course enrollment to the statement, “my math instructor gives overly complex or technical explanations.” The distribution of consolidated response categories that bin agreement, disagreement, and neutral is displayed in Figure 5.7. Based on the fact the support course had self-selected enrollment of students seeking extra help, I hypothesize that the proportion of students enrolled in the support course that agreed with this statement was significantly greater than those who are not enrolled in the support course.

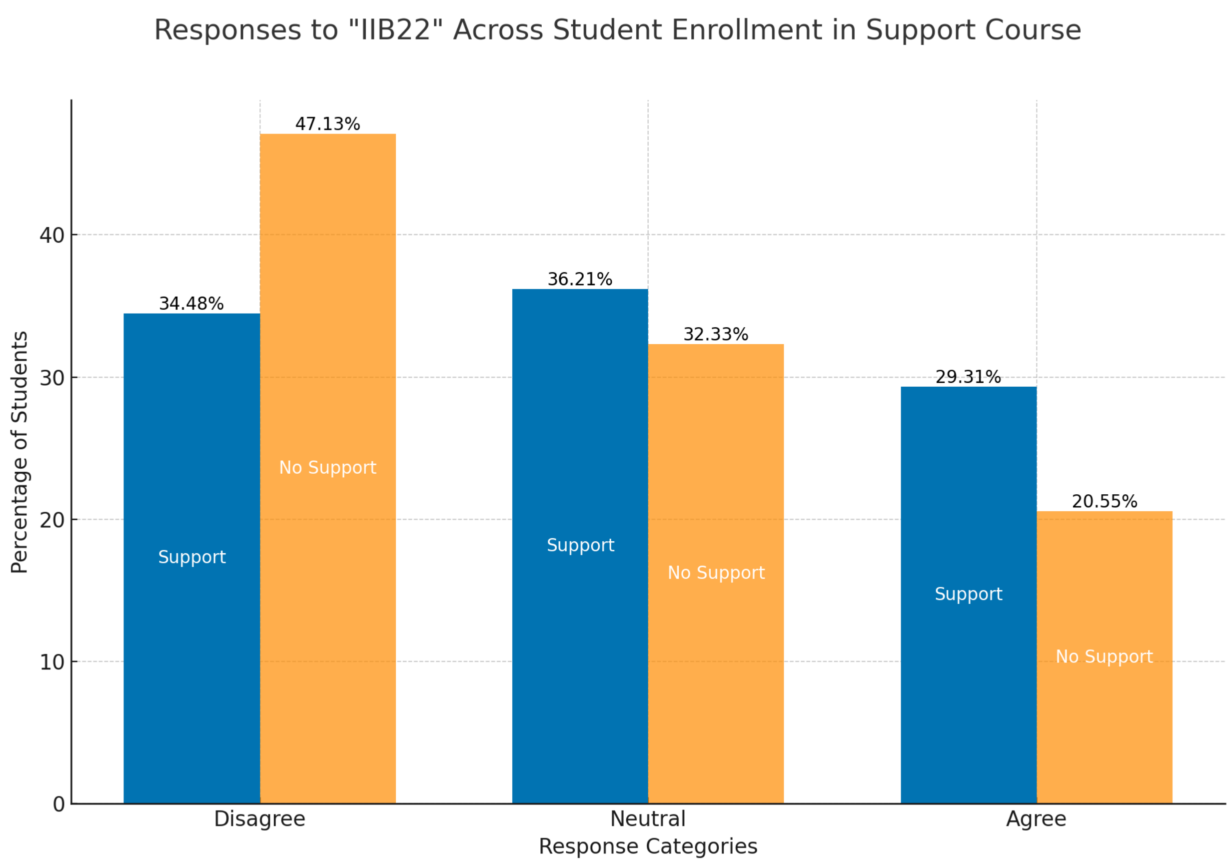

Figure 5.7: : Distribution of response categories to the statement, “my math instructor gives overly complex or technical explanations” across support course enrollment.

The chi-squared test indicates no significant difference in the distribution of responses across enrollment status for the statement ($\chi^2(2) = 4.039$, $p = 0.133$).

Revealing the specific differences in responses using a series of two-sample proportions tests, the results indicate no significant difference in disagreement (Z = -1.856, $p = 0.063$), neutrality (Z = 0.605, $p = 0.646$), or agreement (Z = 1.568, $p = 0.117$). Thus, I must retain the null hypothesis.

Grouped Items Analysis

Nate Brown and colleagues at Penne State University developed the items for the inclusive instructor behavior (IIB) and sense of belonging sections of the survey. While they have not run a factor analysis on the sense of belonging sections yet, they have run a factor analysis and confirmatory factor analysis on the IIB items. These analyses created the six factors, with their subsequent related items and the statements students responded to shown in Table 5.8 along with the ordinal alpha computed for this data set associated with each factor. Since we are examining the impact of support course enrollment on several predefined factors based on previous research, the factor loadings of each item are not re-evaluated in this analysis.

I calculated the ordinal alpha for each factor to measure the internal consistency of each factor in this data set. Ordinal alpha is the analogous version for ordinal data of Cronbach's alpha used for scale data. Rather than using Pearson correlations that rely on the use of means as Cronbach's alpha does, ordinal alpha utilizes polychoric correlations that estimate the relationship between ordinal items based on theorized continuous latent variables. Ordinal alpha is a number typically between 0 and 1, with values closer to 1 indicating stronger internal consistency.

Table 5.8: All Inclusive Instructor Behavior (IIB) items from the survey grouped into their factors with the full statements students responded to shown with the ordinal alpha for each factor.

Factor Item Group with Statements	Ordinal Alpha
1. Helpful Teacher: • IIB9-Teaches to all students, not just those who've already seen this material. • IIB10- Is helpful during office hours. • IIB2-Explains things in different ways when we ask. • IIB16- Makes us feel comfortable asking questions. • IIB15- Makes sure all questions get answered before moving on. • IIB3-Pauses to let us absorb material or formulate questions.	0.784
2. Engaging vs. Disinterested: • IIB20- Has little or no enthusiasm for teaching. • IIB21- Has little or no interest in students' success. • IIB7-Talks enthusiastically about math. • IIB24- Engages in small talk with the class. • IIB4-Jokes with the class.	-0.139
3. Too Complex Teaching: • IIB12- Is too advanced to be teaching this course. • IIB18- Gives exams which are hard to finish in the allotted time. • IIB1-Teaches too fast. • IIB22- Gives overly complex or technical explanations.	0.677
4. Group Work: • IIB8-Encourages us to work together. • IIB19- Checks in on us when we work in groups. • IIB23- Provides supplementary materials like handouts or worksheets.	0.686
5. (Poor) Attention/Time Management: • IIB11- Makes mistakes which confuse students. • IIB13- Pays more attention to some students than others. • IIB14- Doesn't manage class time well. • IIB17- Takes too long to grade and/or return homework, quizzes and/or exams.	0.737
6. Bad Teacher: • IIB6-Criticizes our answers to their questions. • IIB5-Puts us down. • IIB25- Smirks or laughs at our questions. • IIB26- Says the material is simple, easy, or obvious. • IIB27- Seems annoyed, frustrated, or exasperated by our questions. • IIB28-Blames us when we don't understand something.	0.867

Typical interpretation of a cut-off for ordinal alpha as a measure of an acceptable internal consistency is 0.70 or greater. Based on the results of the ordinal alpha for each factor shown in Table 5.8, most show acceptable or better internal consistency, except for “engaging vs. disinterested,” which indicates issues with that particular factor scale. The negative ordinal alpha indicates that based on how students responded in this dataset, these items do not appear to measure a single underlying sentiment. Thus, I will remove this factor from the subsequent analysis and focus on the other factors that demonstrated acceptable or better internal consistency. My hypothesis is that students enrolled in the support course will show higher levels of agreement to the Helpful Teacher and Group Work factors, while showing lower levels of agreement with the other factors. Thes hypotheses are based on sentiments of support course enrolled students of instructors’ willingness to help or encourage students as well as the support course enrolled students having more engagement with group work in the SI sessions, outside of the lecture.

A series of Mann-Whitney U tests were conducted on each of the factors across support course enrollment. The results of this series of tests including the U-statistic and p-value are shown in Table 5.9, with effect sizes along with 95% confidence intervals included only for p-values that were significant or marginally significant. Based on the results reported in Table 5.9, the only factors that seemed to show any significant difference or marginally significant difference are the Group Work and Too Complex Teaching factors respectively. The effect size for the Group Work factor of -0.16 is small with a 95% percent confidence interval that includes 0.

Table 5.9: Results from a series of Mann-Whitney U tests conducted on each IIB factor across support course enrollment. Effect sizes with 95% confidence intervals are only included for significant or marginally significant p-values.

Item Group	U Statistic	P-Value	Effect Size	95% CI Lower	95% CI Upper
Helpful Teacher	19290.0	0.197	NA	NA	NA
Too Complex Teaching	24947.5	0.057	0.147	0.122	0.172
Group Work	18311.0	0.036	-0.16	-0.424	0.103
(Poor) Attention/Time Management	23374.0	0.383	NA	NA	NA
Bad Teacher	22451.0	0.573	NA	NA	NA

While the negative effect size indicates that students enrolled in the support course were favored slightly, when the confidence interval includes 0 it is an indication that this effect is not significantly different enough to determine which group the effect favors. The marginally statistically significant effect size for the Too Complex Teaching factor of 0.147 (CI: [0.122, 0.172] is also small, but favors the students not enrolled in the support course. That indicates that, with marginal statistical significance, students not enrolled in the support course agreed slightly more to the items in that factor collectively.

These results indicate that there are no statistically significant differences in each of these factors across support course enrollment. Thus, I must reject each of my hypotheses and accept their respective null hypotheses. The next section focuses on more survey items that indicate a shift in attitude towards students' confidence in mathematics.

Changes in Attitude Towards Confidence in Mathematics

Students from the survey responded to two questions that were paired together that asked them to indicate their level of agreement on a 6-point Likert scale with the statement, “I am confident in my mathematical abilities” from the beginning of the course and now. The 6-point Likert scale was coded from “strongly disagree” to “strongly agree”, leaving no neutral option. The survey was administered near the end of the semester to give the highest range of time to consider reporting some change in their confidence over the semester, but the students answered both of these questions at the same time, on the same screen as each other when taking the survey. The paired question as it appeared on the screen of a student taking this survey is shown in Figure 5.8. Since this analysis focuses on paired responses from students, I filter the results down to the 57 students enrolled in the support course and 696 students not enrolled in the support course that gave responses to both items.

In this section, I compare the responses from the students enrolled in the support course against the students who were not enrolled in the support course, with the goal of indicating that enrollment in the support course may have some effect on student’s attitudes towards mathematics, specifically their confidence in their mathematical abilities. Based on the qualitative results of increased confidence of students enrolled in the support course from Chapter 4, my hypothesis is that the proportion of students enrolled in the support course that show a positive shift in confidence is significantly greater than those not enrolled in the support course.

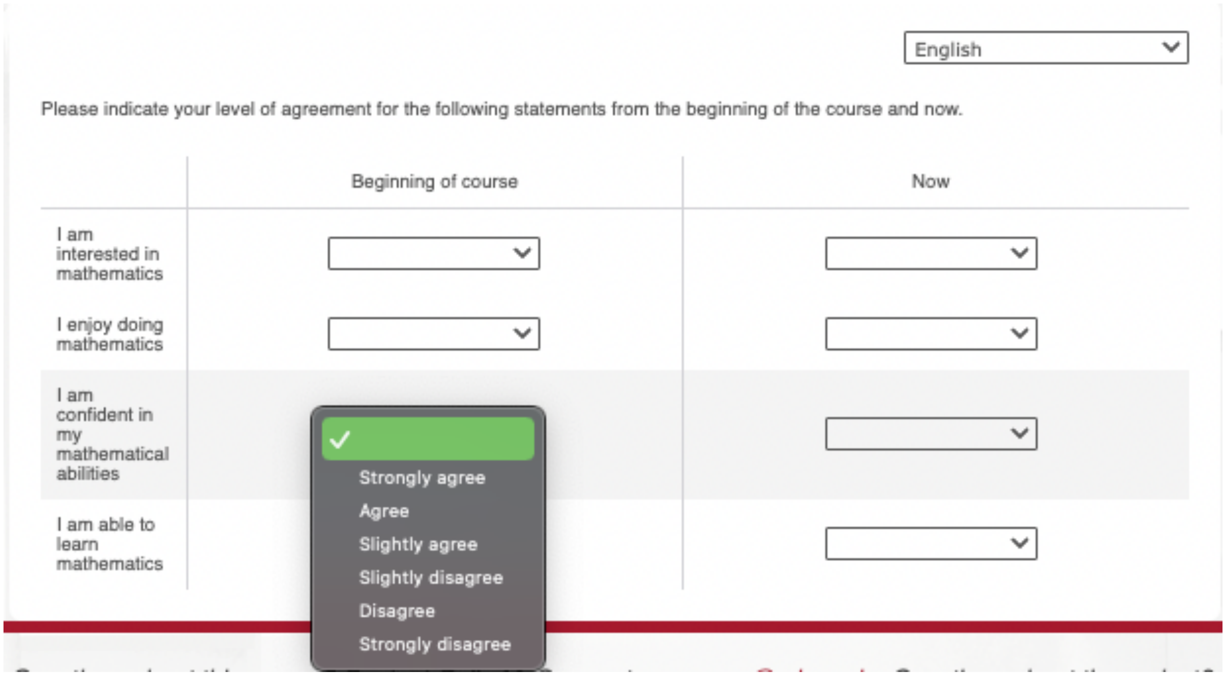

Figure 5.8: A screenshot that shows exactly what students saw while taking the survey. It is a table where the first column is the statement rate their level of agreement to, the next column is a drop-down menu that allows selection for their agreement level at the beginning of the course, and the last column is a drop-down menu that allows selection for their agreement level at the time the survey was administered.

To display the two populations' change in confidence overall, I begin with two heat maps that show all responses from students enrolled in the support course in Figure 5.9 and the students not enrolled in the support course in Figure 5.10. I first display the heatmaps, explain how to interpret a heatmap, and then report the results.

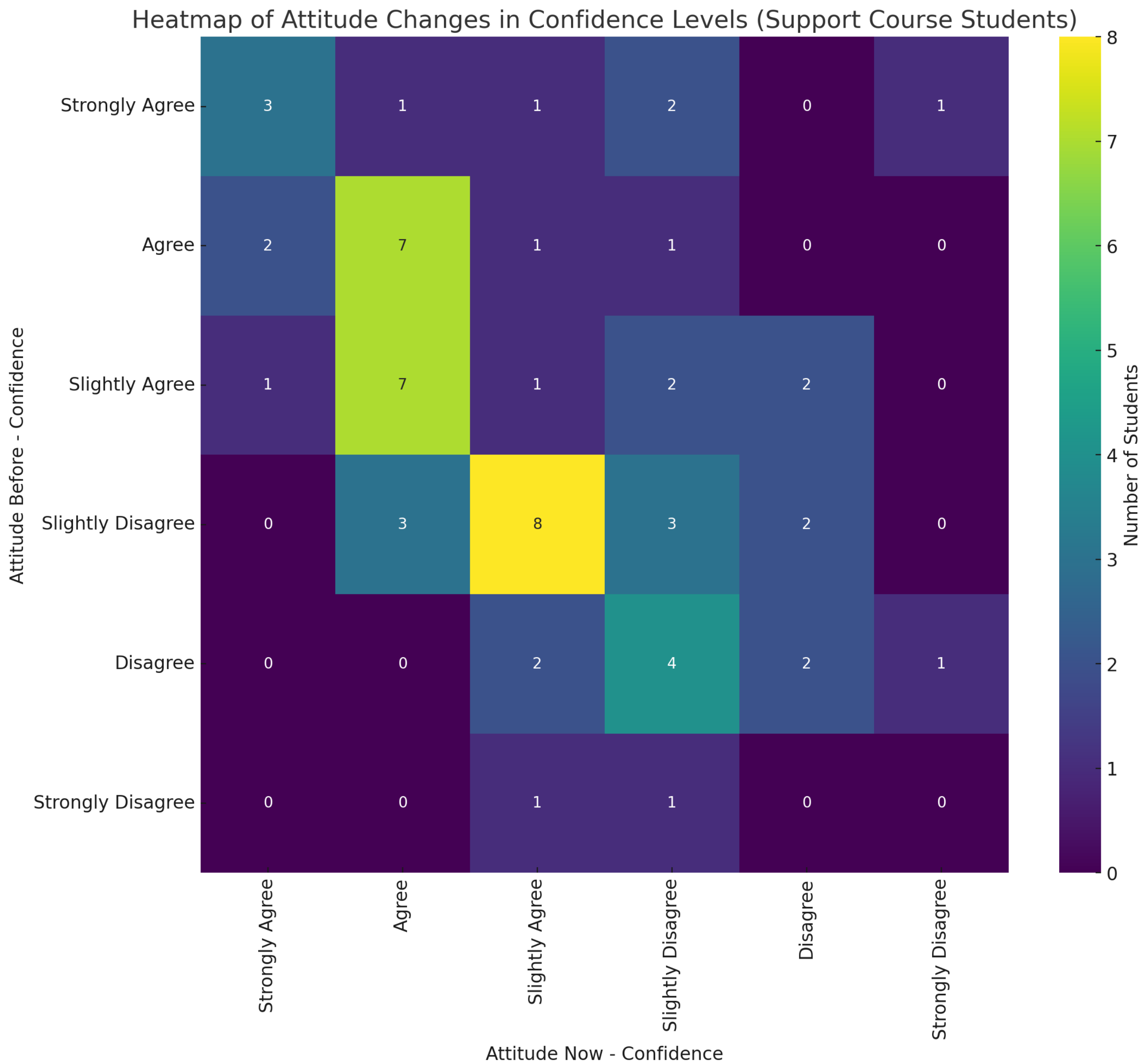

Figure 5.9: A heatmap that shows the responses from students enrolled in the support course corresponding to their confidence levels at the beginning of the course (vertical axis) and now (horizontal axis). The number in each cell indicates the number of students who responded with that pair.

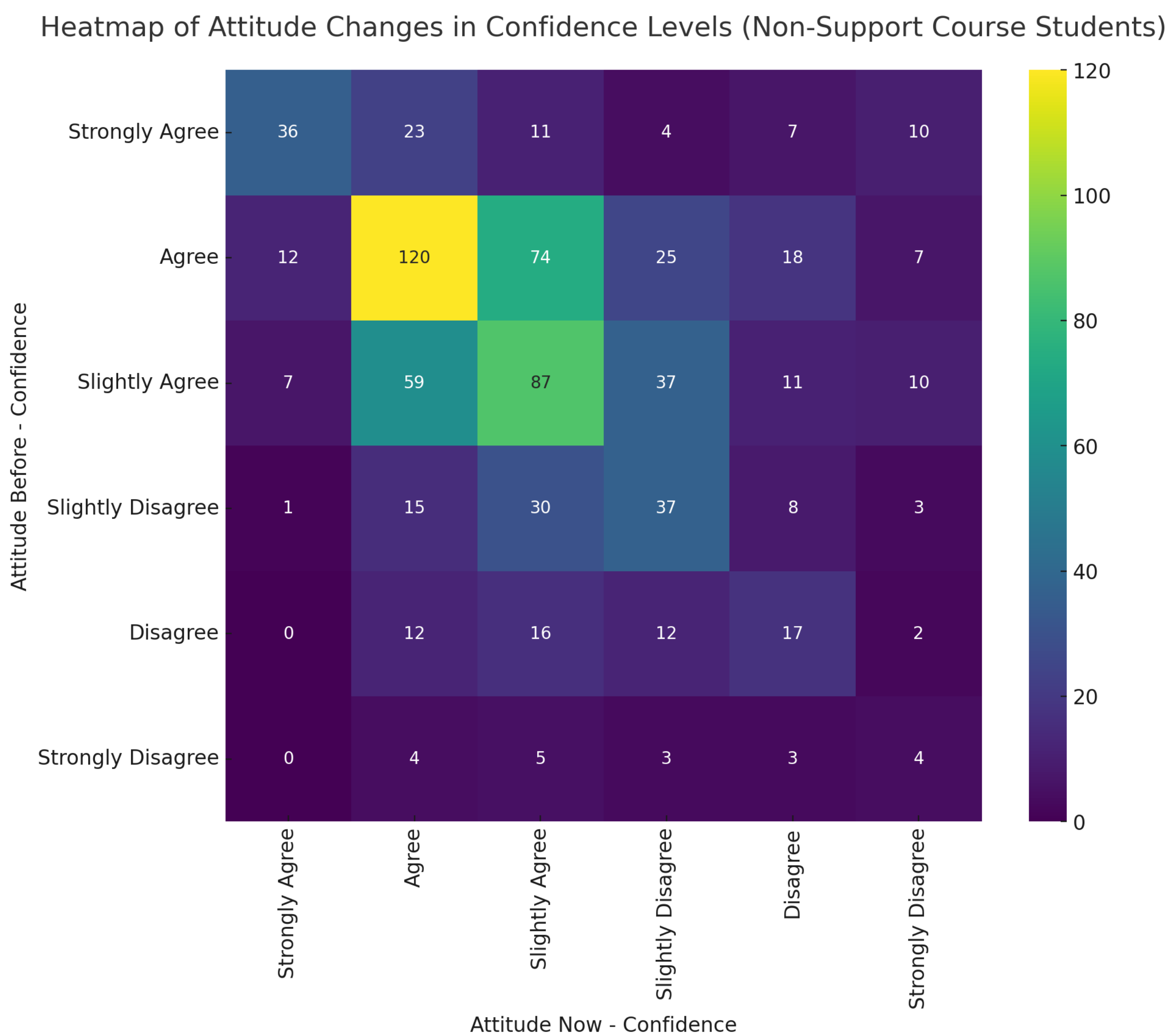

Figure 5.10: A heatmap that shows the responses of students not enrolled in the support course corresponding to their confidence levels at the beginning of the course (vertical axis) and now (horizontal axis). The number in each cell indicates the number of students who responded with that pair.

Interpreting Heatmaps

When presenting these heatmaps, it is important to take time to understand exactly how to interpret the result. Starting with the broad setup of this heatmap, the vertical axis shows the six different responses students could choose for their perception of agreement to the statement at the beginning of the semester. The horizontal axis shows the six different responses students could choose for their agreement to the statement when they took the survey near the end of the semester.

The value in each cell indicates how many students reported that specific combination of confidence levels. For example, in Figure 5.9 the cell in the row “Agree” and column “Strongly Agree” has the value 2 and color of indigo, which indicates that two students responded this way. The value-assigned color-scale called “viridis” along the right ranges from dark purple (low values) to bright yellow (high values) and corresponds to the magnitude of the value in each cell.

General patterns to observe across the entire heat map are based in terms of a six-by-six matrix. The main diagonal formed by cells from upper left corner to lower right corner represent students who maintained the same confidence level throughout the course. The upper triangular part, the portion that lies above the main diagonal, includes cells from the top left towards the bottom right, moving upwards and rightwards. The cells inside the upper triangular part represent a negative shift in confidence since it only includes cells where the confidence level at the beginning of the course (on the vertical axis) is lower than the confidence at the end of the course (on the horizontal axis). Conversely, the cells inside the lower triangular part beneath the main diagonal represent a positive shift in confidence.

Reporting Results from the Heatmaps

Observing the heatmap for students enrolled in the support course (Figure 5.9), there appears to be a higher concentration of students in the lower triangular part, specifically for the seven students whose responses shifted positively from “Slightly Agree” to “Agree” as well as the eight students with a positive shift from “Slightly

Disagree” to “Slightly Agree”. In comparison to the heatmap for students not enrolled in the support course (Figure 5.10), there appears to be more of a symmetry across the main diagonal with a slightly higher concentration of students in the upper triangular part, specifically for the 74 students whose responses shifted negatively from “Agree” to “Slightly Agree”. From this first pass, it appears by observing the heatmaps that students enrolled in the support course have slightly higher proportion of positive shifts in confidence as compared to students not enrolled in the support course. More detail about this difference between groups must be explored to determine the exact differences.

First, I ran a Wilcoxon Signed-Rank Test to compare the paired ordinal data to determine if there is a significant difference in the median of the differences in confidence reported by students. This test considers the magnitude and direction of the changes in confidence levels for each individual student, providing an overall look at how positive and negative shifts in each group are distributed. This test revealed that while the difference in confidence levels overall for students not enrolled in the support course were statistically significant ($W = 36103.0$, $p < 0.0001$), the difference in confidence levels overall for students enrolled in the support course did not show statistical significance ($W = 362.5$, $p = 0.166$). However, there is more detail I can extract from the data displayed on the heatmaps.

I calculated confidence shift categories based on the upper triangular parts, main diagonals, and lower triangular parts to indicate how many students were in each category of a positive shift in confidence, a maintained confidence, and a negative shift in confidence. The results of this calculation are visualized in Figure 5.11.

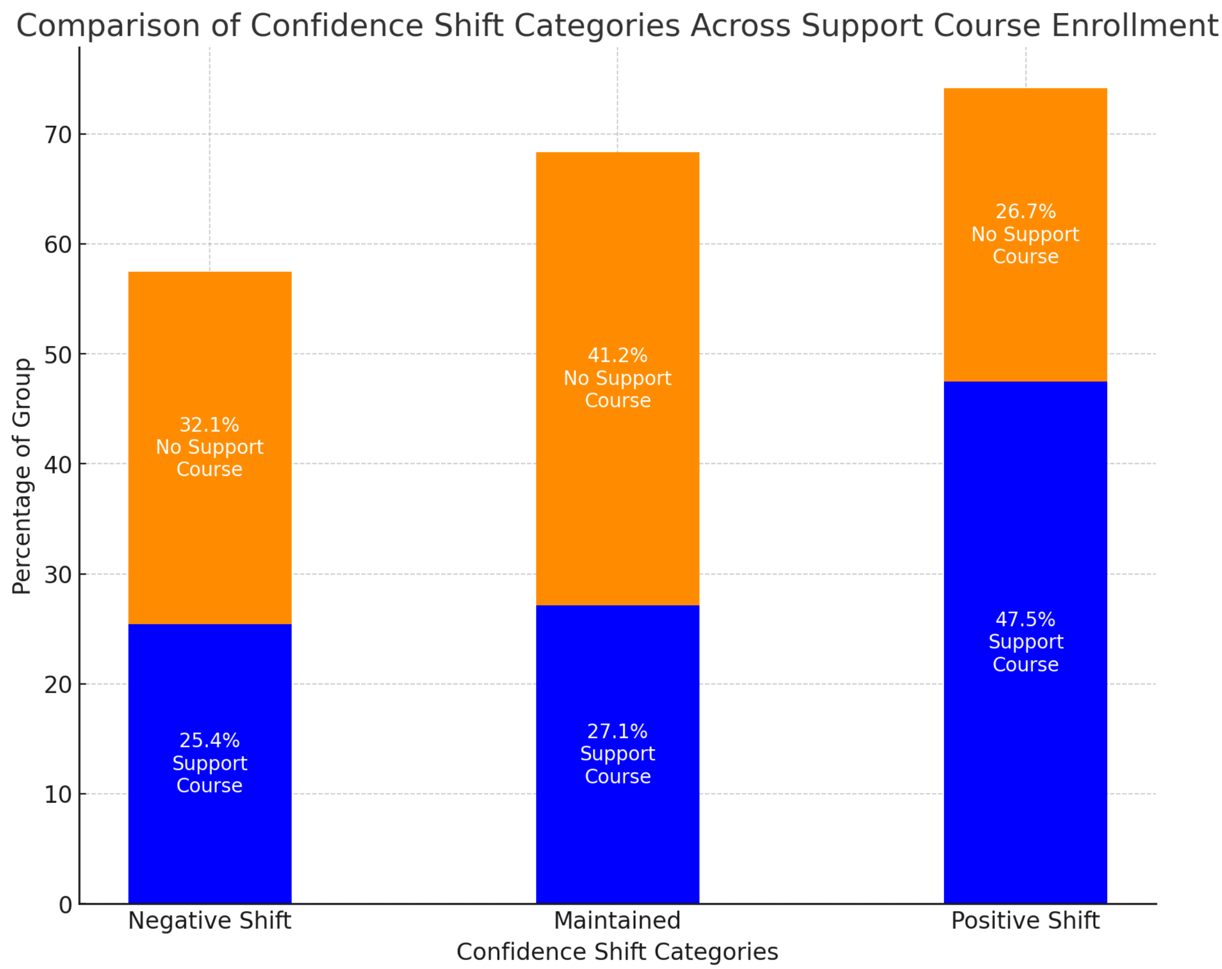

Figure 5.11: A stacked bar chart that compares the percentage of population from students enrolled in the support course and not enrolled in the support course across each category of confidence shift categories.

A chi-squared test was performed across the three confidence shift categories and revealed that there is a statistically significant association between support course enrollment and the confidence shift categories ($\chi^2(2) = 11.779$, $p = 0.00277$). To investigate the detail of these differences, a series of two-sample proportions tests that compared the proportion of students in each confidence shift category across support course enrollment showed that there was no significant difference in negative shifts (Z =

-1.054, $p = 0.292$), a significant difference in maintained confidence (Z = -2.127, p = 0.033), and a highly significant difference in positive shifts (Z = 3.404, $p < 0.001$).

The negative Z-score from the difference in the number of students who maintained confidence indicates that a larger proportion of students not enrolled in the support course showed a maintained confidence. The positive z-statistic from the difference of the proportion of students who showed a positive shift in confidence indicates that a larger proportion of students enrolled in the support course showed a positive shift in confidence. That is, not only is there no statistical evidence that students in the support course lost confidence more than students not enrolled, but that students in the support course actually reported they gained confidence significantly more than students not enrolled in the support course. Thus, I can reject the null hypothesis and accept that students in the support course reported greater positive shifts in confidence over the semester.

I performed one final analysis to determine the effect size of these changes with 95% confidence intervals, to add a finer detail to the results from the two-sample proportions tests. For effect sizes in differences in proportion, Cohen's h was calculated for each test result. The effect size of the differences from each category across support course enrollment are a negative shift in confidence with h = -0.147, 95% CI [-0.263, -0.031], a maintained confidence with h = -0.299, 95% CI [-0.418, -0.180], and positive shift in confidence with h = 0.434, (95% CI [0.302, 0.565]. Interpreting these effect sizes based on the standard scale, the negative shift difference of h = -0.147 is approaching a small but non-trivial effect but likely not practically significant, the maintained confidence difference of h = -0.299 falls between a small and medium effect size, and the positive confidence difference of $h = 0.434$ is approaching a medium effect size suggesting a moderate and practically significant effect. Each of these effect sizes are in the direction that favors students enrolled in the support course. Since none of the confidence intervals contain zero, I can be relatively sure that these effect sizes are statistically significant.

Sense of Belonging

In the survey, students responded to a 32-item list of statements that were designed to ask a variety of different aspects of their sense of belonging. Each individual item on the survey along with a summary of the responses is in Appendix I. Students were asked to respond to these items on a scale of agreement from 1 – 6, one indicating strongly disagree, and 6 indicating strongly agree, which removed any neutral option. The 32 items are preempted by a short explanation as to the context in which they should answer these questions. The survey reads,

> The following questions focus on your experience with math courses and in the math academic community. When we mention the math academic community, we are referring to the broad group of people involved in that field, including the students in a math course.
> We would like you to consider your membership in the math community. By virtue of having taken many math courses, both in high school and/or at college, you could consider yourself a member of the mathematics community. Given this broad definition of belonging to the math community, please respond to the following statements based on how you feel about that group and your membership in it.

There are apparent themes across the 32 items, with the first four directly asking about sense of belonging in the math community in different ways such: as a feeling of "belonging to" the community (item Belong1), being a "member of" the community (item Belong2), being a "part of" the community (item Belong3), and feeling a "connection with" the community (item Belong4). A chi-squared test of these four items across support course enrollment showed that there was no significant difference in the distribution of the responses across support course enrollment ($\chi^2(15) = 18.21$, $p = 0.252$). Rather than comparing one specific item or the other, I conducted a Principal Component Analysis (PCA) on these first four items as a group to investigate whether there is a difference between how students enrolled in the support course responded the items collectively.

PCA helps determine if these questions are all reflecting the same underlying sentiment, which in this case is sense of belonging. The first principal component is the "direction" in which the combined responses vary the most, where high loadings (whether positive or negative) on this component indicate that those questions are good indicators of the underlying sentiment. The analysis revealed a single principal component that explained 88.27% of the variance. The factor loadings shown in Table 5.10 indicate a strong underlying construct of sense of belonging, ranging between 0.920 and 0.963.

Table 5.10: Each of the first four items focused on sense of belonging with their corresponding factor loadings.

Item Statement	Factor Loading
Belong1 – I feel that I belong to the math community.	0.920
Belong2 – I consider myself a member of the math world.	0.949
Belong3 – I feel like I am a part of the math community.	0.963
Belong4 – I feel a connection with the math community.	0.927

The ordinal alpha (or polychoric alpha) measured for the group of four sense of belonging items is calculated to be 0.50, indicating questionable or poor internal consistency on a typical scale. However, short scales (such as 2 - 4 items) and contexts including educational research known to be inherently noisy often have lower alpha values. While this suggests some level of measurement error, the scale still provides valuable insights into students’ sense of belonging in the context of this analysis. My hypothesis is that students in the support course reported a higher sense of belonging than the students not enrolled in the support course.

First, I computed the factor scores for each student based on the PCA loadings for the sense of belong items group. These factor scores represent each student’s overall sense of belonging captured by the combined items, with a violin chart in Figure 5.12 visualizing the difference in distribution between the students enrolled in the support course and those not enrolled in the support course. The median factor score for students enrolled in the support course is 0.377 (IQR = 2.456), while the median factor score for students no enrolled was -0.430 (IQR = 2.467), which are shown as the median (50^{th} percentile) in black solid line on the violin chart. The blue dashed lines represent the 25^{th} and 75^{th} percentiles.

To investigate the nature of the differences between these two groups, I used a Mann-Whitney U test to compare the combined sense of belonging items, which have been shown to have high reliability to show a sense of belonging, between students enrolled in the support course and not enrolled in the support course. The results indicated a significant difference in factor scores between the two groups ($U = 36933.0$, $p = 0.011$), suggesting that students in the support course reported a higher sense of belonging compared to their peers. The effect size of this difference is computed to be 0.599 (95% CI: [0.524, 0.674]), which indicates a moderate effect size in favor of the students enrolled in the support course. Thus, I can accept my hypothesis that students in the support course reported feeling a higher sense of belonging as compared to students not enrolled.

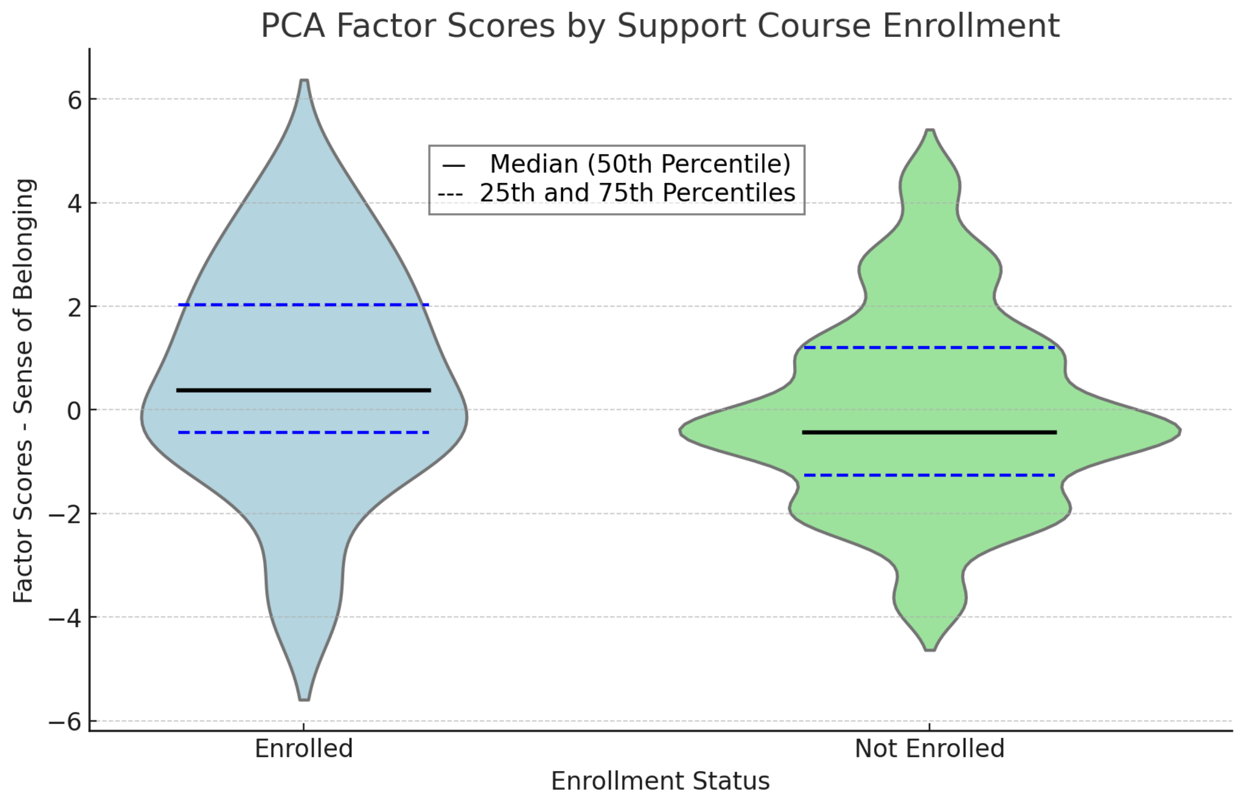

Figure 5.12: A violin chart that visualizes the distribution of responses to the combined sense of belonging items with median (50th percentile) and the 25th percentile and 75th percentile quartiles overlayed.

Another theme of items that could be grouped together focus on the negative feelings around lack of inclusivity and lack of acceptance. I performed a chi-squared test of these five items across support course enrollment which indicated that there was no significant difference in the distribution of responses between students enrolled in the support course and not enrolled ($\chi^2(30) = 38.70$, $p = 0.133$). However, I can run a PCA test to determine how the responses from students in the support course differed when the responded to these five items collectively. When grouped together, the first principal component explains 68.62% of the variance, with relatively strong factor loadings ranging from 0.791 to 0.821 and the full statements students responded to in Table 5.11.

Table 5.11: Each of the five items focused on lack of inclusivity and lack of acceptance with their corresponding factor loadings.

Item	Factor Loadings
Belong5 – I feel like an outsider.	0.809
Belong8 – I feel disregarded.	0.791
Belong11 – I feel neglected.	0.821
Belong13 – I feel excluded.	0.796
Belong15 – I feel insignificant.	0.794

While the factor loadings are all relatively strong, the ordinal alpha for this group I call the "Lack of Inclusivity and Acceptance" group is calculated to be 0.62, which can also be interpreted to fall into a range of a questionable level of the scale's internal consistency. However, accepting marginally acceptable reliability, the factor scores between students enrolled in the support course can still be compared. My hypothesis is that students enrolled in the support course reported less feelings of the lack of inclusivity and acceptance as compared to students not enrolled in the support course.

For the Lack of Inclusivity and Acceptance group of items, the median PCA score for students enrolled in the support course is 0.180 (IQR: 3.951) and the median PCA score for students not enrolled is -0.295 (IQR: 2.321). The distribution of results between groups with the median, 25^{th}, and 75^{th} quartiles are shown on the violin graph in Figure 5.13.

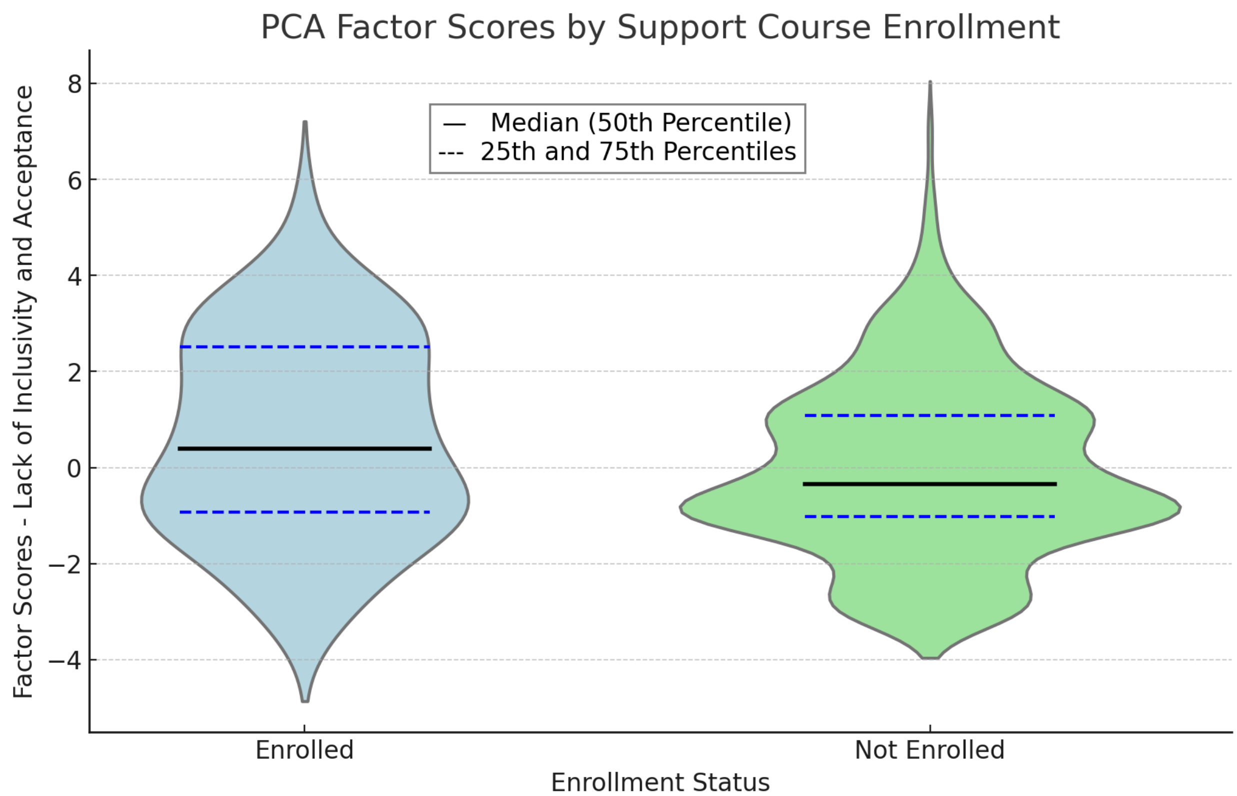

Figure 5.13: A violin chart that visualizes the distribution of responses to the combined lack of inclusivity and acceptance items with median (50th percentile) and the 25th percentile and 75th percentile quartiles overlayed.

To determine the nature of the difference of these effects across support course enrollment, I conducted a Mann-Whitney U test which indicated a statistically significant difference between the two groups, favoring the students enrolled in the support course (U = 36343.5, p = 0.016). The effect size of this difference is 0.588 (95% CI: [0.509, 0.661]), indicating a moderate effect size towards students enrolled in the support course. That is, students enrolled in the support course agreed more with the lack of inclusivity and acceptance items group. Thus, my I must reject my hypothesis.

Summary of Results from Chapter 5

An investigation into grade distributions across support course enrollment showed no significant difference in DFW rate. However, the results did show that while students in the support course were more likely to receive an ‘A’ and less likely to receive a ‘D’, they were also more likely to receive a ‘WU’. An ordinal logistic regression indicated that support course enrollment was not a significant contributing factor to the differences in grades between the two groups. Moreover, there were little to no contributing effects from multiple other potential predictors such as class attendance and various tutoring sources.

Next, student persistence for all students in Precalculus and Calculus I was measured in terms of students' self-reported plans to either enroll in the next logical course, enroll in the same course, or not enroll in a math course. While there were no significant differences in the number of students who planned to take the next logical course or not enroll in a math course, a slightly greater number of students in the support course planned to enroll in the same course. With two conflicting statistical test results on the plan to enroll in the same course being significantly higher for students enrolled in the support course, the results were inconclusive.

I also investigated persistence in terms of students’ plan to enroll for only the Precalculus students, since those enrolled in the support course and Precalculus formed an appropriately sized population for reliable statistical testing. The results of these tests were also inconclusive, with only the proportion of Precalculus students enrolled in the support course planning to re-enroll in Precalculus were slightly greater with a marginal statistical significance. Thus, only focusing on grades and persistence was not sufficient to determine which group of students were more successful.

In the second section of this chapter, I expanded the definition of success to include students’ perceptions of the inclusivity of certain instructor behaviors, students’ changes in confidence over the course of the semester, and students' reported sense of belonging. While students in the support course overall reported negatively in regard to select induvial items of the inclusivity of instructor behaviors, there were no statistically significant differences across groups when comparing along previously determined factors. However, there were statistically significant positive results of their shifts in confidence as well as their sense of belonging to the math community. Sense of belonging was determined by grouping four items that were chosen to collectively measure the underlying theme of sense of belonging from the items. The positive shift in confidence and their sense of belonging produced medium or moderate effect sizes that favored students enrolled in the support course. On the other hand, analysis of a group of items that focused on the lack of inclusivity and acceptance was also a moderate effect size that indicated students in the support course felt more agreement with statements related to lack of acceptance and lack of inclusivity in the math community.

Broadening the definition of success provided a more holistic and clearer picture of how students experiencing a support course may succeed in ways that are not typically measured. Going beyond grades and persistence, which showed little statistical differences across support course enrollment, shifts in attitudes towards mathematics such as confidence and feelings of a sense of belonging contributed to an understanding that the support course effects students in ways that have potential to not only effect their success in their current course, but also future courses. Detailed discussion of the nuances and context of these complex findings is found in Chapter 6.

Chapter 6

The purpose of this chapter is to not only provide discussion of the interpretation of the results reported in the previous two chapters, but to synthesize and interpret those results, discuss implications on future implementation of mathematics support structures and future research, and discuss reasonable theoretical contributions to broader field of systemic change. The scope of Chapter 4 involved detailed vignettes of students' mathematical stories and a broad look across all students who took the survey and those interviewed that produced results about the barriers faced by emergent identities from analysis. The scope was narrowed in Chapter 5 to include only the data of students enrolled in Precalculus and Calculus I, with the focus of the chapter on the utility of holistically expanding the definition of student success to go beyond grades and course taking patterns to include the inclusivity of instructor behaviors, shifts in confidence, and sense of belonging when comparing the success of students across support course enrollment.

Results from the broader population in Chapter 4 provide nuanced insights into the results of Chapter 5, creating a richer, more complex understanding of student experiences that may complicate or mitigate the aspects of student success that were analyzed. However, it is important to discuss the specific individual findings of each chapter on its own before relating the results of both chapters together. So, in this chapter I begin with commentary and interpretation of the specific results as they were presented in Chapters 4 and 5 individually, followed by a synthesis of how the results from both chapters taken together can inform further discussion and interpretation of results. Then, I discuss my perception of where this dissertation fits in the context of the broader scheme of research on student success and systemic change. Lastly, I discuss lessons learned for the future of not only my own continued research, but the implementation of the equity-focused student and instructor supports, including implications on how the current support course could be modified to accommodate more students based on the results of this study.

Discussion of Results from Chapter 4

Chapter 4 was structured deliberately to put student voices front and center, with significant analysis the conversations I had with seven different students as well as the input from a wide range of students across the students enrolled in P2C2 courses that filled out the free-response items on the survey. The emphasis on student experiences, as voiced by their own input and my careful creation of narratives from qualitative analysis built a greater context for the quantitative aspects that followed. The qualitative nature of this chapter not only highlighted students' specific stories of identity-related mathematical experiences, but also brought to focus emergent identities from the broad population of students who responded to the survey. This section follows the flow of Chapter 4 by discussing the results in the order as they were presented.

Discussion of the Mathematics Narratives and Their Threads of Continuity

The vignettes in Chapter 4 reflect the value a Figured Worlds perspective interfaced with Critical Race Feminism (CRF) places on believing and lifting up individual narratives, which is validated by the rich detail of the complex identities and unique individuality they provide. After presenting the narratives I constructed around how these students define mathematics, what it means to them, and their personal mathematics journey, this section discusses each of their significance. Collectively, their stories demonstrate the vast interconnectedness of the numerous aspects of students' fluid identities. Individually, their stories highlight the the unique trajectories each and every student brings with them as they enter new classrooms each term.

Carina's narrative exemplifies how her identity as an international student and athlete intersects with her academic pursuits. Her experiences underscore the importance of instructional practices that accommodate diverse educational backgrounds, seen in her appreciation for relearning foundational concepts in a supportive environment. From a CRF perspective, Carina's story also reflects the resilience and attitude she demonstrated, which is often required by women to navigate multiple figured worlds simultaneously.

Amy's story reveals the dual pressures of racial and gender stereotypes. The stereotype that "Asians are naturally good at math" places an undue burden on her, exacerbated by the gender dynamics in group settings where her contributions are overlooked. The CRF lens highlights the intersectionality of her experience, microaggressions, and systemic biases that undermine her confidence, emphasizing the need for inclusive instructional practices that validate her experiences and contributions. Beyond the inclusivity they ought to demonstrate, her story emphasizes the need for instructors, TA's, SI leaders, and other people in positions of power to be trained on how to combat racism and sexism in the moment it occurs. Not only to provide relief for the student experiencing it, but so that other students know that this type of behavior is unacceptable. However, Amy's inspired attitude and resilience fueled her motivation to succeed despite the extra pressures she feels and the lack of support she had in the moments of her gendered and racialized mathematics experiences.

Adeline's transition from high school into college mathematics illustrates the significant shift in the figured world of education. Her struggle to regain confidence in math after excelling in high school points to the critical role of supportive instructional practices in higher education, including measures taken by instructors to promote the variety of supports offered outside of class such as tutoring, counseling, advising, or support courses. The CRF framework reveals how her intersectional identity of a woman in STEM and a first-generation college student compound these challenges, necessitating her motivation to "learn how to love math again."

Santiago's story as a first-generation Latino student in computer science underscores the systemic barriers faced by underrepresented minorities in STEM fields, despite SWU being a 'Hispanic Serving Institution' or HSI. The CRF perspective would push back on the term 'serving' in this common indicator colleges in the US use to denote their motivation to enroll a higher proportion of Hispanic students. Serving Hispanic students is not simply enrolling more of them but providing language support, mentorship, and representation in faculty that students like Santiago desperately search for. Santiago's resilience and determination to seek out these supports and motivate his own success to become someone who represents Latinos in higher education highlights the critical role these resources play in fostering academic success and confidence.

Belinda's experiences as a first-generation Latina student highlight the intersectionality of language barriers and cultural perceptions of mathematics. From a CRF perspective, she faces barriers that are unknown to those who do not share her experience despite her enrollment in an HSI that may enroll more of, but potentially not 'serve', Hispanic students. Belinda is another case of inspired resilience, as she uses her adolescent experiences of growing up in a family that struggled to pay for food as motivation to succeed in college. Her narrative demonstrates her belief in the agency built into the promise of social mobility that college offers. She also challenges the notion that math is not universally applicable, where she advocates for a broader understanding of its multi-disciplinary relevance in daily life. The support she receives through SI sessions and ALEKS demonstrates the positive impact of these supports for her, but also emphasizes how these supports could be infused with culturally responsive pedagogy to support the diversity of backgrounds students utilizing them.

Micah's journey underscores the need for practical and hands-on learning approaches, reflecting his alignment with the figured world of the student-workforce and his dreams of becoming an automotive design engineer. His identification of math as "cheat codes" for achieving efficiency in his automotive career illustrates the practical value he places on mathematical skills. While Micah is a white male, the CRF perspective still lends an intersectional perspective on the additional layer of complexity introduced by his learning disability. Micah's narrative pushes back on instruction as a one size fits all approach, underscoring the importance of adaptive teaching methods that can support students with diverse learning needs.

Silvia's transition from a rigid, male-dominated educational system in Italy to a more supportive and inclusive environment in the US underscores the transformative potential of higher education. Through a CRF lens, her experiences with sexism in mathematics and STEM in general were fundamental to her identity and the motivation for agency and growth in courses that are still male dominated. Her self-perception as a person who would likely not be good at math because of her past experiences shifted when she was offered a job to teach math to other students as an SI leader, despite the pressure she feels as a woman in STEM. Her narrative reveals how inclusive instructional practices and inclusive hiring practices in higher education can alter identity and increase participation and confidence in mathematics, highlighting the need to continue promoting equity work in STEM education.

The interviewed students' definitions of math, while insightful and diverse, are not exhaustive. For example, no students mentioned philosophical debates about the nature of math or directly expressed the narrative that the math learned in school is useless. An potential explanation for the lack of philosophical debates around the epistemology of math, like whether it exists solely because created by humans or would exist in the universe without the presence of humans, is because these students have never had the question posed to them before. Moreover, due to the power dynamic in an interview setting, students may not have expressed views they hold, such as the "math is useless" narrative, because it could be disappointing to the researcher.

Discussing Identities in Transition

In the sections following the vignettes and the common threads of continuity found across them, details of the tension students feel between the figured worlds they inhabit were presented as well as some specific identities and their experiences. A small fraction of students spoke to their experiences as members of the student-workforce, their transition into adulthood, and their experience as self-identified first-generation college students or women in STEM. While only a small number of students shared their experiences, I argue that these narratives are not merely anecdotal.

Rather, they have the potential to be representative of a broader population of students' experiences with their transition to adulthood or their first-generation student status.

Just as how individual student narratives captured through qualitative research methods can serve as microcosms of the broader student experience, I liken this notion to how government representatives often view letters from constituents as indicative of larger public sentiments. A thoughtful representative, just as a thoughtful researcher, recognizes that these communications reflect the concerns, experiences, and opinions of many others who may not voice their perspectives directly. CRF emphasizes the importance of amplifying marginalized voices and not focusing on the small percentage of students who speak up. Student narratives through interviews or through free-response survey items, no matter how few of them there are or how brief they are, provide a platform for these voices. Capturing and analyzing them ensures that the perspectives of underrepresented groups are considered in the formulation of research, policies, and practices aimed at promoting equity and inclusion.

Tensions Between Conflicting Roles in Multiple Figured Worlds

The first report of the tensions students feel as they navigate their roles in multiple figured worlds is the transition between the figured worlds of high school and college mathematics. Students are experiencing shifts in power dynamics from high school to college where they must take more responsibility for their learning, but they simultaneously resent high school math for not preparing them enough while also praising high school math for being more directed and supportive.

Figured Worlds theory suggests that the transition from high school to college involves navigating new figured worlds with different expectations, values, and norms.

This shift requires students to re-negotiate their identities and adapt to new learning environments. Adding a CRF perspective, these experiences highlight how socioeconomic factors and systemic inequalities can exacerbate these challenges. For example, the inaccessibility of tutoring in high school is often based on not only the prohibitive cost, but also whether their home is a distraction-free place conducive for learning, or whether they have access to their own or public transportation to meet a tutor if they could afford one. Multiple factors in students' lives create additional barriers due to diverse or marginalized backgrounds, in particular the students who faced linguistic and cultural barriers as they entered high school in the US from another country.

The inclusion of the transition into college math from high school was an emergent theme from the analysis. While this emergent theme was anticipated before collecting data, another theme emerged that was unexpected: students' experiences with the tension between navigating the figured worlds of college math and being a member of the student-workforce. While I can only speculate about why students take jobs in tandem with being college students due to the lack of details I have, I was inspired to report the unexpected emergent theme because of the number of students who commented on how this experience was a salient aspect of their identity and the wide-spread results on how many hours students work per week.

Viewing the transition into college math as a member of the student workforce is one subset of the dynamic and complex developmental stage of the transition into adulthood. From a Figured Worlds perspective, the transition into adulthood involves navigating multiple, often conflicting, figured worlds that force students to make difficult decisions about their priorities. These student-workers must find ways to balance their academic responsibilities with their roles as workers, family members, and emerging adults. Interfacing a CRF perspective, the intersectional nature of these experiences is emphasized, stressing how race, gender, and socioeconomic status compound students' experiences and shape their pathways into adulthood and their educational journeys. The result of this analysis shows how students not only struggle with balancing their roles and time management, but demonstrates the emotional and academic impact these tensions can make.

Discussion of Instructional Practices that Mediate Identity

The investigation into responding to my second research question uncovered several instructional practices that promote equitable experiences for all students, with a particular focus of the analysis on women and first-generation students in STEM. This section highlights the depth and richness of qualitative data, which affords a view into the lives of students and specific examples of how certain instructional practices mitigated barriers they faced based on their identity. As compared to the quantitative data results, which were largely inconclusive, the qualitative aspects of this analysis shown brightly.

For women, the quantitative analysis performed did not reveal statistically significant differences in the responses across gender on multiple statements regarding their perception of instructors' tendency to highlight some student voices over others. However, the qualitative results showed that women were disproportionately affected by the overbearing presence of men in their class, inequitable and harmful group work experiences, and the narrative that STEM is a male-dominated field. On the other hand, women reported specific instructional practices that positively impacted their experience including the attention to contribution from the entire class and supportive, interactive environments with peer explanations and small group dynamics.

For Belinda, these instructional practices helped overcome language barriers, reduce feelings of isolation, and build her confidence in both math and English. I conjecture that it is clear that these instructional practices will help most, if not all, students in some way when practiced by pedagogically trained and engaged educators. Just as the curb-cut phenomenon, where a structure designed and implemented specifically for people with disabilities that affect mobility to be able to use sidewalks turned out to benefit a significant number of people it was not necessarily designed for, instructional practices that focus on equity and identity-related barriers have the potential to benefit a wide range of students.

First-generation college students reported feeling this status reflected increased obstacles from the lack of resources, preparedness, or confidence. Both Adeline and Santiago, two first-generation college students I interviewed, shared experiences that emphasized the importance of having instructors and TA's that were not only available to talk, but approachable and encouraging. When Santiago was self-conscious comparing his own progress and performance in comparison to other students, an instructor and a TA collectively helped him make the decision to persist with the major he chose regardless of how he perceived other students. Adeline also had a professor who gave her words of encouragement of her potential to contribute to the field and she spoke directly about having the knowledge that someone cared enough to say this to her made a huge difference.

While the quantitative analysis of this section that focused on the perceived academic rigor of the climate in their math courses revealed no statistically significant difference between first-generation and non-first-generation students, the qualitative aspects of analysis demonstrated the reality of their personal struggles. Acknowledging that those struggles were at least somewhat mediated by a simple encouraging conversation with those students is an instructional practice that can easily be integrated into many educators' lives.

Through a CRF lens, the power structure involved when a person of mathematical authority such as an instructor or TA says that they believe in someone, or encourages them to persist because others feel that way, students are likely to take that encouragement with more weight than if these same words came from a friend or other person not with the same positional authority. In that sense, the power dynamic caused by the hierarchy of mathematical authority in an institutional context can work both ways: instructors and TA's have the power to denounce and subjugate, but they also have the power to promote and liberate. How instructors and TA's decide to utilize that power is where first-generation college students such as Adeline and Santiago, who benefited from some encouragement to continue their inspired motivation to better themselves and their families.

The characteristics of instructional practices found to help mediate identity-related barriers to equitable engagement and self-confidence were identified through honoring and believing students' lived experiences. Students spoke to the specific ways that encouraging participation from everyone and creating space for non-dominant voices to speak were integral to their positive shifts in attitude and performance.

Instructors facilitated inclusive atmospheres, where contributions were perceived to increase in value and students recognized when instructors were attending to a shared understanding among the class before moving on. Group work with structure, such as small group sizes with rotating assigned roles, provided organization to a dynamic where certain voices and contributions would dominate without that organization. Lastly, the availability and approachability of instructors created spaces for students to engage outside of class and allowed instructors to attend to equity through encouraging conversations with students who sought advice or assistance.

Inquiry-Based Mathematics Education (IBME) is mentioned in Chapter 2 in reference to Laursen and Rasmussen's (2019) inclusion of a fourth pillar that is focused on the need for instructors to attend to equitable instruction. This fourth pillar is to address and mitigate barriers to learning, specifically for students from underrepresented groups to promote equity in mathematics education. The other pillars are also important to note, as they contain the instructional practices I identified in this study and include additional practices as well. The first pillar focuses on students' engagement with meaningful mathematics to help develop critical thinking and problem-solving skills through active engagement in mathematical inquiry. The second pillar focuses on structuring collaborative groups that can process and make sense of mathematical ideas. The third pillar puts the onus of responsibility on the instructor to make inquiry into student's thinking in order to help students develop a deeper understanding of mathematical concepts, which promotes students actively engage with other students' thinking as well.

The reason why I listed these four pillars is to allow comparison of the instructional practices identified in this analysis and to demonstrate how they generally align with the four pillars of IBME. I suggest that IBME is a candidate for a good starting place for the use of active learning in classrooms as a mitigating factor for inequitable experiences faced by students of many intersectional identities, as I have shown in this study. It is important to note that active learning is not a monolith, as its fidelity of practice by instructors and general reception and engagement from students varies drastically across several potential factors of the characteristics of the implementation which include funding, time and labor, physical space, instructor preparedness, and student buy-in.

However, alongside focused and intentional professional learning opportunities for instructors, TA's, and SI leaders, I believe that the results of this study join the growing body of research that demonstrate how practicing IBME in mathematics classrooms is a positive step towards equitable instructional practices and moreover, equitable learning outcomes. With IBME being implemented more often and with more fidelity across lecture, recitation, and SI sessions, I believe that over time the current equity gaps across P2C2 courses, as they are defined by the university, can realistically be decreased or even closed. With greater influence and more time, perhaps how those equity gaps are defined could be broadened to include more affective aspects of student success as I did in this study for a better understanding of student experience as it relates to their persistence in math courses and STEM overall.

Discussion of Results from Chapter 5

Chapter 5 was structured to demonstrate a change in the conceptualization of student success through the reporting and basic interpretation of results through two connected and sequential perspectives. The scope of the first section includes a conception of student success that focuses only on grades received and course taking patterns as students' planned persistence in the next logical math course. The scope of the second section becomes wider, broadening the definition of student success to include affective metrics of self-reported perception of the inclusivity of instructor behavior, shifts in confidence, and students' overall sense of belonging.

The goal of this section of the discussion is to further interpret the results from both sections of Chapter 5 and make the argument that we can extend these results to not be entirely based on student perception and the outcomes of success, but the influence that the implementation of support structures and instruction overall has on those outcomes. My argument is to essentially hold students accountable for their outcomes but also redirect the onus onto the university, math department, and instructors to hold them accountable for student outcomes as well. In this way, a greater investment in a more broadly defined conceptualization of student success can be made.

In this section, I comment on various limitations to the data as well as how these limitations informed the decisions that were made regarding which tests would be performed. Quantitative analysis always requires decisions to be made by the researcher, which were made in the case of this dissertation with a high level of fidelity, honesty, and rigor. I conducted this quantitative analysis with full awareness of common questionable research practices by referencing John, Loewenstein, and Prelec (2012) and avoided them to produce fair and reliable results. The following two subsections follow the subsections of Chapter 5 by discussing the reported analysis for student grades and course persistence, followed by a discussion on the holistic interpretation of success.

Discussion of Student Success Based on Grades and Course Persistence

First, a statistical analysis using a series of chi-square tests was performed to determine if there was a significant difference between the distribution of each demographic category. These categories included gender, race or ethnicity, sexual orientation, and a group of special population indicators (e.g. first-generation, student athlete). The tests indicate that there was no statistically significant difference in the distribution of each of these categories, suggesting that the representation of each demographic category of the 60 students enrolled in the support course was reasonably similar to those of the rest of the 747 students enrolled only in Precalculus or Calculus I.

However, one aspect that was not considered across this demographic comparison is that students in the support course voluntarily opted into enrolling course. While presenting some preliminary data from this study, other researchers and math department members suggested that I should consider the ‘type of student’ who does this is typically a ‘good student’. Anecdotally, this could mean they are often a well-performing student who is striving for an ‘A’ grade rather than a ‘B’ grade, rather than a student who is aware they need help to have a chance to pass the course.

In my experience speaking with the seven students who not only were enrolled in the support course but also signed up for interviews (another filtering mechanism that has potential to introduce similar bias), there was a good mix of both ‘types’ of students. For example, Silvia and Amy are both students who likely wanted a boost to their grade, but they seemed to be experienced and skilled enough that they would pass the course. On the other hand, Santiago and Belinda were both students who struggled greatly in previous math courses, where Belinda decided to enroll in the support course because she was taking Precalculus for the second time after failing the previous semester. In this sense, I believe that there is a relatively good mix of the ‘types’ of students that may have different motivations for enrolling and even replying to interview recruitment. Since I do not have specific data for each of the 60 students’ motivations for enrolling, I cannot definitively say what the distribution of these ‘types’ across the entire group of support course enrolled students.

Further indication of the similarity across support course enrollment is demonstrated in the statistical comparison of grade distributions of the two groups. Binning the grades into whole grade categories (removing the +/-) was performed to create a statistically reasonable group of six grade categories rather than proliferating the distribution of grades to over a dozen categories with the +/- attached. This choice in preparation for analysis was made because while a sufficient number of students not enrolled in the support course filled each +/- category, the size of the group of students enrolled in the support course did not. These grades were the final grades reported on students’ transcripts, rather than the raw scores.

While it would have been interesting to run additional statistical analysis on the Grades as scale variables of a real number between 0 and 100 that students received, I had limited access to that data and each instructor may or may not manipulate those scores as they translate them to letter categories based on their own ‘curve’ and their own judgement for borderline cases. Grading on a curve or ‘curving’ grades is a common practice that usually involves either adjusting the cutoff points for each grade by lowering the threshold for grade categories (e.g., 78 for B- instead of 80), adding a fixed number of points to all students’ scores to boost grades, or an outdated and not often used technique of normalizing scores to a predetermined distribution like a bell curve. I did not attend to or collect specific details about how grades may have been curved for the students in this data set because whatever curving strategy may have been utilized was assumed to be applied to all students across both groups equally.

The next point of analysis of grade distribution reported was the DFW rate. The DFW rate is often reported by the university in internal data dashboards and commonly used as a metric to identify courses that warrant attention from the departments who offer them. For example, in the Fall of 2022, the DFW rates for Precalculus and Calculus I were 31% and 28%, which were changes of -8.8% and -5.6% from the previous year respectively. These rates have generally varied between 25 - 30% for both courses over several years, with a spike during 2020 and 2021 that has since returned to pre-pandemic levels. Due to these long-standing trends in DFW rates for Precalculus and Calculus I, these classes consistently fit the criteria of courses that are targeted for extra support by the university which explains why there are supplemental instruction (SI) sessions offered for these courses and funding is negotiated for the Math and Science Learning Center (MSLC) which offers tutoring for these courses.

The DFW rates calculated for the survey population are 17.24% and 19.36% for the students enrolled in the support course and not enrolled in the support course, respectively. While there is no significant statistical difference in these proportions, there is a noticeable difference in the typical 25 – 30% DFW rates observed across the entire population of students enrolled in Precalculus and Calculus I. While DFW rates could have potentially gone down since 2022, this difference in the survey population and the general population may indicate some bias introduced by the students who chose to complete the survey. It appears the bias favors students who are more likely to pass the course because a student who knows they are not passing may not be as incentivized by nominal course credit to complete a 30- to 45-minute survey for a class that they will not pass.

The ordinal logistic regression analysis reported next was inconclusive, indicating that support course enrollment on its own was not a significant predictor of grades received. Furthermore, additional data regarding students' general tendencies to attend lecture, recitation, office hours, and support structures such as the MSLC or private tutoring did not factor in with statistical significance. Perhaps with complete scale grades in the form of a real number between 1 and 100, I could have potentially run a type of linear regression that would take into account specific grade values but, access to that data was limited and overall incomplete in the data set for this study. Making the decision to treat the grades as ordinal and run the ordinal logistic regressions made the most sense based on the completeness of the grades and the adjusted grades binned into their respective whole letter categories.

Next, I focus on discussion of the results presented regarding student persistence in their math courses across support course enrollment. These results were performed on two overlapping pairs of student groups. First, I compared all students enrolled in Precalculus and Calculus I across enrollment in one of the support courses. Then, I compared students only enrolled in Precalculus against students supplementarily enrolled in the Precalculus support course. This decision was based on the insufficient number of students enrolled in the Calculus I support course to provide meaningful statistical results.

The persistence categories compared across support course enrollment were designed to include students who planned to choose the next logical course, the same course they were currently enrolled in, and the option that indicated they did not plan to enroll in another math course. While there were other options for students to choose on this survey item that included other courses provided by the math department, I made the decision to analyze persistence or re-enrollment in the Precalculus through Calculus II (P2C2) pathway for the sake of keeping the focus on the next logical course. I could not make assumptions about why students may have chosen, for example, Linear Algebra, after completing Precalculus instead of Calculus I since that course requires a prerequisite completion of Calculus II and that choice does not make sense.

The results showed that 55.93% of students in the support course planned to enroll in the next logical course in the series compared to the 39.10% of students not enrolled in the support course, but this was not a statistically significant difference. Further testing indicated that controlling for gender also did not change this result. The reason why there is no statistically significant difference of the observed apparent difference between them is because the two-sample proportions test conducted takes into account not only the difference in proportions, but also inherent randomness and the population size differences.

However, a two-sample proportions test did indeed indicate there was a significant difference in the number of students enrolled in the support course who planned to re-take the same course. This result was surprising to me but could be interpreted as a reflection of a combination of two factors: why students enrolled in the support course to begin with, and the collection bias of the survey. This difference could be a reflection of the how students enrolled themselves in the support course because they were anticipating the possibility of the difficulty of the course, and despite receiving extra support they still did not pass and planned to re-enroll. The collection bias of the survey indicated that it could potentially favor students who are more likely to pass, which may be reflected in the relatively low proportion (~2%) of students not enrolled in the support course who indicated they planned to re-enroll.

Another mitigating factor is that only 71.18% of support course-enrolled students and 42.67% of students not enrolled in the support course responded to one of the three categories analyzed. That means either students selected a course that was not in the P2C2 sequence or did not respond to this question, as it was not required to complete this question on the survey. The decision to not require the completion of any individual items on the survey other than the few required items (e.g. which course they were enrolled in, their age, and their level of consent to the survey) was made with the intent to gather as much data as possible on each question that students chose to answer, as to not lose an entire survey entry based on a student choosing not to respond to one or two questions they felt uncomfortable about.

For the analysis of just the Precalculus students across those enrolled in the Precalculus support course and not enrolled, a higher proportion of students responded in one of the three categories with 78.05% of students enrolled in the support course and 72.21% of the students not enrolled in the support course. Despite the increased accuracy and completion of the survey item, the statistical tests performed collectively showed no significant difference in persistence across support course enrollment. There was a marginally significant result for students enrolled in the support planning to re-enroll in precalculus ($Z = 1.926$, $p = 0.054$), where the traditional cutoff for statistical significance is a p-value of strictly less than 0.05. However, the marginal significant result here is not surprising, because of the statistically significant result in the same category when compared across support course enrollment in combined Precalculus and Calculus I dataset.

Overall, the only significant differences are present in the first section of Chapter 5, which are certain letter grade outcomes and the minor differences in persistence. Students enrolled in the support course were more likely to get an ‘A’ grade and less likely to get a ‘D’ grade as compared to their peers not enrolled in the support course. However, support course students were also more likely to receive a ‘WU’. One way to interpret this result is that the support course leveled the playing field for students who were more likely to do poorly in the course. This interpretation is consistent with the finding that the support course students were more likely to say they were going to repeat the course because such a sentiment reflects their expectation of not doing well. The support course enrolled students might be the most vulnerable, and hence having no statistically significant difference in grades overall might just be a positive outcome. There is precedent for this idea of a level playing field, as a similar argument is made when comparing student success in the form of DFW rates across course variations in undergraduate P2C2 courses (Voigt et al, 2019).

Collectively, these results could be interpreted as another reflection of the survey's population bias, but they could also indicate some minor level of positive influence the support course is having on students' grades for those who do not receive WU's. In terms of persistence, even though support course students more often planned to enroll in the same course, there was no significant difference in the proportion who were planning to take the next logical course. That is, the persistence rate of planning to take the next logical course was the statistically the same between the two groups regardless of the difference of students planning to re-enroll which aligns with the sentiment of leveling the playing field.

Discussion of the Holistic Interpretation of Success

Widening the scope of student success by broadening the definition of success to include perception of instructional practices, shifts in confidence, and sense of belonging required the use of a wider array of statistical tools than the previous section of Chapter 5. First, multiple individual Inclusive Instructor Behavior (IIB) items were tested, and then the range of previously determined factors that included multiple groups of IIB items that reliably measure underlying sentiments. Then, heatmaps and a Wilcoxon signed-rank test appropriate for paired ordinal data were used to determine statistical differences in the shifts in confidence across support course enrollment. Lastly, two aspects of sense of belonging were tested across the items grouped by their internal consistency to measure both a general sense of belonging sentiment, as well as a sentiment of the lack of inclusion or acceptance. When significant differences were found, Mann Whitney U tests were conducted to determine the effect size of that difference along with calculating 95% confidence intervals.

The underlying sentiments across IIB items that are measured by the factors developed by Nate Brown at Penn State were all tested except for one, titled ‘Engaging vs. Disinterested’. This factor has two items that indicate a negative aspect about instructors and three items that indicate a positive aspect about instructors. It is likely that the lack of internal consistency of this factor has to do with grouping these positive and negative factors together. Since the general results of the items that belong in each group were shared with me, but the specific results of why each of those items were grouped in that way was not shared with me, I removed that factor from the subsequent analysis. Due to limited contact with Nate Brown during the analysis stage of this dissertation, I was unable to communicate with him about that factor in particular. However, the internal consistency of the remaining factors measured by ordinal alpha are interpreted as acceptable or better than acceptable.

The results of the differences of students’ perception of the inclusivity of instructor behavior across enrollment in the support course were minimal. While the small effect size of the ‘Group Work’ factor appeared to favor students enrolled in the support course, the confidence interval included 0 which indicates there is no statistical significance of the direction of that small effect regardless of the p-value. A 95% confidence interval for ordinal data such as the IIB items offer a range of interpretation, which acknowledges a measure of uncertainty around a result derived from a sample population. Mathematically, a 95% confidence means that when the population is randomly sampled 10,000 times, you would expect 9,500 of those samples to include the true population parameter. The uncertainty of the direction of such a small effect size due to 0 being within the confidence interval indicates that the significance of that effect is lost.

On the other hand, the factor that measured an underlying sentiment of a perception that the teaching in their math class is too complex showed students not enrolled in the support course agreeing more to the items grouped into that factor. That is, with a small marginally significant effect size with a 95% confidence interval of [0.122, 0.172], students not enrolled in the support course perceived the instruction to be too complex. One interpretation of this result is that the extra time spent in the support course engaging in mathematics could be a factor that helps students reduce their perception of the instructors' teaching to be too complex. However, the marginal significance of the p-value, which is just slightly over the typically strict 0.05 threshold indicates that there is not enough evidence in this data to definitively determine that this effect size is significant, despite the confidence interval not including 0.

I am inspired to include marginally significant results in my report by a meta-analytic mindset that acknowledges the fact that this result could be useful in a future meta-analysis. Additionally, the history of the creation of the threshold for 0.05 to be so strict is essentially arbitrary and not universally optimal, as it was originally designed as a research guideline. Mathematically, a p-value of 0.05 implies that there is 5% probability of observing the data, or something more extreme, if the null hypothesis is true. That is, there is a 5% chance I collected this data, analyzed it, and calculated this result when the reality is that the result does not actually reflect the population I collected data from. The strict adherence to the 0.05 threshold receives ongoing criticism today, and I want to acknowledge my part in attending to that debate.

Next, a statistically significant positive shift in attitude towards students' confidence in mathematics was found for students enrolled in the support course with a moderate effect size of $h = 0.434$. This moderate effect size is universally accepted as a practically significant effect, as it is approaching Cohen's threshold for a 'medium' effect size on a scale from little to none (<0.2), small (<0.5), medium (<0.7), and large (<1.0). While this scale is also relatively arbitrary and depends on the context of the research, this is a widely utilized scale to generally determine the practical significance of an effect size beyond the p-value and the confidence interval associated with it.

So, what does it mean for a student's confidence to be approaching a moderately-sized positive shift? The realistic and practical significance is up to subjective interpretation within the context of the research. In a breast cancer study by Berry et al (2005), a relatively small effect size on Cohen's scale that indicated an absolute reduction of 1-2 fewer deaths per 1000 women translates to thousands of lives saved when scaled to the population level. Similar contexts that force a re-evaluation of the interpretation of a small effect size are found in vaccination programs (Rolfes et al, 2019), as well as the use for aspirin to prevent heart attacks (ATC, 2002). Moreover, Hattie (2009) conducted a meta-analysis of over 800 educational intervention studies relating to student achievement and argued that for students at the margin of passing or failing, the effect of the smallest improvements can have a large impact on students' success.

Acknowledging this argument to consider the context of the research and the practical implications of effect sizes on this student population, I am inclined to believe that this shift in confidence makes a significant impact on students' lives inside mathematics settings, as well as in their overall academic experience as STEM students. Higher confidence in purely mathematical settings is likely to be interpreted as a positive characteristic. Extending from mathematics settings, when STEM students begin to take physics, chemistry, or engineering courses, which are math-heavy fields, a higher confidence in the mathematics required has positive implications across many STEM disciplines. Furthermore, when paired with the increased confidence found across multiple support course students in the qualitative analysis, I feel comfortable stating that the positive shift in confidence observed has widespread and lasting implications.

The next section focuses on the statistical results of comparing two factors I created that have marginally acceptable internal consistency of measuring underlying sentiments of a general sense of belonging and a lack of inclusivity and acceptance. While the marginal acceptability of the internal consistency of these factors is questionable, with ordinal alphas of 0.50 and 0.62 respectively, the results of the comparisons of these two factors can still highlight important differences across support course enrollment. However, the interpretation of the practical significance of the effect size of those differences should be taken critically, due to the ordinal alpha levels.

Students enrolled in the support course reported a statistically significant difference in higher sense of belonging compared to their peers, with a medium effect size of 0.599 (95% CI: [0.524, 0.674]). Even on the lowest end of this confidence interval, students enrolled in the support course showed a significantly larger sense of belonging based on their collective responses to four similar questions about their overall sense of belonging in the math community. However, the subsequent test on students' collective responses to the items that were grouped to create the 'lack of inclusivity and acceptance' factor favored the students not enrolled in the support course, also with a medium effect size of 0.588 (95% CI: [0.509, 0.661]).

This discrepancy between students in the support course strongly feeling more of a general sense of belonging while simultaneously feeling similarly strong about the lack of inclusivity and acceptance is surprising. One might expect that if support course students felt so strongly about their sense of belonging, they might also feel strongly about their inclusion and acceptance in math settings. Since that is not the case in these results, I must interpret this discrepancy as an indication that for these students, a sense of belonging coexists paradoxically with a sense of inclusivity and acceptance.

While there is tension between the two states of feeling a sense of belonging and feeling a lack of inclusivity and acceptance, both states exist simultaneously for the students responding to this survey. My explanation for this is how students interpret the items on the survey, specifically their personal definition of a 'sense of belonging'. It is possible that students interpret 'belonging' as a feeling that they 'ought to belong', indicating critical push back against prevailing narratives around who 'belongs' in STEM fields. However, the feeling of being included or being accepted in that space where they 'ought to belong' could be interpreted based on thoughts of specific experiences they had that are conjured when they were posed the survey items with the words "acceptance" and "included."

If it is the case that students interpreted the survey items this way, then looking to the specific inclusion of the impact of the support course on the decision to respond that way is another level of complexity to these results. Acknowledging there are some relatively difficult steps to interpret these two results collectively, they appear to be connected to their enrollment in the support course. Simply put, when students responded to these questions, they felt that while their general sense of belonging is high, their sense of the lack of inclusion and acceptance was also high. Difficult to interpret results such as these can influence not only future versions of the survey, but also how to augment instructional practices that explicitly target inclusion and acceptance.

Synthesis of Results from Chapters 4 and 5

The qualitative nature of the results Chapter 4 and the quantitative nature of results of Chapter 5 complement each other in a balance of individuality and collective experience. While the descriptive and specific results of Chapter 4 are constructed mostly from individual voices and emergent themes to explore from those voiced experiences, the results from Chapter 5 demonstrate the comparison of experiences of subpopulations and their collective responses as a sample of the whole population of students. Next, I synthesize the results from both chapters by leveraging the benefits from the multi-faceted aspects of this mixed-methods study.

In Chapter 4, I constructed narratives that act as a microcosm of mathematical journeys and contextualize broader experiences of emergent identities and identity-shaping events such as life transitions into college math and the workforce, women in STEM, and first-generation college students. I identified barriers to mathematics access and opportunity related to students' identities and the roles they inhabit and reported the instructional practices that mediate those identities in ways that foster more equitable experiences for these students. The results of Chapter 5 indicate that students who enroll in the support course, regardless of their identity or their current experience with the emergent transitions, are impacted positively overall by their engagement with this extra support.

The experience of the support course is essentially meeting at least once weekly with a near-peer SI leader who utilizes active learning techniques in a low-pressure collaborative setting with just a few other students. The approachable and relaxed atmosphere of these sessions provides opportunities for students to engage with just-in-time support that aligns with the content and pacing of the course. In the context of the turbulent life transitions and the gendered and racialized experiences in mathematics presented in Chapter 4, the practical significance and impact of the effect of the support course on students overall suggests that the support course helps students in meaningful ways.

However, I do not believe the chain of inference is not as static as it may appear. That is, I believe there is more to this notion of simply enrolling and engaging with a support course is enough to make significant changes in students' experiences. I am inclined to think that there is a more complex system of motivation and momentum that fuels multiple small, yet significant, changes that travel outwards from their experiences in the support course that propagate into the recitation course, the lecture course, and the changes in identity that students experience.

Positive interactions around confidence building, encouragement to seek help, and increased value of student contributions are at the center of that ripple effect. Increased confidence in individual math problems build outwards to eventually become increased confidence in whole sections of material, and then the content that fills an exam. Encouragement to seek help starts with a short conversation in the support course and builds outwards to eventually become multiple conversations with their professor in office hours, and then building community and potential networking connections. When students' contributions are valued more by others, that builds outwards towards students building up the belief that their own contributions have value, promoting increased engagement and contribution in the recitation or lecture courses as well.

The incremental and cumulative nature of this outward ripple effect from relatively simple interventions suggests that focusing on the nuances of what may appear to be small effects has potential to impact larger trends of growth within the interconnected web of norms, practices, values, and roles of the multiple figured worlds students interpret. In this way, retaining a more holistic conceptualization of student success has broader implications than simply identifying which students are excelling in more than grades and course persistence. There are even undetected and potentially impossible to capture positive changes that ripple outwards from their mathematics experiences to their other courses and other aspects of life such as family, friends, and their eventual careers.

Students who recognize how incremental and progressive shifts in confidence and sense of belonging affect the ways they interact with others, how they perceive their own contributions in class, their ability to learn, and potentially their final grades have the potential to recognize how these kinds of growth can make positive changes in the rest of lives as well. That is, advocating for a widespread adoption of interventions that trigger these ripple effects that affect lasting and meaningful changes is a form of liberation from the systemic inequities present in higher education as well as the confines of students' self-perception.

Implications of this Dissertation on Systemic Change Research

In this dissertation I utilized the theory of Figured Worlds interfaced with Critical Race Feminism, which is something that has yet to be done in the field of systemic change research. While each theoretical perspective inevitably has aspects of reality that are highlighted or subdued, this synthesis of the sociopolitical CRF theory with a Figured Worlds perspective emphasized not only the characteristics of roles, culture, practices, values, and norms that are highlighted in Figured Worlds, but also the power dynamics, systemic inequities, and historically socialized disparities of the intersectionality of women, people of color, and historically underrepresented populations.

The level of detail and contextual nuance demonstrated by my use of Figured Worlds interfaced with CRF is the heart of this study, where student experience and student success go beyond what might have been captured and analyzed by a traditional quantitative analysis of student persistence and grades. Student success, as it is conceptualized more holistically in this study, is not only an indicator of increased performance of students themselves, but also an indication of the success of the support structures and instructors who have meaningful contacts with these students.

While the use of Figured Worlds interfaced with CRF in this study focused entirely on student experiences, there is a clear path towards the use of these theoretical perspectives to study the cultures, practices, and identities among SI leaders, TA's, and instructors. Moreover, I believe there is potential to this perspective having the power to enlarge the grain size of analysis to math departments or colleges of science as a whole.

One contribution I make to the future of research inspired by the use of Figured Worlds interfaced with CRF in systemic change is the value that can be placed on a mixed methods approach. The qualitative aspects of this dissertation show the rich detail and specific results that can be achieved through interviews and free-response items on surveys. However, typically quantitative measures of success are not particularly apparent in the whole of qualitative analysis. Complementary to the qualitative results, quantitative aspects of this study shine because of their ability to focus not only grades and course-taking patterns but were influenced to extend the conceptualization of student success to include metrics such as perception of inclusivity of teaching practices, shifts in confidence, and sense of belonging.

Furthermore, by demonstrating the effectiveness of broadening the conception of student success to include affective aspects of student experience, I have contributed an idea that has practical applications in the context of studies on student success, persistence in STEM, and the broader field of Systemic Change. This is a call to all systemic change researchers who may focus on student success to acknowledge the affordances and constraints of placing value what is traditionally measured and expanding your perception of student success to begin measuring what you value. That means we do not necessarily have to disregard traditional methods but we can enhance them and build from them with the goal of not only identifying areas that need improvement, but to implement changes that have potential improve those areas and holistically capture how people are affected by those changes overall.

Future Endeavors

My future as an educator begins this fall as the new coordinator for Calculus I at SWU, lifting my position from graduate student researcher to full-fledged instructor. While my research role will likely take a seat secondary to my coordination and instruction duties, continuing to grow in all aspects of my academic impact is greatly important to me. For that reason, I will continue to collaborate in research papers that have potential to impact mathematics education on a grander scale than a coordinator role affords for one course, in one mathematics department, at one university. The beauty of publishing research is the widespread influence it can potentially have on many educators in varying local contexts. In particular I intend to continue my contributions to the field of systemic change as a whole with a goal of promoting active learning and encouraging a critical, sociopolitical perspective of mathematics education.

Coordinators are pivotal in their role as change agents and control important levers for change in math departments, with the power to develop and distribute materials and tools to other instructors, encourage collaboration and foster better communication, and create meaningful professional development opportunities (Martinez et al, 2022; Williams et al, 2022). In addition, a successful coordinator collects, analyzes and responds to local data to inform the iterative cycle of plan, implement, analyze, and redesign. The main aspect of the data collection is to continue to administer a survey to all P2C2 students, with potential for eventually expanding to College Algebra and other courses.

However, there are some ideas I have for the future versions of the survey inspired by what I have learned through the process of this dissertation. First, I would redesign the survey to reduce the large number of specific, individual questions into broader ideas with one Likert-scale question that focuses on each theme of sense of belonging, inclusion, acceptance, and attitudes towards mathematics. In place of the reduced number of items, it would be appropriate to include more opportunities for students to explain their response with free-response items under each main idea. While collecting more qualitative data to analyze alongside each of these themes is more conducive to run a more organized mixed-methods analysis, the reduced number of items will also potentially reduce the overall completion time of the survey.

I also plan to include some items that provide scale or ratio data, including the collection of numerical grades in addition to the final letter grades that I collected for this study. In response to the selection bias of the survey from this study, where it appeared students more likely to pass are the ones filling out the survey, I would encourage more widespread completion of the survey through more intense promotion. Additionally, I am going to plan incentives more thoroughly with all instructors well before the administration of the survey so that we can decide on one universal incentive that attracts as many students as possible to complete it.

As an instructor for Calculus I at SWU, I plan to set an example for other instructors by trying novel instructional techniques by running my class as an active learning large lecture. As the coordinator for Calculus I, I can also promote the use of active learning, following the pillars of IBME specifically, to instructors through a community of practice model. I can also infuse more active learning into the recitation courses with my influence on TA training and the professional learning opportunities for TA's throughout the semester. Beyond my own teaching practices and my influence on instructors and TA's for Calculus I, I also have an idea that has not ever been tried in Calculus I here at SWU.

I plan to include the SI leaders in this network of IBME influence not only through working with the SI director but also making use of the fact that SI leaders are present in the lecture classroom. SI leaders can experience active learning practices as they take shape in large lecture classes and be called on to help facilitate group work, being positioned to travel around the room and assist students in their collaborative explorations of meaningful and engaging material. Essentially, I would position SI leaders as Learning Assistants, which in the past have been difficult to train and hire as a separate entity from SI leaders who are already hired, trained, and required to attend the lecture sections of Calculus I.

This idea to engage SI leaders as facilitators of collaboration in the large lectures goes beyond my own benefit from having another knowledgeable individual helping groups of students around the room, but it also builds the connection and engagement between students who attend the lecture with the SI leaders. Making these connections has the potential to ripple outwards as well, building relationships that encourage students to attend more SI sessions, or even enroll in the support course where SI sessions are required. If students are not only aware of SI sessions or the support course, but also familiar with the SI leader who runs some of those sessions, I believe they will be more likely to seek out and engage with that support structure.

My vision for the future of research and practice involves a central theme of supporting the diverse identities and positively impacting the experiences of all the students who walk through the door of my classroom and beyond. My motivation continues to be driven by an inspired vision for social justice and equitable education for all. As I ascend into my own position of increased power, I am afforded the opportunity to lift others along with me.

Conclusion

Beyond the formal acknowledgements that precede the dedication of this dissertation, this dissertation would not have been possible without the trust, encouragement, and patience exercised in the cultural phenomenon of the mentorship and advising structure of higher education. My growth as an educator and as a critically informed member of an educated society is largely attributed to the positive impact many educators have had on my life. From my father’s 25 years as a middle school educator, to my wife’s dedication to her students, to the dozens of approachable, inspiring, and genuinely interesting instructors I have been fortunate to take a class with in not only the last 15 years since beginning community college but also reaching back to reading Dr. Seuss books and making bottle rockets with vinegar and baking soda with local parents and caretakers in preschool.

I have hope that I can have a similar impact on my children and my children’s classmates, as well as the thousands of students I will be fortunate enough to teach mathematics to in the course of my academic career. While it has certainly been a long road to get to where I am, this academic journey is only beginning and I look forward to improving every year, making as much of a positive impact as I can.

APPENDIX

Interview Protocol

1. What does mathematics mean to you?
    1. Probe: How would you define it?
    2. Probe: How do you imagine yourself using it?
2. Is there anything about your identity or who you are that has affected the way you do or learn mathematics here at our institution?
    1. Or, if they have already answered this question on the survey, use their response to start a conversation about them elaborating on that response.
    2. Probe: How do you identify yourself?
3. Are there teaching practices in your mathematics classes that you feel marginalize you or the way you think?
    1. If so, are there specific moments that you can think of that were awkward, racist, gendered, ableist, or otherwise marginalizing?
4. Have there been experiences in your mathematics class that have impacted your identity or the way you think of yourself outside of math class?
5. Considering your mathematical identity to be connected to the way you feel about your confidence, interest, and enjoyment in mathematics, the next few questions will focus on those
    1. How has your confidence in mathematics changed if at all, and why?
    2. How has your interest in mathematics changed if at all, and why?

    3. How has your enjoyment in mathematics changed if at all, and why? [CM2]
6. Do you have a mathematics story?
    1. Probe: Do you have salient memories of mathematics in your life up to this point?
    2. Probe: A story has a beginning, a middle, and an end. If you know where you started and where you are, where do you see the end of that story?
    3. Probe: What could have changed that story for the better?
7. How would you change mathematics experiences for underrepresented, marginalized, oppressed students?
8. In systemic change, I have focused on department level change in mathematics programs across the country– what would you want to say to someone who is starting a change process in their mathematics department?
9. What student support structures from the university have you utilized as a student so far?
    1. Probe: Have you gone to the MSLC for tutoring? Why or why not?
    2. Probe: Have you visited TA or Professor office hours? Why or why not?
    3. Probe: Have you talked to anyone about your experiences in school, such as with a therapist provided by the school through CAPS?
10. What needs do you have that are beyond the scope of support structures the university might offer?

Learning Lab Survey Text

Start of Block: Introduction Block

Welcome! The Learning Lab Project of California has funded researchers in mathematics education to better support student success in precalculus and single-variable calculus courses at SDSU.

To participate, you must enter your school email, SDSU ID number, which course section you are enrolled in, and your decision about participating.

Please read the project description and detailed consent that follows. Thank you in advance for your time, your viewpoint, and your contribution to this work.

SDSU Student RedID (this is a nine-digit number on your ID card that often begins with the number 8):

____

SDSU Student Email (this is the official school email that ends with @sdsu.edu):

____

Which course and section are you enrolled in?

Course name and number

Instructor

Scheduled time

Discussion Section

Based on your response from the last page, you are not currently enrolled in one of the Precalculus, Calculus I, or Calculus II courses at SDSU. If this is the case, you are not eligible to take this survey.

If you are in fact enrolled in one of these courses, please return to the previous page by using the back button on the bottom left of the screen.

If you are not enrolled in one of these courses, please exit the survey by clicking below:

- ◯ Skip to end of survey, I'm not enrolled in Precalculus, Calculus I, or Calculus II.

Page Break

Results of this survey and the information we gather will be kept completely confidential. Your Participation is optional, but we hope you will contribute to our study, so that we may better understand your experiences with precalculus and/or single-variable calculus courses at SDSU. In addition to questions about your experience in your current mathematics course, this survey contains a few questions about your attitude towards mathematics and prior experience. Please view and save this detailed consent notice for your information. For more information about the research project, you can go to the Learning Lab of California website, and if you have any questions about your participation please contact Colin McGrane at cmcgrane@sdsu.edu. There are three levels of consent to participate in this research project. Your level of consent will not be shared with instructors, only your ID number for the sole use of receiving credit for interacting with this survey. Please respond which level of consent you choose:

- ◯ **Full Consent**: I consent to participate in this survey AND allow the researchers to access my transcript data (course history, grades, etc.)
- ◯ **Partial Consent**: I consent to participate in this survey, but do not consent to researcher accessing my transcript data.
- ◯ **No Consent**: I choose not to participate in the survey.

To participate in this survey, you must be 18 years old, or older. Are you?

- ◯ Yes
- ◯ No

Page Break

Are you currently co-enrolled in any of the following?

- ○ Math 141S -- SI Session / Precalculus Support
- ○ Math 150S -- SI Session / Calculus Support
- ○ None of the above

Do you regularly attend Supplemental Instruction sessions?

- ○ Yes
- ○ No

Do you attend the recitation or discussion section for your class?

- ○ Yes
- ○ No

Please continue and be honest with your responses. From this point, the remainder of this survey should take around 15 minutes of your time.

Your progress will be automatically saved every time you move to the next page. If you experience any difficulties, please contact Colin McGrane at cmcgrane@sdsu.edu.

End of Block: Introduction Block

Start of Block: Classroom experience

Based on your responses so far, you are one of the few students who enrolled in the new support course for ${Q3/ChoiceGroup/SelectedAnswers/1}.

Please reflect on your experience being enrolled in ${Q7/ChoiceGroup/SelectedChoices}.
What encouraged you to enroll in this support course?

Please continue to reflect on your experience being enrolled in ${Q7/ChoiceGroup/SelectedChoices}.

How has your experience in this course supported your success in ${Q3/ChoiceGroup/SelectedAnswers/1}?

____

Please continue to reflect on your experience being enrolled in ${Q7/ChoiceGroup/SelectedChoices}.

How could your experience with ${Q3/ChoiceGroup/SelectedAnswers/1} have been improved?

____

Roughly how often have you missed class meetings for ${Q3/ChoiceGroup/SelectedAnswers/1}?

	(Almost) never	Occasionally	Frequently	I've missed more than half the classes
Regular class meetings	○	○	○	○
Recitation/lab section	○	○	○	○

Where do you go for tutoring, if necessary? Please select all that apply.

- ☐ Math and Stats Learning Center (MSLC)
- ☐ Office hours
- ☐ Friend(s)
- ☐ Private tutor
- ☐ Extra course sessions (e.g., supplemental instruction, extra lab)
- ☐ Review sessions

☐ Other (please explain)

____

Consider your **regular course meetings** ${Q3/ChoiceGroup/SelectedAnswers/3} and primary instructor ${Q3/ChoiceGroup/SelectedAnswers/2} of ${Q3/ChoiceGroup/SelectedAnswers/1}. As compared to other students in class…

	A lot less than other students	Somewhat less than other students	The same as other students	Somewhat more than other students	A lot more than other students
How much opportunity do you get to answer questions in class?	○	○	○	○	○
How much attention does the instructor give to your questions?	○	○	○	○	○
How much help do you get from the instructor?	○	○	○	○	○
How much encouragement do you receive from the instructor?	○	○	○	○	○
How much opportunity do you get to contribute to class discussions?	○	○	○	○	○
How much praise does your work receive?	○	○	○	○	○

Consider your **recitation/lab section** and recitation/lab instructor

${Q3/ChoiceGroup/SelectedAnswers/4}. As compared to other students in class…

	A lot less than other students	Somewhat less than other students	The same as other students	Somewhat more than other students	A lot more than other students
How much opportunity do you get to answer questions in class?	○	○	○	○	○
How much attention does the instructor give to your questions?	○	○	○	○	○
How much help do you get from the instructor?	○	○	○	○	○
How much encouragement do you receive from the instructor?	○	○	○	○	○
How much opportunity do you get to contribute to class discussions?	○	○	○	○	○
How much praise does your work receive?	○	○	○	○	○

Consider your experience in **Supplemental Instruction Sessions** and the various SI leaders that run them. As compared to other students in class…

	A lot less than other students	Somewhat less than other students	The same as other students	Somewhat more than other students	A lot more than other students
How much opportunity do you get to answer questions in class?	○	○	○	○	○
How much attention does the instructor give to your questions?	○	○	○	○	○
How much help do you get from the instructor?	○	○	○	○	○
How much encouragement do you receive from the instructor?	○	○	○	○	○
How much opportunity do you get to contribute to class discussions?	○	○	○	○	○
How much praise does your work receive?	○	○	○	○	○

How would you describe the overall climate within ${Q3/ChoiceGroup/SelectedAnswers/1}?

	1	2	3	4	5	
Excluding and Hostile	○	○	○	○	○	Including and Friendly
Intellectually boring	○	○	○	○	○	Intellectually engaging
Academically easy	○	○	○	○	○	Academically rigorous

I believe that my math ability can be improved through dedication and hard work.

- ○ Strongly agree
- ○ Agree
- ○ Slightly agree
- ○ Slightly disagree
- ○ Disagree
- ○ Strongly disagree

Please indicate your level of agreement for the following statements from the beginning of the course and now.

	Beginning of course	Now
I am interested in mathematics	▼ Strongly agree ... Strongly disagree	▼ Strongly agree ... Strongly disagree
I enjoy doing mathematics	▼ Strongly agree ... Strongly disagree	▼ Strongly agree ... Strongly disagree
I am confident in my mathematical abilities	▼ Strongly agree ... Strongly disagree	▼ Strongly agree ... Strongly disagree
I am able to learn mathematics	▼ Strongly agree ... Strongly disagree	▼ Strongly agree ... Strongly disagree

End of Block: Classroom experience

Start of Block: IIB : Inclusive Instructor Behavior

When answering the following questions, consider only your **current math course**, ${Q3/ChoiceGroup/SelectedAnswers/1}, and **current instructor,** ${Q3/ChoiceGroup/SelectedAnswers/2}.

Rate your level of agreement with the following statements.

My math instructor…

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Teaches too fast.	○	○	○	○	○
Explains things in different ways when we ask.	○	○	○	○	○
Pauses to let us absorb material or formulate questions.	○	○	○	○	○
Jokes with the class.	○	○	○	○	○
Puts us down.	○	○	○	○	○
Criticizes our answers to their questions.	○	○	○	○	○
Talks enthusiastically about math.	○	○	○	○	○

When answering the following questions, consider only your **current math course**, ${Q3/ChoiceGroup/SelectedAnswers/1}, and **current instructor**, Rate your level of agreement with the following statements.

My math instructor…

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Encourages us to work together.	○	○	○	○	○
Teaches to all students, not just those who've already seen this material.	○	○	○	○	○
Is helpful during office hours.	○	○	○	○	○
Makes mistakes which confuse students.	○	○	○	○	○
Is too advanced to be teaching this course.	○	○	○	○	○
Pays more attention to some students than others.	○	○	○	○	○
Doesn't manage class time well.	○	○	○	○	○

When answering the following questions, consider only your **current math course**,

${Q3/ChoiceGroup/SelectedAnswers/1}, and **current instructor**

Rate your level of agreement with the following statements. **My math instructor…**

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Makes sure all questions get answered before moving on.	○	○	○	○	○
Makes us feel comfortable asking questions.	○	○	○	○	○
Takes too long to grade and/or return homework, quizzes and/or exams.	○	○	○	○	○
Gives exams which are hard to finish in the allotted time.	○	○	○	○	○
Checks in on us when we work in groups.	○	○	○	○	○
Has little or no enthusiasm for teaching.	○	○	○	○	○
Has little or no interest in students' success.	○	○	○	○	○

When answering the following questions, consider only your **current math course**,

${Q3/ChoiceGroup/SelectedAnswers/1}, and **current instructor**,

Rate your level of agreement with the following statements. **My math instructor…**

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Gives overly complex or technical explanations.	○	○	○	○	○
Provides supplementary materials like handouts or worksheets.	○	○	○	○	○
Engages in small talk with the class.	○	○	○	○	○
Smirks or laughs at our questions.	○	○	○	○	○
Says the material is simple, easy, or obvious.	○	○	○	○	○
Seems annoyed, frustrated, or exasperated by our questions.	○	○	○	○	○
Blames us when we don’t understand something.	○	○	○	○	○

End of Block: IIB : Inclusive Instructor Behavior

Start of Block: Math Belonging

The following questions focus on your experience with math courses and in the math academic community. When we mention the math academic community, we are referring to the broad group of people involved in that field, including the students in a math course.

We would like you to consider your membership in the math community. By virtue of having taken many math courses, both in high school and/or at college, you could consider yourself a member of the mathematics community. Given this broad definition of belonging to the math community, please respond to the following statements based on how you feel about that group and your membership in it.

When I am in a math setting,

	strongly disagree	disagree	slightly disagree	slightly agree	agree	strongly agree
I feel that I belong to the math community.	○	○	○	○	○	○
I consider myself a member of the math world.	○	○	○	○	○	○
I feel like I am part of the math community.	○	○	○	○	○	○
I feel a connection with the math community.	○	○	○	○	○	○
I feel like an outsider.	○	○	○	○	○	○
I feel accepted.	○	○	○	○	○	○

When I am in a math setting,

	strongly disagree	disagree	slightly disagree	slightly agree	agree	strongly agree
I feel respected.	○	○	○	○	○	○
I feel disregarded.	○	○	○	○	○	○
I feel valued.	○	○	○	○	○	○
I feel neglected.	○	○	○	○	○	○
I feel appreciated.	○	○	○	○	○	○
I feel excluded.	○	○	○	○	○	○

When I am in a math setting,

	strongly disagree	disagree	slightly disagree	slightly agree	agree	strongly agree
I feel like I fit in.	○	○	○	○	○	○
I feel insignificant.	○	○	○	○	○	○
I feel at ease.	○	○	○	○	○	○
I feel anxious.	○	○	○	○	○	○
I feel comfortable.	○	○	○	○	○	○
I feel tense.	○	○	○	○	○	○

When I am in a math setting,

	strongly disagree	disagree	slightly disagree	slightly agree	agree	strongly agree
I feel nervous.	○	○	○	○	○	○
I feel content.	○	○	○	○	○	○
I feel calm.	○	○	○	○	○	○
I feel inadequate.	○	○	○	○	○	○
I wish I could fade into the background and not be noticed.	○	○	○	○	○	○
I try to say as little as possible.	○	○	○	○	○	○

When I am in a math setting,

	strongly disagree	disagree	slightly disagree	slightly agree	agree	strongly agree
I enjoy being an active participant.	○	○	○	○	○	○
If you are seeing this item please answer with "agree".	○	○	○	○	○	○
I wish I were invisible.	○	○	○	○	○	○
I trust the testing materials to be unbiased.	○	○	○	○	○	○
I have trust that I do not have to constantly prove myself.	○	○	○	○	○	○
I trust my instructors to be committed to helping me learn.	○	○	○	○	○	○
Even when I do poorly, I trust my instructors to have faith in my potential.	○	○	○	○	○	○

End of Block: Math Belonging

Start of Block: DEI

What programs or clubs (if any) are you aware of designed to support diversity, equity, or inclusion in Science Technology Engineering and Mathematics (STEM) at SDSU?

____

____

____

____

____

X→ X→

Did you participate in any of these programs?

○ Yes

○ No

Please explain your answer above.

____

____

____

____

____

To what extent do you agree that the diversity of students in math classes improves the experiences and interactions within the course?

- ◯ Strongly agree
- ◯ Somewhat agree
- ◯ Neither agree nor disagree
- ◯ Somewhat disagree
- ◯ Strongly disagree

In your opinion, in what ways does the diversity of students improve the experiences and interactions within the course?

____

____

____

____

____

In your opinion, why does the diversity of students in the course **not improve** the experiences and interactions within the course?

____

____

____

____

____

End of Block: DEI

Start of Block: STEM Role Models

In your math breakout section (the recitation course with your TA), did you see the presentation on Sea Turtles (or Soft Robotics) ?

◯ Yes

◯ No

How interesting did you find that presentation? Please explain why.

____

To what degree did the presentation encourage you to think about how you may use math? Please explain.

____

End of Block: STEM Role Models

Start of Block: Demographics+Extra

The following demographic questions are intended to help us better understand the variety of student experiences at ${e://Field/Site}. For more about why we ask these questions, click here.

(Select all that apply) Do you consider yourself to be:

☐ Man

☐ Transgender

☐ Woman

☐ Not listed (please specify): ____

☐ ⨂Prefer not to disclose

(Select all that apply) Do you consider yourself to be:

- ☐ Alaskan Native or Native American
- ☐ Black or African American
- ☐ Central Asian
- ☐ East Asian
- ☐ Hispanic or Latinx
- ☐ Middle Eastern or North African
- ☐ Native Hawaiian or Pacific Islander
- ☐ Southeast Asian
- ☐ South Asian
- ☐ White
- ☐ Not listed (please specify):

____

- [ ] ⊗ Prefer not to disclose

(Select all that apply) Do you consider yourself to be:

- [ ] Asexual
- [ ] Bisexual
- [ ] Gay
- [ ] Lesbian
- [ ] Queer
- [ ] Straight (Heterosexual)
- [ ] Not listed (please specify):

____

- [ ] ⊗ Prefer not to disclose

(Select all that apply) Do you consider yourself to be:

- ☐ International student
- ☐ First-generation college student (i.e., neither parent nor guardian completed a Bachelor's degree)
- ☐ Commuter student
- ☐ Transfer student
- ☐ Student with a disability
- ☐ Student athlete
- ☐ Current or former English language learner (i.e., English was not the primary language spoken in your childhood home)
- ☐ Parent or guardian (i.e., you take care of dependents)
- ☐ ⊗Prefer not to disclose

What is the nature of your disability? (e.g. what type of disability do you have, is it diagnosed or not, to what degree does your disability affect how you do or learn mathematics, etc.)

____

What is your experience with applying for or receiving accommodations and/or services through the SDSU Student Ability Success Center?

____

Did you use FAFSA (Free Application for Federal Student Aid) to apply for financial aid?

- ○ Yes
- ○ No
- ○ Prefer not to disclose

Did you receive a free grant (e.g., Pell Grant)?

- ◯ Yes
- ◯ No
- ◯ I don't know
- ◯ Prefer not to disclose

Approximately how many hours **per week** did you work at a job this term?

- ◯ 0
- ◯ 1-5
- ◯ 6-10
- ◯ 11-15
- ◯ 16-20
- ◯ 21-30
- ◯ More than 30
- ◯ Prefer not to disclose

What is your age, in years?

____

Page Break

For this next question, please reflect on your identity or who you are as a person. We know that there are many ways in which people identify themselves and learning about your individual experience can help us understand how to serve historically underserved populations.

Are there any aspects of your identity that have impacted your experience in mathematics at SDSU? Please explain.

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Page Break

What is your class standing?

○ First-Year

○ Sophomore

○ Junior

○ Senior

○ Other (please specify)

____

○ Prefer not to disclose

Have you declared, or do you intend to declare, a STEM (science, technology, engineering, or mathematics) major?

○ Yes

○ No

○ Unsure

○ Prefer not to disclose

Which major have you declared, or do you intend to declare?

____

Do you think your previous math courses adequately prepared you for ${Q3/ChoiceGroup/SelectedAnswers/1}?

○ Yes

○ No (please explain)

____

What grade do you expect to get in ${Q3/ChoiceGroup/SelectedAnswers/1} this term?

○ A, A+, or A-

○ B, B+, or B-

○ C, C+, or C-

○ D

○ F

○ Other (please clarify)

____

As of now, what math course (if any) do you plan to enroll in **next**?

- ◯ MATH 141: Precalculus
- ◯ MATH 150: Calculus I
- ◯ MATH 151: Calculus II
- ◯ MATH 252: Calculus III
- ◯ MATH 237: Elementary Differential Equations
- ◯ MATH 245: Discrete Mathematics
- ◯ MATH 254: Introduction to Linear Algebra
- ◯ MATH 302: Transition to Higher Mathematics
- ◯ MATH 303: History of Mathematics
- ◯ Other (please explain)

____

- ◯ I do not plan to enroll in another math course

Is there anything else you would like us to know about you or your experience in mathematics at SDSU?

____

____

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____

May we contact you in the future, to further understand your experience in mathematics at SDSU?

○ Yes, here is my contact email:

____

○ No, thank you.

Page Break

Thank you for completing our survey! If you would like to revisit any of your responses, please use the back button on this page. Submitting this page will finalize your responses and complete your submission. If you have any questions about the project or this survey, please contact Colin McGrane at cmcgrane@sdsu.edu

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