

REHUMANIZING COLLEGE MATHEMATICS: CENTERING
THE VOICES OF LATIN*, INDIGENOUS, LGBTQ+
AND WOMEN STEM MAJORS

by

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DEDICATION

To Ulysses Alejandro Ramirez, whom I miss dearly and wish he was here to witness my completion of this degree.

To Jackson MacArthur Stafford who holds the largest part of my heart and will do so forever.

To the interviewees and all students from marginalized groups who endeavor to complete a STEM major—we believe in you.

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ABSTRACT

Calculus sequences are frequently experienced as gatekeeper courses for STEM-intending students, particularly for students from groups that have been historically marginalized in mathematics including Latin*, Indigenous, LGBTQ+ and women. I report here on research findings that explored attitudes of Calculus 2 students broadly, as well as more specifically from the above-listed groups regarding what practices, pedagogies, and structures feel humanizing to them. I used a transformative mixed methods design, built on a sociopolitical framework, namely the rehumanizing framework outlined by Gutiérrez (2018) that includes eight dimensions. The goal of this research is to answer a call from Gutiérrez in elevating and understanding the perspectives of students who are often ill-served and thereby impact future undergraduate teaching in positive and humanizing ways.

The quantitative analysis of survey questions (n=153) showed that students generally find example scenarios that align with the eight rehumanizing dimensions to be humanizing, based on their ratings of feeling supported in their learning, feeling valued and a sense of belonging, and having connections between their mathematics class and their lives outside the classroom. From qualitative analysis of follow-up interviews with 20 students who self-identified as Latin*, Native American, LGBTQ+ and/or women, a student-driven definition of humanizing emerged. For these focal students, humanizing centers relationality and welcoming/caring/failure-tolerant classroom environment. Teaching actions that focal students described as humanizing were summed up as connections—connections to peers, teachers and to their lives outside the classroom. Blending the quantitative and qualitative analysis shed light on differences between dominant (white, heterosexual, cis-men) and focal group perceptions, especially regarding the Cultures & Theirstories rehumanizing dimension scenario. This was accompanied by cautions from focal students about how implementation of some scenarios matters in meeting a humanizing goal.

PROLOGUE–POSITIONALITY AND RELATIONALITY

There have been many calls over the last several years for researchers to reveal their positionality explicitly in all published works (e.g., Aguirre et al., 2017; Milner, 2007). This helps readers understand possible biases brought to the research and more importantly, the personal lens through which the researcher views the data. In addition to the general need for this positionality and relationality to be stated, the particular research in this dissertation uses a transformative design and liberatory theoretical framework. The intention is to center voices of students from groups who have historically been marginalized in mathematical spaces and to investigate how educators can create rehumanized mathematics courses for undergraduate STEM-intending majors. One compelling reason to rehumanize mathematics classes is to ensure that students can bring their whole selves¹ and participate authentically in their mathematical learning. In the spirit of the rehumanizing framework, it is important to also center the human being-ness of the researcher in regards to this research. Thus, I am providing a dissertation “wrapper” of sorts, with both this chapter and the epilogue (Chapter 7). The organization of the chapters in this way allows space for my positionality and relationality to be addressed in a more thorough way than one or two paragraphs that are typically devoted to a positionality statement embedded somewhere in the dissertation.

I start with some thoughts about me as a human being, which is not a style of writing typically done in a dissertation. However, I argue that it is relevant here due to the framework

¹ Gutiérrez (2018) suggests that “a student should be able to feel whole as a person--to draw upon all of their cultural and linguistic resources.” (p. 1) This concept is frequently referred to as bringing a student’s whole self to mathematics spaces.

used and the intention of the study. I aim to center the voices of students, with over 200 pages of this dissertation devoted to that goal. Simultaneously, I am also a human being and believe it is important for everyone involved in the teaching, researching and learning process to be presented as humans first and their roles second. It is also crucial to note that there is no way to extricate myself from being a human being while I have a researcher hat on. Thus, the next several paragraphs purposefully blend together my human being-ness with my researcher stance.

I prefer to be called Kelly and my pronouns are she/her/hers. I identify as a white, cis-gender, straight woman. Perhaps the most important-to-me aspect of my identity is as a mother, to a son who is now well into his adulthood. I am a first-generation college student and grew up knowing I wanted to go to college to study mathematics. I have a bachelor's degree in mathematics from Arizona State University (1987), a masters degree in mathematics from the University of Utah (1995), and another masters in statistics, with a probability emphasis, from the University of Utah (2020). Currently, I am a PhD candidate in mathematics education at Montana State University in the Mathematical Sciences department (intended graduation date of 2022). Mathematics and teaching at the collegiate level have been lifelong passions of mine and perhaps a narrow focus, which is common for an autistic person, like myself. I always wanted to attend college to study mathematics and never once considered changing my mind about that, regardless of push-back or confusion from others around me. I find great joy in the struggle and creativity necessary to do mathematics.

With that said, my journey to working in academia took a somewhat circuitous route. In between my bachelors and first graduate degree, I was an enlisted soldier in the U.S. Army where I trained and worked as a Persian Farsi linguist for a few years. I learned to be more disciplined, organized, collaborative and efficient during my years spent as a soldier. Attitudes

from that disciplined training also still show up as structured tendencies in my teaching and living. Between the Army and graduate school, I spent a few years as a stay-at-home mom to my son, where I learned endless new domestic skills and gratefully practiced empathy and kindness--characteristics still quite relevant to teaching and researching. It was in these years that I enthusiastically learned how to learn on my own, outside an academic setting. When I returned to school in fall of 1993, my intention was to seek a PhD in mathematics, but I resigned from that degree program, leaving with a masters degree, due to factors around becoming a single mother. I then spent eight years working as a software engineer for an international computer graphics company. My particular work there included overwhelmingly large, detailed and mathematically intense projects that suited my interests well and were quite fulfilling. While working as a software engineer, I also taught one or two classes per year as an adjunct instructor for the University of Utah (U of U) mathematics department because I had a passion for teaching. When my son started junior high school, I took a full-time teaching faculty job at the U of U where I spent almost two decades, serving in many teaching, advising, teacher mentoring and leadership roles.

Pursuing a PhD in education at a later stage of life than very young adulthood is not the most common route students take. According to National Science Foundation (NSF) data, the median age for women earning a doctorate is higher than men, although that age gap is closing over the last 50 years (NSF, 2017). One could conjecture that 50 years ago, women attended graduate school at much later ages due to their family responsibilities; this was certainly true for me. After resigning from my mathematics PhD program in the mid-1990s due to parenting priorities, I was excited to return to school to finally complete my PhD (while still working full-time) when my son started college. After a year or two of mathematics and education

graduate classes, I chose probability as my focus. At that time, my reason for pursuing a PhD was primarily to fulfill my own personal goals, and I had no intention of changing my job, i.e., I assumed I would remain a teaching faculty at the U of U until retirement. However, a personal trauma that caused cPTSD (complex post traumatic stress disorder) interrupted that degree-seeking process (after I had already passed all my written exams as well as my oral exam) and also changed me and my brain forever. The repercussions of living with cPTSD, which included a heightened desire to serve others in empathetic and inclusive ways, along with other changes within the U of U mathematics department and education college, led me to switch gears and pursue a PhD in undergraduate mathematics education, instead of mathematics. Eventually, my journey brought me to Montana State University (MSU) to complete such a PhD program.

As a cis-gender, heterosexual white person, I have not been the target of discrimination or oppression due to my race or sexual orientation. My race has allowed me to enjoy a sense of belonging in white, patriarchal mathematics spaces. However, my experience being a woman and first-generation student has caused me to recognize classist and sexist ways that I have been treated throughout my career, both in software and in academia. My autism affects how many social cues I pick up on, so it took some time to fully understand discriminatory practices and attitudes aimed toward me. This was perhaps exacerbated by the fact that I have always been considered “gifted²” in mathematics and able to out-perform many of my peers in academic mathematical settings. In my younger years, I happily benefited from the genius myth (e.g. Lamb, 2015) in mathematics and enjoyed the power that association gave me. It is only with

² I am not personally a fan of this word and still struggle to understand the humane-ness of such a binary view of seeing people. I prefer to disrupt the genius myth that exists in mathematics. I use this word here only to nod to the normative way folk around me categorized me.

more knowledge and awareness that I now realize how damaging that genius myth can be, both to people who are told they fit that mold and those who are told they do not.

I feel strongly and passionately about the research reported in this dissertation and in its potential to impact our teaching practices to better serve undergraduate students who have not historically been attended to in kind, inclusive ways. I am no longer content to only focus on work that I find individually rewarding. My own trauma and the trauma I have witnessed others dear to me go through have impacted me in ways that drive me to take up the call to rehumanize mathematics classrooms, embrace teaching with empathy, and hear from the voices of the too-often forgotten and ill-served. Additionally, my decades of experience teaching undergraduate calculus courses and mentoring mathematics PhD students in their own teaching make me well-situated for the research focus of this dissertation.

My own experiences and reflections of power dynamics, particularly present in academia, have led me to focus my research on elevating the voices of students and honoring their wisdom. I know personally how detrimental it is to have others speak for me or make assumptions about what people want without actually asking the people themselves. I believe it is imperative that we check with people about what they want, listen attentively and seek to create structures and systems that authentically serve those we are intending to serve. Indeed transformative justice is about healing, restoring right relations with students and building trust, and my goal is to center students' well-being as opposed to being extractive. This is my personal lens and commitment that I bring to this research, impacting all my research decisions, including my research questions, theoretical framework, methodological design and interpretive lens.

As part of my relationality with others, I have close-to-my-heart relationships that have also influenced the way I view the world, my teaching and research. I have witnessed first-hand

the traumas and oppression caused by society for trans folx and for people of color. This has caused me to critically reflect about how my being white and cis-gender have privileged me in previously invisible-to-me ways. This reflexivity and empathy allows me to believe what students tell me about their own academic experiences of oppression and to listen intently about what would make it better for them.

To conclude, it could be helpful to point out known biases that may impact the data analysis and findings of this research. My decades long experience teaching calculus and mentoring other teachers may impact my understanding and views of student reports regarding their experiences with mathematics instructors and courses. I was cognizant of this during the research reported on here and I maintained an observer-researcher role rather than the role of teacher or mentor of teachers. Additionally, I have a particularly positive bias toward students who have experienced marginalization, years of microaggressions, anxiety or trauma due to their treatment by others, as explained above, and this likely helped me as a researcher to relate to the participants of this study.

CHAPTER ONE

INTRODUCTION

Background for this Study

In mathematics education, a historical myth that mathematics is a “pure” subject devoid of biases, politics, culture or inequities has been shattered by several scholars (Battey & Leyva, 2016; Gutiérrez, 2018; Martin et al., 2010; Martin, 2019; Nasir et al., 2008). This long-held myth is further challenged in Su’s (2020) book *Mathematics for Human Flourishing* as he compellingly highlights how mathematics can be used to develop several virtues and help human beings flourish. Indeed, feeling fulfilled, joyful or creative about mathematics or building a sense of community within mathematics necessarily acknowledges the bringing in of human emotion into the doing of mathematics, which is a recognition of the natural blending of mathematical experiences with experiences in being human. In fact, as mathematicians and mathematics educators, we explicitly endeavor to provide opportunities for students to experience this joy for themselves. It can be argued then that the heart of mathematics and the mathematics teaching profession is not the sterile nature of mathematics. Instead, the heart of teaching mathematics is the potential for fulfillment, joy, creativity and community rapport.

Ultimately, this study is designed to add to the body of research intended to chip away at this age-old idea of the sterility of mathematics as something separate from our human being-ness, and to answer the many calls made by various scholars to use a sociopolitical lens when doing mathematics education research (Adiredja & Andrews-Larson, 2017; Aguirre, et al., 2017; Gutiérrez, 2013). Students should not be expected to leave their identities, their

human-ness, at the door to simply follow algorithmic rules of mathematics as automatons. On the contrary, students should be encouraged to bring their full selves into mathematics classes in order to more fully experience mathematics in ways that are meaningful to them.

The research reported here addresses the issue of human being-ness in collegiate mathematics. The focal student group for this study is those taking Calculus 2, because typically only students intending to major in science, engineering, technology or mathematics (STEM) enroll in Calculus 2. Indeed, Calculus 2 is not required nor often recommended for students in non-science oriented fields. Calculus 2 classes can be used or taught or experienced in ways that students feel create a barrier, i.e., gatekeeper, or a pathway, i.e., gateway, into their chosen major (Anderson & Burdman, 2022; Bressoud et al., 2015). This is due to the fact that for a lot of STEM degrees, students are not allowed to fully declare or be considered as full major status until they have successfully completed Calculus 1 and 2. Therefore, these courses are incredibly important to study with the goals of continuously making improvements to teaching and learning within such classes.

This research aims to center the voices of students from historically marginalized groups within collegiate mathematics in order to better understand their experiences and what they might imagine would create better learning environments where students may bring their whole selves³. The goal is to contribute research that illuminates ways of teaching that feels humanizing, particularly for students who have often been left out but desire to belong in the world of mathematics and other STEM majors that require foundational mathematics courses.

³ Gutiérrez (2018) suggests that “a student should be able to feel whole as a person--to draw upon all of their cultural and linguistic resources.” (p. 1) This concept is frequently referred to as bringing a student’s whole self to mathematics spaces.

Research Problem & Purpose of Study

This study is in response to many calls, from both mathematics education researchers and mathematicians, for making mathematics humane for students in ways that help them flourish (Gutiérrez, 2018; Su, 2020). Perhaps more importantly, this research seeks to center the voices of students from groups who have been historically marginalized in mathematics for far too long (e.g. Gutiérrez, 2018; Marker & Hardman, 2020; Martin, 2012; Sterenberg, 2013). It is a fool's errand to theorize about what is experienced as humanizing for groups of students without explicitly checking in with at least some of them and reporting on what they say about their own experiences.

Research has shown the need for colleges to graduate more STEM majors, including those from diverse backgrounds, but not enough students from historically marginalized groups actually persist in their desire to complete a STEM degree (PCAST, 2012). From a capitalistic or economic view, one could persuasively argue that workers with diverse backgrounds are needed in STEM fields in order to be competitive internationally (NASEM, 2019; PCAST, 2012). Perhaps more compellingly and ethically, one could argue that for whatever reason students wish to pursue STEM degrees, be it financial gain, joy and curiosity, or a deeper moral purpose, it should be the goal of educators to ensure that students with the desire to learn are taught in ways that maximize their likelihood for success and provide positive learning environments for doing so (Goffney et al., 2021). In other words, it is imperative and a duty to society to teach undergraduate calculus as gateway courses into STEM, rather than using calculus to be a gatekeeper. Gutiérrez's rehumanizing mathematics framework (2018) is one framework that can be used to potentially optimize the chances for students from historically marginalized groups in

mathematics, with diverse backgrounds, to persist in their STEM majors. This transformative study applies that framework to investigate ways that students themselves view or imagine undergraduate mathematics courses as humanizing. The findings have the potential to positively impact the teaching of undergraduate mathematics courses.

Contextual Grounding

This section presents an overview of important background features and the rehumanizing framework that underpins and informs this research. More details will be provided in Chapter 2 to flesh out nuances and to summarize research results to date.

College Calculus

For STEM majors, calculus courses serve as either gateway (i.e., pathway) or gatekeeper (i.e., barrier) courses depending on how the courses are taught and administered (Bressoud et al., 2015; Rasmussen & Ellis, 2013). Thus, the quality of undergraduate calculus teaching is important; however, students from diverse backgrounds have reported that poor quality of calculus teaching affects their desire to persist in completing a STEM degree (PCAST, 2012). The Progress through Calculus national research project further showed that, nationally, women in calculus 1 classes were proportionally underrepresented, while men were proportionally overrepresented (Bressoud et al., 2015), white students outnumbered Black, Latin* and Indigenous students, both in absolute numbers and as proportional representation (Bressoud et al., 2015) and women were more likely than men to leave their STEM majors after Calculus 1 (Ellis et al., 2016). Additionally, the chapter about calculus in the *The Compendium for Research in Mathematics Education* (Larsen et al., 2017) makes an explicit call for further research about

“what is happening in calculus classrooms” (p. 546). Scholars agree that more work needs to be done to address equity concerns for calculus students, especially those from historically marginalized groups within mathematics. This research study takes up these calls to produce knowledge about student perspectives of positive learning experiences in their college calculus courses.

The Racialized and Gendered Nature of Mathematics

Several researchers have studied how mathematics is a racialized and gendered space, namely one dominated by white, patriarchal norms, practices and policies (e.g., Battey & Leyva, 2016; Martin 2009, 2013). Rather than being a neutral, objective discipline free from issues of race, gender or culture, researchers have argued that mathematics is experienced by students as culture-heavy and oppressive in racialized and gendered ways (Battey & Leyva, 2016; Gutiérrez, 2009; Martin et al., 2010; Martin, 2019; Nasir et al., 2008). Some scholars have followed up with specific examples that showcase how students from historically marginalized groups experience mathematics spaces as racialized and gendered (e.g. Leyva et al., 2021; Voigt, 2020). Students experience such spaces as oppressive in ways that negatively impact their opportunities to learn (Aguirre et al., 2017; Martin, 2012). These findings shed light on the need for research that elevates the voices of students from historically marginalized groups within mathematics in order to move toward dismantling the racialized and gendered discourse in mathematics (e.g., Ladson-Billings, 2006; Leyva et al., 2021; Martin, 2019; Stinson, 2013).

The Call for a Sociopolitical Turn in Mathematics Education

Due to the oppressive way that some students experience mathematics, several mathematics education researchers have pushed for a sociopolitical turn in mathematics

education, both in teaching and in research (e.g., Adiredja & Andrews-Larson, 2017; Aguirre et al., 2017; Gutiérrez, 2013). Sociopolitical theory is built on the foundation of sociocultural theory and views learning environments as being influenced by social, cultural, power and identity norms or contexts (Aguirre et al., 2017). Sociopolitical turns in mathematics education provide theoretical foundations to use for teaching and research, with a goal of improving equity and liberatory justice within mathematics classes. Scholars argue that focusing mathematics education research primarily on mathematics content or on “gap gazing⁴” (Gutiérrez, 2008) does not produce equitable results for students, and in fact may contribute to negative stereotypes and stereotype-threat (Gutiérrez, 2008; Martin et al., 2010; Stinson, 2013) . They go further to recommend that all mathematics education research include elements or attention to equity issues, again with a goal to ensure that students are being well-served, particularly those from groups that have been institutionally or historically marginalized in mathematics spaces. Thus, a sociopolitical turn in mathematics education research would address equity-related concerns in mathematics instructional practices and allow “us to see the historical legacy of mathematics as a tool of oppression as well as a product of our humanity” (Aguirre et al., 2017, p. 125). The specific framework guiding this research study is developed from a sociopolitical worldview that elevates the perspectives of students from historically marginalized groups within mathematics.

⁴ Gap gazing is the act of recognizing and documenting academic achievement gaps between white students and Black, Latin*, Indigenous students or other students from historically marginalized groups. This can cause harm to already vulnerable students because it promotes deficit thinking, increases the likelihood of stereotype threat, and tends to focus on “fixing” individual students rather than addressing the systemic issues. Additionally, it promotes a narrow idea of what equity is.

Rehumanizing Mathematics

Gutiérrez (2018) offers one possible answer to the call for a sociopolitical turn in mathematics education by contributing a framework for instructional practices. She states a need for mathematics teachers and researchers to *rehumanize* mathematics, which includes putting the person back into mathematics⁵. Additional moves that could be considered rehumanizing include changing up the traditional authority and power structures within the classroom and expanding our notions of what it means to do mathematics. For educators and researchers who want to heed this call, Gutiérrez suggests eight possible domains of attention that constitute a framework for ways in which we can rehumanize mathematics. These include “(1) participation/positioning, (2) cultures/theirstories, (3) windows/mirrors, (4) living practice/futures, (5) broadening mathematics, (6) creation, (7) body/emotions and (8) ownership” (p. 4). To do this work authentically, she calls on researchers and educators to gather “evidence from those for whom we seek to rehumanize our practices that, in fact, the practices are felt in that way” (p. 3-4). Thus, we need to collect information from the students themselves about what is experienced or imagined as rehumanizing for them. In particular, data should be collected from students from historically marginalized groups in mathematics, including Black, Latin*, Indigenous, LGBTQ+ and women students. This research study aims to contribute precisely to this endeavor.

⁵ It should be stated explicitly that Gutiérrez (2018) views this framework as distinct from the rehumanistic movement in mathematics from the 1990s. “Although these two perspectives share the goals of solving problems in society, understanding properties of objects in the world, and posing new questions, rehumanizing mathematics also squarely addresses the politics of mathematics and mathematics education.” (p. 4).

Guiding Research Questions

These research questions are posed to center student voices and add to the research base for understanding rehumanized mathematics and how it is experienced or imagined by undergraduate students who are intending to major in STEM-related fields. The overriding research question aims to capture the voices of many students and subsequent parts of that question are meant to iteratively move toward compiling data from students from groups for whom the system has previously failed.

What classroom structures, practices and pedagogies do undergraduate Calculus 2 students perceive as rehumanizing in their college mathematics classes?

- a. In particular, what are the perceptions of students from historically marginalized groups (in STEM) from various races, ethnicities, LGBTQ+ statuses, and/or genders? And how do these perceptions compare to overall perceptions?
- b. In what ways does examining student perceptions contribute to the existing rehumanizing framework?

Significance of Study

This study seeks to contribute to building a research base for the rehumanizing mathematics concept, study how the concept of rehumanizing is operationalized for students in college Calculus 2 courses and reify the concept of rehumanizing by applying a theoretical framework in a real-world setting. Although there has been a framework set out (Gutiérrez, 2018) that includes suggestions of ways to rehumanize mathematics classrooms for mathematics students, to date there has not been much research reporting student experiences directly

regarding their ideas of what is and is not rehumanizing in the classroom. The rehumanizing framework includes eight potential dimensions, and this research will provide an opportunity to investigate what dimensions are most salient to a group of undergraduate students and in what ways. Additionally, this research will help fill a gap in the research literature regarding what concrete steps could be done in the undergraduate mathematics classrooms to move toward a rehumanization goal, which could have a direct and immediate impact in praxis.

Roadmap of this Dissertation

Chapter 2: Literature Review and Theoretical Framework situates this study within relevant research literature and explains the framework that guides the study. First a research-based description of equity is provided. This is followed by a review of college calculus research, including what is missing from that body of literature. This segues into a section about how mathematics is a racialized and gendered space. Next, a summary of the calls for a sociopolitical turn in mathematics is provided which then lays the foundation for the rehumanizing framework that is used to guide this research. Finally, a thorough description of the rehumanizing mathematics framework is provided.

Chapter 3: Methods catalogs the methods that were employed for this research project. The research questions were investigated using a transformative mixed methods approach. In other words, data was collected and analyzed sequentially to add layers of nuanced data and designed and implemented all within a transformative lens. First, all Calculus 2 students from two institutions were invited to participate in a survey and a portion of those students filled out the survey. Next, interviews of 20 students from groups that have historically been marginalized

in mathematics were conducted. Details of the research planning, data collection and data analysis process and decisions are explicated in this chapter.

Chapter 4: Quantitative Findings begins with student descriptions, providing information about all the students who filled out the survey. This demographic information is displayed graphically. This is followed by histograms that compare the distribution of answers to each Likert question from the survey for two groups, namely the dominant and focal groups. The dominant group responses came from students who identify as white, cis, heterosexual men and the focal group responses came from students who identify as Native American, Latin*, LGBTQ+, and/or women. The differences between the two groups' responses is considered by using chi squared tests as well as classification trees.

Chapter 5: Qualitative Findings first describes the 20 interviewees in detail. Next, the findings from the interviews regarding how students define humanizing along with teaching practices they find humanizing are presented. Results from the interview discussions that give more nuanced information directly about the eight rehumanizing dimensions are given next. Blending of the quantitatively significant differences between the focal and dominant groups are built upon with explanations from analysis of the qualitative data. This chapter is concluded with the findings from the open-ended questions on the survey.

Chapter 6: Discussion and Conclusion starts with a summary of the findings that address the research questions. Theoretical contributions are also discussed to address the last research question. Implications for teachers and for future research, as well as significance and limitations of this study are explored. I next provide a researcher's reflection, followed by my final thoughts.

Glossary of Terms

Cisgender/cis--Cis is short for cisgender and indicates that the person the word describes identifies as the same gender as the gender presumed at birth.

Folx--This term is used to specifically disrupt the overly gendered use of our colloquial language that frequently seeps into our written and verbal language. It is intended to be an inclusive term and shorter than saying “all human beings.”

Latin*--As Leyva (2021) points out, Latin* is intended to be an inclusive term for all people or all genders who identify as in the “Latin American diaspora and origin” (Salinas, 2020).

STEM--This is an acronym that stands for Science, Technology, Engineering and Mathematics.

PWI--This is an acronym for Predominantly White Institutions, meaning a college whose student enrollment is more than 50% white students.

Dehumanizing--Gutiérrez (2018) gives several examples about what can be considered as dehumanizing to students. She points out that “schooling often creates structures, policies, and rituals that can convince people they are no longer mathematical” (p. 2) are often felt as dehumanizing. Other practices that can feel dehumanizing include tracking, “evaluation that does not honor complexity,” “being asked to leave one’s identity at the door (e.g., color-blind teaching, strict pacing guides,...),” valuing speed over reflection and “separation of mathematical practices from politics/values/ethics” (p. 3). Moreover, students being treated as if they are “interchangeable with others--with little or no attention to their identities” (p. 3) is felt as dehumanizing.

Rehumanizing--Here, several quotes from Gutiérrez (2018) are given to build up possible ideas of what might be considered rehumanizing. However, this “definition” should be considered as a

partial definition since evidence and input from students is needed here to fully define this term, which is indeed one goal of this research. Educators and researchers endeavoring to “stand in the shoes of our students, to understand their conceptions” will lead toward “recognizing and embracing [students’] humanity” (p. 2). This is one way to move toward rehumanization of mathematics, but rehumanizing “reflects an ongoing process and requires constant vigilance to maintain and to evolve with contexts” (p.3). This suggests that there is actually no closed form definition of rehumanizing; rather it is a goal to constantly be striving for and collecting evidence for because it “is an ongoing performance” (p. 3). Rehumanizing mathematics “seeks to not only decouple mathematics from wealth, domination, and compliance (O’Neil, 2016); it also couples it with connection, joy, and belonging” (p. 4). Most importantly, the foundation of rehumanizing work “begins with the power of communities and assumes a relational view...so that we might better understand and live alongside of one another and so that we might practice mathematics in ways that transform reality in emancipatory ways (Gerdes, 1985).” (p. 4).

The eight dimensions that comprise the rehumanizing framework are (1) Participation & Positioning, (2) Cultures & Theirstories, (3) Windows & Mirrors, (4) Living Practices & Futures, (5) Broadening Mathematics, (6) Creation, (7) Body & Emotions, and (8) Ownership.

CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Introduction

In this chapter, I have summarized research from key areas that will help frame this study. I first set the stage by establishing some sense of how mathematics education researchers have been defining and using the word “equity,” because the idea of equity is the springboard or precursor for the rehumanizing framework that is used for this study (as briefly described in chapter 1 and fleshed out in more detail below). I next consider research that investigates and reports on college calculus, because that is where this study and its participants are solidly situated and because college calculus historically serves as a gateway (or sometimes a gatekeeper)⁶ to all STEM majors. This leads to research that outlines how mathematics courses are in fact not neutral spaces and instead are racialized and gendered spaces within which students function. Finally, I segue to a summary of calls for a sociopolitical turn in mathematics education research, which is where the rehumanizing literature and framework is explained in detail.

⁶ The use of gateway vs. gatekeeper here is intended to signify that calculus is a foundational and required mathematics course for all STEM majors. As such, it can either be used or implemented in ways that serve as a barrier, i.e., gatekeeper, or as an access or entry, i.e., gateway, to a student’s intended major.

As early as the 1980s, there have been fairly consistent calls for equity in mathematics education (e.g. Atwood & Doherty, 1984), both in teaching and in research. These calls have focused particularly on groups who have been marginalized in systemic and institutionalized ways including Latin*, Indigenous, Black, LGBTQ+ and women students (e.g., Atwood & Doherty, 1984; Gutiérrez, 2012; National Council of Supervisors of Mathematics (NCSM) and TODOS: Mathematics for ALL, 2016; National Council of Teachers of Mathematics, 2014; Voigt, 2020). This begs the question, however, of what does equity mean? The word “equity” has more frequent and widespread use nowadays than four decades ago, but the definition is still fuzzy and its focus has admittedly evolved over time. In this short section, the aim is to provide a literature-based definition of equity as it relates to mathematics courses that will be used as a contextual background for the entire chapter.

An important point to start this discussion about equity is that equality and equity are distinct terms, with equality about sameness and equity about fairness (Gutiérrez, 2012). In other words, offering the same lesson to all students could be considered equal, but not necessarily fair or equitable given students’ differentiated learning needs. Teaching with an equity lens, then, would involve offering what is needed for each student to successfully learn, which might represent varying levels of support for different students. Another way to view this is that students need equal access to high quality math instruction, but high quality math instruction would not treat every student the same in the mathematics classroom.

By and large, organizations, researchers and educators have used equity to refer to equal access and achievement (e.g., Gutiérrez, 2012; NCSM and TODOS: Mathematics for ALL,

2016; NCTM, 2014), usually referencing traditional measures of achievement in the form of grades or standardized exam scores. The National Council of Teachers of Mathematics (NCTM), for example, has a public equity and access statement, stating that students should have access to “high-quality mathematics instruction, learn challenging mathematics content, and receive the support necessary to be successful” and that “all students attain mathematics proficiency” (NCTM, 2014). In this statement, their focus is on access and achievement as the main tenets of equitable mathematics education for students.

Likewise, the TODOS: Mathematics for All organization includes equity as a key ingredient in their mission statement: “Mathematics for ALL is to advocate for equity and high quality mathematics education for all students— in particular, Latina/o students” (NCSM and TODOS: Mathematics for ALL, 2016). Although they do not go in more depth about how they are defining equity, their website and materials do reference access and achievement ideas, as well as social justice goals.

In one chapter of a book published by the Charles A. Dana Center at the University of Texas at Austin (2019), Marshall & Leahy looked at many artifacts of published works to pin down a more comprehensive definition of equity in the context of mathematics teaching. They outlined four perspectives of equity, including (a) access, (b) outcomes, (c) diversity and inclusion, and (d) social justice. *Access* is defined as stated above, namely that all students, particularly students who have previously been underserved by educational institutions, have access to high quality teaching and learning environments. *Outcomes* points to the goal that all students, again particularly those who have been historically marginalized, “should be supported to meet or surpass academic achievement and attainment objectives, including college readiness and completion” (p. 138). The *diversity and inclusion* perspective has a goal of having

proportional representation of students, especially students from groups who have been marginalized and ill-served by mathematics institutions. Furthermore, the goal promotes authentic engagement so students can “advance in academic and professional pipelines, especially those of high value” (p. 139). Finally, the *social justice* perspective of equity desires all students to learn in environments that are “just” and “sustainable” (p. 140) and for students to learn problem solving skills that are used to address social issues.

Marshall & Leahy (2019) call for teachers, institutions and policy makers to consider how we can measure equity in mathematics spaces. Most “currently available reports tend to focus on access and attainment” (p. 141). Although important, such data is incomplete in describing progress being made with regard to equity goals. Thus, these scholars give an example of a superset of five possible equity dimensions that could lend themselves to areas for quantifiable measurement, namely “access, attainment, advancement, authentic engagement, and empowerment” (p. 141). They further call institutions and administrators to identify valid and reliable tools to measure these dimensions, as this data and analysis will allow the community to more accurately evaluate the progress of various pathways toward equity goals.

The five example equity dimensions listed above (Marshall & Leahy, 2019) were provided without definition as possibilities for future researchers, teachers and administrators to explore, expand on and measure. Gutiérrez (2009) offers a similar view of dimensions of equity that have been better defined. She outlines two independent axes of equity, namely one critical axis and one dominant axis. The dominant axis of equity contains access and achievement and the critical axis contains identity and power. Gutiérrez colloquially refers to these axes as “playing the game” (dominant axis) and “changing the game” (critical axis) (p. 5), and she states that all four of these equity dimensions must be attended to for true equity. Building on this

framework, the most recent MAA Instructional Practices Guide (Abell et al., 2018) provides succinct definitions of the four dimensions as follows.

- *Access*: This refers to the ability to gain intellectual and physical access to mathematical ideas and mathematical teaching and learning spaces (e.g., classrooms, tutoring centers, office hours, and informal interactions).
- *Achievement*: This refers to students' success in mathematics as traditionally measured (e.g., performing well on homework and exams, succeeding in courses, and majoring in fields requiring mathematical knowledge).
- *Identity*: This refers to who our students are, including the resources and ways of knowing they bring to the learning environment, and to who they become through their participation in mathematics.
- *Power*: This refers to attending to the distribution of power between instructor and student, between students, and between students and mathematics (e.g., constructor of knowledge versus passive receiver of knowledge, mathematics as an empowering force versus mathematics as a barrier). (Abell et al., 2018, p. 93)

Conducting research with an equity lens is foundational for this research project. The above-described view of equity provides the foundation for all the findings reported in this chapter, and it is the underpinning of the theoretical framework, namely rehumanizing mathematics, used to analyze and answer the posed research questions.

College Calculus

Keeping the established notion of equity in mind, I use this section to discuss research on college calculus. Calculus is important to this research study because it serves as either a sequence of gateway or gatekeeper courses, depending on how the courses are taught and administered. Indeed calculus sequences⁷ are *the* primary mathematics courses leading into all STEM majors. A new report from Just Equations and the California Education Learning Lab

⁷ Calculus here is referring to the sequence of calculus courses that STEM-intending majors take in college, which typically includes two or three courses.

notes how this gatekeeping characteristic of calculus disproportionately impacts students from marginalized groups.

Calculus' reputation as a weed-out course is well deserved (Chen, 2013; Leyva, McNeill et al., 2021), as it is a key reason that women and students from minoritized backgrounds represent 70 percent of college students but only 45 percent of students earning STEM degrees (Gates et al., 2012).” (Burdman et al., 2021, p. 4)

Thus, the quality of calculus teaching in colleges is important (Gasiewski et al., 2012). Indeed, the large-scale study by Gasiewski et al. (2012) found characteristics of instructors to be profound on student engagement and success. They went so far as to describe a composite of what a “gatekeeper professor” (p. 252) does vs. what an “engaged professor” (p. 253) does in their teaching to distinguish between pedagogies and supports that discourage vs. encourage engagement and persistence for STEM majors.

The President’s Council of Advisors on Science and Technology (PCAST) report projected that there is a great need to graduate more STEM majors from colleges and universities (PCAST, 2012). However, they found that fewer than 40% of students who originally expressed interest and intent to major in a STEM field actually persisted through graduation with their STEM degree, which is backed up by previous studies (e.g. Kokkelenberg & Sinha, 2010). Further, the report listed poor quality and uninspiring teaching of calculus, in ways that made it feel like rote or merely algorithmic learning to the students, as one reason students were leaving their STEM majors. Students in such situations form conclusions that mathematics and STEM disciplines are “dull and unimaginative” (PCAST, 2012, p. 28). These findings were in line with previous reporting from Seymour (2006), where exit interviews were conducted both for students who switched out of a STEM major and for graduating seniors who stayed in their STEM major.

She found that the most common complaints from students who left STEM majors regarded poor instruction in their science and mathematics courses, with calculus often cited.

The foundational importance of college calculus motivated a large-scale nationwide calculus study undertaken by the National Science Foundation (NSF) and the Mathematical Association of America (MAA) a little more than a decade ago, called Progress through Calculus. The research group for that study collected data from a nationally representative sample, including Hispanic serving institutions, historically Black colleges and universities, community colleges, research universities, liberal arts colleges and private universities. Thus, their findings are reflective of all undergraduate students in calculus. From that vast body of work, it is known that, nationally, men disproportionately outnumber women in Calculus 1 classes (Bressoud et al., 2015) and Black, Latin* and Indigenous students are vastly outnumbered by white students, both in absolute numbers and by proportional representation (Bressoud et al., 2015). Furthermore, women are more likely than men to leave their STEM majors after calculus 1 (Ellis et al., 2016). Seven characteristics of successful college calculus teaching were also identified that can be implemented by mathematics departments to improve their teaching and in turn positively impact student success in calculus (Bressoud & Rasmussen, 2015). The seven characteristics are (1) regular use of local data to guide curricular and structural modifications, (2) attention to the effectiveness of placement procedures, (3) coordination of instruction, including the building of communities of practice, (4) construction of challenging and engaging courses, (5) use of student-centered pedagogies and active-learning strategies, (6) effective training of graduate teaching assistants, and (7) proactive student support services, including the fostering of student academic and social integration.

A second round of research has been conducted for the Progress through Calculus study for which the results are only now being published and will provide more nuanced information about how these seven characteristics of successful college calculus programs can be utilized to move the needle toward converting calculus from a gatekeeper to a gateway course, meaning students' success and persistence in their STEM major is improved in these courses. Hagman (2021) has extended this work by adding an eighth characteristic for successful college calculus, namely a focus on equity, diversity and inclusivity. In her paper, Hagman points out that upon further analysis of the data, it appears that the departments from the original study that were considered successful in terms of their teaching and student achievements in calculus were primarily successful in serving mostly white or Asian students who are men. So even with a representative sample of students across different types of universities, "successful" programs were under-serving certain groups of students. In other words, the success was not as equally shared among historically marginalized groups, implying that colleges have much room for improvement in serving students from these populations. She concludes that there is indeed a missing characteristic from the seven characteristics highlighted by Bressoud and Rasmussen (2015). This EDI (equity, diversity and inclusivity) characteristic was only uncovered by attending to what was missing from the data on successful calculus programs, rather than what was consistent across all successful programs.

Although the chapter about calculus in *The Compendium for Research in Mathematics Education* (Larsen et al., 2017) primarily focuses on summarizing calculus research regarding limit, derivative and integral, they augment their summary with an explicit call for further research related to this dissertation study. Specifically, the authors stated a serious need for innovative teaching practices to be collaboratively paired with research, and they acknowledged

the lack of research studies that focus on “what is happening in calculus classrooms” (Larsen et al., 2017, p. 546). Larsen and colleagues further noted the absence of studies in the college calculus arena that prioritize equity issues. Their call for such research urges the mathematics education community to build a research base of evidence-based instructional practices, with an eye toward equity, that can then be expanded with other future research.

Building on this call for researchers and practitioners to collaborate in studying and implementing college calculus instructional strategies, two books of case studies have recently been or are in the process of being published. First, the MAA is publishing a special *Notes* volume, i.e., book, containing many illustrative case studies that represent innovative practices happening in college calculus courses across the United States (Voigt et al., in press). The case studies showcase course structure, assessment practices and institutional changes that are being made to support student learning and move toward addressing equity and inclusion concerns. Second, a large national study was taken up in the Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL) project (Smith et al., 2021). The purpose of their research was to “stimulate and better understand how to enact and support institutional change aimed at implementing active learning in undergraduate mathematics learning environments, focusing in particular on large-enrollment entry courses: precalculus to calculus 2 (P2C2).” (Smith et al., 2017, p. 121). Their findings included student perceptions of active learning stating that students felt more engaged, had deeper understanding of the content, and enjoyed collaborating with peers. These positive benefits were somewhat dependent on instructor-student relationships, i.e., students wanted to know the teacher cared about their learning and success in the course.

College calculus is pivotal for STEM majors and the subject of extensive research. However, more work needs to be done to address equity concerns for calculus students, especially those from historically marginalized groups within mathematics. Several researchers have begun to address this need in their work examining how mathematics is a racialized and gendered space, which is the topic of the next section.

Racialized and Gendered Nature of Mathematics

Mathematics has long been viewed by both mathematicians and non-mathematicians as a neutral, objective discipline, free from issues of race, gender or culture, but several scholars have disputed this view (Battey & Leyva, 2016; Gutiérrez, 2009; Martin et al., 2010; Martin, 2019; Nasir et al., 2008) and noted specific ways that students from historically marginalized groups experience mathematics spaces as racialized and gendered (e.g. Leyva et al., 2021; Voigt, 2020). In this section, I summarize some of the research documenting how mathematics and mathematics classes are framed as white, patriarchal⁸ spaces.

Racialized Nature of Mathematics

Students' academic and racial identities are commingled. Thus, there is no way to separate race from a conversation about what happens in academic settings, including mathematics classes. In their paper "A Framework for Understanding Whiteness in Mathematics Education," Battey and Leyva (2016) disrupt the notion that mathematics is a racially neutral space by stating that "racial ideologies, however, shape the expectations, interactions, and kinds of mathematics that students experience" (p. 49). They further identify three dimensions of white

⁸ Patriarchal here refers to the systemic way that mathematics has been dominated and run mostly by men for centuries.

institutional space, namely, (1) institutional, (2) labor and (3) identity. These dimensions taken together serve to document (a) how whiteness oppresses students of color and (b) how “whiteness impacts White students to reproduce racial privilege” (p. 49).

Battey and Leyva (2016) pull from several articles by Martin (2009, 2013) to form the basis for their *institutional* dimension. Martin’s perspective of mathematics education as “white institutional space” (Martin, 2013, p. 323) is based on four tenets:

(a) Numerical domination by Whites [meaning there are more white people than people of color] and the exclusion of people of color from positions of power in institutional contexts, (b) the development of a White frame that organizes the logic of the institution or discipline, (c) the historical construction of curricular models based upon the thinking of White elites, and (d) the assertion of knowledge production as neutral and impartial, unconnected to power relations (Martin, 2013, p. 323).

The combination of these four tenets is the foundation for describing institutionalized ways that whiteness impacts mathematics spaces.

The next dimension of *labor* focuses on the ways that students of color are required to exert more energy in “regulating dissatisfaction, frustration and anger due to being subjected to deficit views, racial slights, and forced compliance” (Battey & Leyva, 2016, p. 61). Battey and Leyva further elaborate that deficit views of historically marginalized students of color have negative impacts on test scores, achievement, collaboration and persistence. In this way, whiteness serves as a “dividing line” (p. 61) between students who do and do not have the extra burden of emotional and relational labor in mathematics classes (e.g., Gholson & Martin, 2019).

The final dimension of this framework is *identity*. In this dimension, Battey and Leyva (2016) agree with Martin (2009) in arguing that “colorblind ideologies and practices marginalize students of color and prevent their positive co-construction of racial and mathematics identities” (p. 61). Colorblindness is aligned with the longstanding belief in mathematics spaces mentioned

earlier in this section that mathematics is a neutral discipline and as such race should not be discussed or addressed explicitly. This silencing of race contributes to students' identities, though, in ways that depend on a student's race, and creates a believed hierarchy of mathematical ability by race. White students typically are assumed to be legitimate students in mathematics spaces, whereas Black, Latin* and Native American students are "delegitimized mathematically" (p. 61).

The three dimensions documenting white institutional space that "serves as a tool to detail the ways in which whiteness reproduces advantage and disadvantage in Mathematics" (Battey & Leyva, 2016, p. 51) are certainly not independent. Taken as a whole, the dimensions provide lenses through which whiteness can be identified in mathematics spaces. The overriding goal of identifying whiteness in mathematics education is to disrupt and deconstruct the historically prevailing white framework and thereby allow students of color to flourish. This is not to suggest that individuals are to blame here, but rather to point out that whiteness is systemic. "It can be internalized and reproduced by even those who do not intend to perpetuate racism" (Battey & Leyva, 2016, p. 75). One component of the work needed to accomplish this deconstruction goal then is to center the experiences and voices of students of color. This is summarized by Moore (2008), "Deconstructing the white institutional space will require that we discard this constraining white frame and center the experiences and voices of students of color in the project of identifying and eliminating the structural remnants of our white racist past" (p. 163). Although this comment was originally stated with regard to law schools, it is equally compelling in mathematics spaces (Battey & Leyva, 2016).

Gendered Nature of Mathematics

Alongside discourses that claim mathematics is a race-neutral space, there exist gender-neutral discourses. However, beliefs that mathematics is neutral with regard to gender oppress women and gender-nonconforming people (Esmonde, 2011). Leyva et al. (2021) argue further that such gendered discourses are “analogous to colorblindness discourse” and allow educators and institutions to “ignore inequities in mathematics education that women and gender-nonconforming individuals experience” (p. 4).

In his article “Unpacking the Male Superiority Myth and Masculinization of Mathematics at the Intersections: A Review of Research on Gender in Mathematics Education,” Leyva (2017) synthesizes several decades of research on gender in mathematics education to “better understand the gendering of mathematics that impacts opportunities for learning and succeeding in mathematics” (p. 398). He categorizes the literature in two main areas, namely “research focused on student achievement and research that examined aspects of student participation in mathematics” (p. 400).

Before reporting on these findings, it is important to point out a challenging aspect of many of the research studies he reviewed in that they conflate gender and sex. Leyva points out the “problematic use of gender to describe sex differences or differences in mathematics achievement and participation according to students’ biological sex, namely, being female or male (Damarin & Erchick, 2010).” (p. 397). This conflation obscures or altogether dismisses the complexity of gender and the fact that it is socially constructed.

Many of the quantitative studies regarding gender focus primarily on the achievement differences between women and men students. And those “difference-as-deficit” (Damarin & Erchick, 2010, p. 320) conclusions “perpetuate a long-standing myth of male superiority on

mathematics assessments that disallows agency among women and other marginalized groups” (Leyva, 2017, p. 397). In other words, the sex-based differences in achievement led some researchers to conclude (incorrectly) male superiority in mathematics. Fortunately, qualitative studies have been conducted in the last few decades that shed more nuanced light on students’ attitudes, experiences and persistence in mathematics and consider gender as socially constructed. Leyva (2017) points out that

Scholars exploring mathematics participation with more localized and sociocultural analyses of gender, therefore, have detailed mathematics as a masculinized domain (as opposed to one of male superiority) in which students discursively negotiate their identities and practices with gendered norms and experiences in their mathematics education (p. 398).

Thus, research has disrupted and disproved the myth of male superiority in mathematics. A more correct way to interpret the sex-based differences in achievement is that “narratives of women’s underachievement and underrepresentation in mathematics contribute[s] to the masculinization” (p. 398) of mathematics. This interpretation is based on research that considered “sociocultural considerations of achievement in light of variation across schools, individuals, and other contextual factors that may influence student performance” (p. 403).

Leyva’s synthesis therefore concluded that mathematics is a masculinized domain that people navigate with various gender identities. One example of ways that the masculinized nature of mathematics shows up for women is the discourse that suggests if women’s achievement is less than men’s achievement, then women should change and be more like the men, i.e., “become less anxious, more confident; in essence, more masculine” (Boaler, 1997, p. 285). In other words, a masculine domain is one where the default assumption is that men’s (or boys’) performance is the norm and women (or girls) need to change to fit that norm and to strive for that norm, rather than making changes to teaching and learning.

In discarding the male superiority myth in mathematics, qualitative studies focused more on how “sociocultural factors shaped perceptions of mathematics as a gendered (i.e., male) domain that in turn negatively affected females’ mathematics task performance and persistence (Bornholt et al., 1994; Brandell & Staberg, 2008; Forgasz et al., 1998; Forgasz et al., 2004)” (Leyva, 2017, p. 408). Leyva (2017) documented several studies that showcase how “teacher-student interactions, teacher beliefs, and student engagement” (p. 409) impact the gendering of norms in mathematics spaces that address what counts as mathematically correct and elegant.

One highlighted study, regarding teacher-student interactions, showed that when high school geometry teachers had sex-based differentiated interactions with their students, they communicated their internalized beliefs that female students are less mathematically able than male students (Becker, 1981). These interactions then influenced students’ perceptions of their mathematical abilities as well as their behaviors in class, according to sex. The female students tended to behave in more passive manners, like being quiet, while the male students took more active roles by asking questions and calling out answers. Although this study was published decades ago, more recent research has found similar conclusions about how teacher-student interactions influence student engagement, differentiated by sex (e.g. Beilock et al., 2010; Solomon et al., 2011).

A study by Fennema et al. (1990) found that first-grade teacher beliefs about students’ mathematical ability differed by sex. Teachers were more likely to attribute “male students’ success to ability, whereas chosen female students’ success was attributed to either individual effort or ability” (Leyva, 2017, p. 411). This caused concern by the researchers that “teacher beliefs may produce inequitable patterns of student acknowledgment that lead to sex-based

achievement differences” (p. 411). In other words, this study sought to determine a possible cause of sex-based achievement differences, rather than contributing to a male-superiority myth.

In a third study, highlighting the differences in student engagement, Boaler (1997) compared students’ experiences in two different high schools, over a three-year period. She “attributed differences in participants’ mathematics engagement to the alignment between the schools’ pedagogical approaches and students’ sex-based mathematics learning styles” (Leyva, 2017, p. 412). One conclusion from this research is that the alignment of gender identity with pedagogical or teacher moves may impact student success differentially. This study did additionally bring up questions regarding the intersection of class and gender, or other socially constructed identities, and how those interactions of identity impact student achievement.

In conclusion, mathematics is a masculinized domain (Esmonde, 2011; Esmonde & Laguna-Osuna, 2013; Leyva, 2017). Research has shown that students navigate mathematics in gendered and contextualized ways that are impacted by teacher interactions, teacher beliefs, curriculum, and learning environments. This can result in both (or either) empowerment and marginalization for students. Building on the goals for disrupting racialized norms in mathematics spaces, research that elevates the voices of women and gender-fluid students may contribute to dismantling the masculinized way mathematics is experienced.

At the Intersection of Race and Gender in Mathematics

In his review of gendered research in mathematics education, Leyva (2017) stated explicitly that “intersections of gender with other dimensions of students’ identities generally remain minimally explored in analyses across achievement and participation studies” (p. 420). He goes further to state that research in this area is definitely needed, and that there is some

concern that intersections can commonly be misinterpreted to be “compounded instead of related and interconnected” (p. 421). He argues that future research should be based on intersectionality theory as well as fully consider that gender is socially constructed and thus, research in this area needs to be nuanced.

Taking his own advice, Leyva joined Quea, Weber, Battey and López (2021) to conduct research that detailed “racialized and gendered mechanisms of undergraduate precalculus and calculus instruction” (p. 1). In-depth interviews with 20 students, including four Black women, four Black men, four Latina women, four Latino men, and four white women produced findings that fell into three main areas. The first conclusion reported was that “instructors do not need to explicitly mention race, gender, or language interpreted as coding race and gender for an instructional event to be perceived as racialized and/or gendered” (p. 26). Oppressive moves by the teacher relating to mathematical ability were felt as racialized and/or gendered. The “second conclusion is that instructors’ behaviors and comments cannot be decontextualized from sociohistorical realities in which they occur” (p. 27). When students felt ignored or dismissed, these actions were frequently interpreted as racialized and/or gendered actions. The “final conclusion is that participants’ perceptions of instructional events as racialized and gendered...reveal mechanisms of inequality in undergraduate precalculus and calculus instruction that perpetuate whiteness and patriarchy in mathematics education” (p. 27). This occurred when instructors seemingly (a) created “differential opportunities for classroom participation and instructor support,” (b) limited “within-group peer support” and (c) “activat[ed] exclusionary ideas of who belongs in STEM” (p. 27).

LGBTQ+ Issues in Mathematics

As with intersectional-focused research in mathematics education, there is not a lot of research to date that focuses on LGBTQ+ issues in mathematics classes. One study of particular importance for this research project is a dissertation by Voigt (2020) that examines how college calculus students, who self-reported an LGBTQ+ identity, experience mathematics spaces. In one part of his study, analyzing data collected from 25,588 calculus students from 20 universities or colleges, Voigt found that bisexual and queer+⁹ students “reported the least amount of interactions” from all groups and “reported less sense of community and classroom participation in their mathematics courses” (p. 154) compared to their peers. Additionally, “Lesbian and Gay students reported similar levels of participation compared to their Straight peers” (p. 155). This was a surprising finding, as previous literature had suggested that lesbian and gay students would experience alienating microaggressions that would negatively impact their participation. Finally, “Queer-spectrum¹⁰ students report[ed] lower amounts of community and classroom participation, less responsive instructional environment, lower mathematical affect...and anticipate[d] getting a lower course grade” (p. 156). This negative finding for queer-spectrum students was in line with research reporting on students from other historically marginalized groups (e.g., Gutiérrez, 2018; Martin et al., 2010).

These findings regarding LGBTQ+ students are in alignment with the above documentation of research on the racialized and gendered nature of mathematics. Overall, the findings in this section point to the need for research that elevates the voices of students from

⁹ Voigt uses queer+ to “indicate students who indicated Pansexual or Demisexual, Queer or Multi-Queer.” (p. 117).

¹⁰ Voigt describes queer-spectrum students as “students who identify as Lesbian, Gay, Bisexual, Transgender, Two-spirit, Intersex, Pansexual, Asexual, or in other ways Queer because of their queer sexual identity or non-cisgender identity (Kumashiro, 2001).” (p. xx)

historically marginalized groups within mathematics in order to disrupt the racialized and gendered discourse in mathematics. The next section foregrounds the theoretical lens that will be used to work toward accomplishing this.

Sociopolitical Turn in Mathematics Education

Over the last 15 to 20 years, a series of mathematics education researchers have pushed for a sociopolitical turn in mathematics education. Sociopolitical theory is prefaced by a sociocultural theory of learning that frames learning environments as organized from both social and cultural perspectives. Sociocultural framing could be said to include two social dimensions. One such dimension “refers to the nature of mathematics as a knowledge that is constructed in an interpersonal interaction between the teacher and students and also among students themselves” (Valero & Zevenbergen, 2004, p.1). In this dimension, the social interactions between and among participants is the core. The second social dimension could be thought of as the community within the classroom, where the culture and practices created in the classroom are the core of this social dimension. Thus, the sociocultural framework provides a more expansive perspective of educational research than a mere focus on content in that it seeks to understand social interactions and impacts on mathematical learning.

Building on, and including, the sociocultural perspective, sociopolitical framing “stands on the assumption that mathematics education is, in essence, a social and political practice” (Valero & Zevenbergen, 2004, p.2). Or as Gutiérrez (2013) puts it, sociopolitical framing further includes understanding “knowledge, power, and identity as interwoven and arising from (and constituted within) social discourses” (p. 4). This framing is social because it is situated within the social contexts of the classroom, school, local community, nation and the world. It is political

because it addresses concerns of power, privilege, equity and “the democracy in mathematics education” (Valero & Zevenbergen, 2004, p.2). This perspective is crucial to understanding how mathematics education practices impact students and their participation in mathematics and further, in STEM majors.

In this next section, I recount many of these sociopolitical turns in a fairly sequential order, to allow the story to unfold as it was originally created. Key pieces of this story include challenges, problems that need to be addressed, or explicit calls to action that are outlined by various scholars. For consistency in the story-telling aspect of this section, all such challenges, etc. will be classified and referred to as calls to action and each will be explained as to what problem authors were referring to and what their implicit or explicit call to action is. It may also be worth noting that this section focuses primarily on current theorizing and recommendations made by various researchers, rather than research findings. Here the stage is set for the necessity of and framing for further research in exploring equity-related concerns in mathematics instructional practices.

In her presidential address at the American Educational Research Association (AERA) conference in 2006, Gloria Ladson-Billings essentially called the education research community to action to focus their research on historically marginalized groups of students (Ladson-Billings, 2006). She observed that education researchers studied poor and other historically marginalized groups of students by race or ethnicity, but collectively, not enough was done to provide remedies to solve these problems. Ladson-Billings claimed that we need not focus on the achievement gap, but instead she reframed the problem as the education debt that has accumulated over the years, comparing it to the difference between the national deficit and national debt (which is the sum of the yearly deficits). She further argued that the “historical,

economic, sociopolitical, and moral decisions and policies that characterize our society have created an education debt” (p. 5). The “sociopolitical debt” (p. 7) with our students is the result of students and families of color being “excluded from the decision-making mechanisms” (p. 7) that would lead to quality education. The implication is that education researchers need to contribute research to decrease and then alleviate this education debt, including in the sociopolitical realm within education.

In an article entitled “Mathematics as Gatekeeper: Power and Privilege in the Production of Knowledge” Martin et al. (2010) sharply rebuked two National Council of Teachers of Mathematics (NCTM) events where mathematics education researchers were questioning “where is the math?” in mathematics education research. (For context, the “where is the math?” proponents argued that mathematics education research should focus primarily on mathematical content and not on social, cultural or equity issues within mathematics courses.) Martin’s first rebuke was in response to an editor comment in the *Journal for Research in Mathematics Education*, the second in regard to a research symposium panel entitled *Keeping the Mathematics in Mathematics Education Research* where the focus was on centering mathematics content in mathematics education research. This rebuke article highlighted issues of power and privilege in mathematics classrooms and discussed the “myth of neutrality,” pointing out specifically that mathematics education is indeed political (Martin et al., 2010, p. 13). They bring up important questions to showcase the political nature of mathematics education including questions about what mathematics is, who it is for, what purposes it serves and who gets to decide what counts as mathematics education research? In response to the sentiment that scholars should make sure that mathematics education research really contains enough mathematics, Martin et al. state the following,

Rather than generating concern about studies that do not give priority to mathematics content, it may be more informative to understand why studies that have continued to do so have offered so little in the way of progress for students who remain the most underserved (Martin et al., 2010, p. 16).

The call here is to essentially turn the question upside down to change the focus.

The Martin et al. (2010) paper also provides a hypothetical example of a woman researcher studying students' "systematic errors in multi-digit subtraction problems involving whole numbers" (p. 18), using a cognitive and developmental psychological framing for data analysis. Without considering the students' cultural, racial and other complex identities, the conclusions drawn are incomplete and deficit-oriented. This example was used to highlight how the focus and framing of research can impact interpretations of the findings; this can lead scholars and others to reach incorrect conclusions if the context of a student's cultural and mathematical identity is not considered. Thus, Martin et al. (2010) make an explicit call to action for mathematics education researchers to acknowledge that centering mathematics in mathematics education research is a "political statement" (p. 13), not a neutral one, and it represents power dynamics that also play out in mathematics classrooms. In their final statement that "mathematics should not be the gatekeeper for the production of knowledge in the field" (p. 21), Martin et al. (2010) imply that equity issues should be regarded as at least equally important as mathematics content in doing mathematics education research.

Similarly, Gutiérrez, in her article entitled "The Sociopolitical Turn in Mathematics Education" (2013), lobbies for mathematics education researchers to move beyond the sociocultural stance (Lerman, 2000) to a sociopolitical stance instead. She states that

the fact that mathematics is a human practice means it is inherently political, rife with issues of domination and power, just like any other human practice. So, while many mathematics educators are comfortable with including social and cultural aspects in their

work, most are not so willing to acknowledge that teaching and learning mathematics are not politically neutral activities. (p. 40)

Her argument contains elements from critical race theory (CRT) and, like Martin et al. (2010), seeks to address issues of power and identity in mathematics education. She reiterates some of the questions posed by Martin et al. (2010) and additionally queries about why we study particular mathematical concepts, who benefits from these highlighted mathematical concepts, who is missing from the mathematics classroom, and how students' identities are impacted by the chosen focus. She notes that asking such questions and doing research with methodologies that are aligned to address these questions will help frame the solutions to persistent problems from a more critical lens and contain opportunities for insights and perspectives that a purely cognitive or sociocultural framing cannot offer. Researchers operating within this sociopolitical framework would seek to “understand mathematics education” as well as to “transform mathematics education” (p. 40) in order to move the needle toward more socially just mathematics spaces/practices/classrooms.

In her article, Gutiérrez makes the case that a sociopolitical lens for research seeks to dismantle the power structures to build something better in its place. The power structures include “(1) the *power of mathematics* [and] (2) the power associated with *being successful in mathematics*” (Gutiérrez, 2013, p. 46, emphasis in the original). She does caution against extreme dismantling that loses sight of the original goals, i.e., dismantling for dismantling's sake, and asks instead for a deliberate and thoughtful approach.

The power of mathematics is articulated by Gutiérrez as the societal reality that mathematics is thought of as solving many world problems and is thus privileged with being the measurable way of uncovering truth.

The argument goes something like this: *mathematics, as a rational, universal, and logical discipline is located in a unique position to be the ultimate arbiter of truth. Its ability to model the real world and to maintain a kind of internal certainty gives evidence of this privileged and earned position.* This concept of power is the foundation of assertions that learning mathematics gives students power in society (Malloy, 2002). It is as if mathematics carries with it something separate from humans that can be conveyed to individuals, thereby affording them a more powerful view of the world (p. 47, emphasis in the original).

This notion that mathematics has such power influences what mathematics is covered and used.

Gutiérrez suggests that we can be “more deliberate in how and when we want to use/create mathematics in our everyday lives” (p. 47) as a result of reflecting on this power of mathematics.

The natural consequence of using mathematics as the arbiter of truth is that individuals are then given the power associated with being successful in mathematics. In other words, people who are successful in mathematics are considered more intelligent and esteemed than those who have not been successful in mathematics. Oftentimes, this is referred to as the genius myth within mathematics and predicated on the idea that mathematics ability is fixed. This debunked myth is harmful in many ways, and especially for students from historically marginalized or vulnerable groups (Chestnut et al., 2018).

After listing many possible benefits, as well as a few challenges with the sociopolitical turn in mathematics education research, Gutiérrez (2013) ends on a compelling call to action,

If, as a field, we are not willing to recognize the political nature of mathematics education or the fact that teaching and learning are negotiated practices that implicate our identities, we might as well give up on all of this “talk” about equity” (p. 63).

This quote aligns with earlier sentiments in the article which argue that part of creating equity for mathematics learners is to do the necessary work, both in research and in teaching, to support students in maintaining “a sense of wholeness while doing mathematics” (Gutiérrez, 2013, p. 61).

Other researchers have picked up this call to action for a sociopolitical turn in mathematics education, and have further elaborated concrete steps that can be or have been taken. Aguirre et al. (2017) target mathematics education researchers in their article and outline four political acts that mathematics education researchers can do to pivot toward the important role that equity needs to play in research. Their underlying assumption is that “power relations exist in all interactions and relationships, including in education and research spaces” (Aguirre et al., 2017, p. 126). The four political acts they recommend that could positively impact equity are: (1) infuse all mathematics education research with an equity lens, (2) obtain the necessary knowledge to do genuine equity work, (3) challenge the false dichotomy between mathematics and equity and (4) expand the view of what counts as mathematics.

Adiredja & Andrews-Larson (2017), in their article entitled “Taking the Sociopolitical Turn in Postsecondary Mathematics Education Research,” make another and more specific call for mathematics education researchers to take up the sociopolitical lens in research at the undergraduate mathematics level. They extend Gutiérrez’ (2013) argument to explicitly call for a sociopolitical lens to be used in teaching undergraduate mathematics courses. To provide proof of concept examples of how research with a sociopolitical framing can impact teaching, they cite two studies that highlight how this framing was used to improve teaching in ways that benefited student outcomes for historically marginalized students. These two studies “showed that two underrepresented groups, Black students and women (respectively) were able to perform equally well as compared to their peers when given access to meaningful engagement with mathematics.” (p. 452-453).

The first study Adiredja and Andrews-Larson (2017) cite was conducted by Fullilove and Treisman (1990). They studied an achievement gap in grades between Black vs.

Chinese-American college calculus students during Treisman's graduate work at University of California Berkeley. They found that the Chinese-American students tended to study in groups whereas the Black students tended, instead, to study in isolation. Recitation sessions were thus constructed to provide opportunities for students to be put into diverse groups where they worked on challenging mathematics problems. They then found a strong correlation between participation in these diverse learning communities and Black students' calculus achievement, persistence in STEM-related majors, and graduation rates.

The second cited study by Adiredja and Andrews-Larson (2017) discussed the effects of Inquiry-Based Learning (IBL) on achievement and attitudes in women undergraduate mathematics students (Laursen et al., 2014). This study analyzed data from over 100 courses, spanning four institutions. IBL is an instructional process that involves deliberate collaboration between students as they work on mathematical problems. The goal with this approach is for the students to create conjectures and mathematical arguments on their own, with minimal guidance from the teacher. They found that the "IBL courses eliminated a gender-based gap in self-reported learning gains that existed in non-IBL courses. Moreover, interest and confidence in doing mathematics also increased for female students in IBL courses" (Adiredja & Andrews-Larson, 2017, p. 453).

The takeaway from this Adiredja and Andrews-Larson article (2017) is that we need more research studies and teaching changes at the undergraduate level to remedy equity problems in mathematics courses for students from historically marginalized groups. In their own words, "the central claim of [their] paper is that sociopolitical perspectives offer insights that have the potential to advance research on equity issues at the postsecondary level" (p. 446). On that note, in the calculus chapter of *The Compendium for Research in Mathematics Education*

Larsen et al. (2017) also make a direct call for more research to take up the sociopolitical turn in mathematics education research to create a more equitable and socially just space for calculus learners, both at the high school and college level. This argument reflects the need for mathematics education research that, like mine, is in a robust mathematical context, such as undergraduate mathematics teaching, but centers sociopolitical concerns.

Ernst (2018) goes on to challenge the idea that mathematics is solely “an unqualified force for good” (p. 187). He acknowledges and catalogs ways that mathematics is used for good, including applications of technology that we all use for surviving and thriving as well as the joy it brings to those who choose to study it beyond what is required for school mathematics.

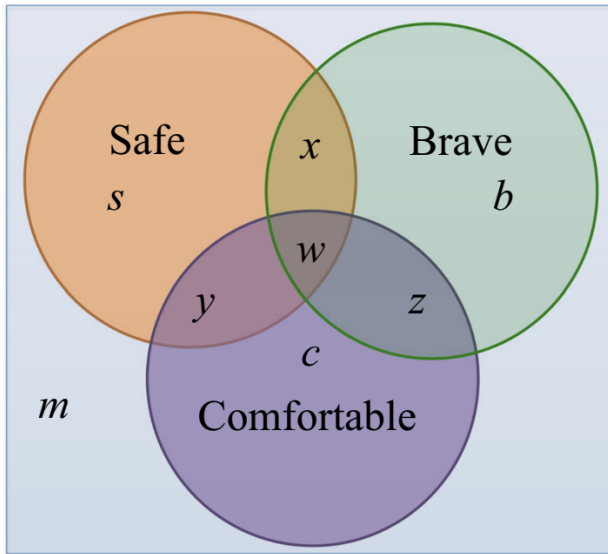
However, he also details how mathematics is or can be used for harm. This includes mathematical applications that are used for human destruction, but also it includes the inhumane way mathematics is perceived or stigmatized by society or ways that it gets used as a barrier for some students. This sentiment can be seen in his observation that,

[Mathematics] does harm through dehumanized thinking which fosters instrumentalism and ethics-free governance and social practices. Also, because of its over-valuation in the modern world through education it facilitates social reproduction and the perpetuation of class-based social injustice. Through its social image (coupled with school learning experiences) it aids the development of negative attitudes in some learners, and its gender-biased image maintains social disadvantage for females, especially in the English speaking world. (p. 205)

Although he does not specifically make a call for applying a sociopolitical lens when doing mathematics education research, Ernst does make an explicit call to include training students in the ethics of mathematics embedded in undergraduate mathematics courses. He states that “students should see mathematics as more than just a set of tools, and instead be shown that it is [a] long-standing discipline with its own philosophical issues and controversies, including human and ethical dilemmas” (p. 207). The implication is that the teaching and researching of

mathematics requires responsible and ethical framing that considers the complexities of human-beingness, which is indeed aligned with a sociopolitical lens. Ernst justifies this call to action “so that mathematicians gain a sense of its social responsibility” because “it is wrong to ignore or label its negative social impacts as ‘incidental’ outcomes or as ‘collateral damage’” (p. 208).

Finally, Hauk et al. (2020) made yet another call to action to include equity in every bit of Research in Undergraduate Mathematics Education (RUME), and they provide accessible tools to help their readers--researchers and practitioners alike--make strides forward in that arena. They cite Aguirre et al (2017) in the call for a sociopolitical lens in mathematics education research and focus on the first political act, namely increasing the equity lens in mathematics education research. In providing clear definitions to tease apart the difference between equity, diversity, inclusivity and social justice, they point out that equity can sometimes be measured by its complement, namely inequity. They argue logically that if inequities are decreased, then equity is necessarily increased. In their discussion about courageous conversations, they present a Venn diagram (see Figure 1) that breaks down the overlap/relationship between brave, comfortable and safe spaces. They chose these three words because “unlike the term equity, each of the words in the Venn diagram— safe, comfortable, brave—has a small set of well-established meanings in conversational English” (p. 67). Comfortable can be taken to mean “affording or enjoying contentment and security” (p. 68). One definition of safe is “secure; free from risk of harm” (p. 68). And, a provided definition of brave is the “mental or moral strength to venture, persevere; withstand” (p. 68). The Venn diagram is accompanied by insightful and tangible examples aimed to increase the understanding of how it can be used in discussions and in reflections on how to frame research.



U=Personal Experience of Challenging Conversation

Figure 1. Safe, Brave, Comfortable Venn diagram (Hauk, et al., 2020).

Circling back to the beginning of this journey of exploring the calls for a move to a sociopolitical lens when doing mathematics education research, a quote from Aguirre et al. (2017) comes to mind. They argue that “equity is an intentional collective professional responsibility of the Mathematics Education Researchers community. It is as necessary and as important as mathematics is to mathematics education” (p.141). A variety of researchers have argued that the answer to the question of “Where is the math?” in mathematics education research is perhaps not compelling. Instead, these scholars suggest replacing the question altogether with something more thoughtful and complicated, i.e., a question that views mathematics education through a sociopolitical lens. Coming to terms with the fact that human beings do mathematics (which necessarily implies that mathematics is a human endeavor rife with all the complexities that are inherent to human beings) is a step toward taking up the next and more specific call to rehumanize mathematics.

Building on the call for a sociopolitical turn in mathematics education research, Gutiérrez (2018) makes an argument that researchers and educators with an equity stance have spent much time researching and talking about how to “play the game” (p. 1). The focus has long been on access and achievement, but the next step is to focus on how to “change the game” (Gutiérrez, 2018, p. 1) by addressing power and student identities within classrooms and institutions. This perspective, clearly aligned with her earlier work, has led Gutiérrez to build a framework based on sociopolitical theory, thereby continuing the above conversation in a more specific and focused direction. Her use of the sociopolitical lens can be seen in the following quote.

Rehumanizing mathematics also squarely addresses the politics of mathematics and of mathematics education. That is, rather than assuming a neutral response or failing to attend to power dynamics, rehumanizing mathematics recognizes that challenging the status quo will likely be met with great opposition from those with privilege and high status who benefit from the system remaining the same. It also seeks to highlight where power dynamics have played out in the history of mathematics and where mathematics might come to serve the people as opposed to vice versa. (p. 4)

Gutiérrez explicitly argues that “equity” can seem to represent a “destination” whereas, “‘rehumanizing’ is a verb; it reflects an ongoing process and requires constant vigilance to maintain and evolve with contexts.” (Gutiérrez, 2018, p. 3). She intentionally calls her framework *rehumanizing* rather than humanizing because mathematics has been practiced humanely in many times and by many peoples and thus we need to investigate ways to return to mathematics that is humanizing. This is illuminated by the quote that Gutiérrez

¹¹ I would like to explicitly thank Dr. Rochelle Gutiérrez for her gracious attitude and work in reading and providing thoughtful and encouraging feedback for this section of chapter 2. Attending to her comments ensured that my description of her framework is aligned with her intent.

Begins with the assumption that people throughout the world already do mathematics in everyday ways that are humane (Carraher, Carraher, and Schliemann 1985; Lave 1988; Maginglia 1994, 2002; Nuñez, Schliemann, and Carraher 1993; Save 1998). Yet schooling often creates structures, policies, and rituals that can convince people they are no longer mathematical. In this way, those structures, policies, and practices can be experienced as dehumanizing (Gutiérrez, 2018, p. 2).

The implication is that there is a need to create structural changes to teaching and learning mathematics that will allow students to experience the mathematics classroom and learning as humanizing. Gutiérrez's goal here is that mathematics classes provide spaces that both help us solve problems in the world while simultaneously bringing us joy. She wants mathematics classes to be a place where both learners and educators can bring their whole selves to the endeavor of mathematics and flourish (as Francis Su would call it; Su, 2020). To accomplish this lofty goal, student voices must be centered and documented regarding what feels humanizing to them, which relates back to the notion that rehumanizing is a verb.

It is important to expand on this idea of rehumanizing to be more precise. Gutiérrez is *not* suggesting that mathematics is not already being humanized in many spaces and in many ways. She is advocating for mathematics to be purposefully humanized, i.e., not left to chance. The “re” is referring to a bringing back of the natural state of being mathematical that human beings have and practice but then sometimes gets drilled out or erased by the system of schooling. Rehumanizing mathematics is a recognition that there are many humane, useful, joyful ways that human beings practice mathematics outside the school setting. It is not trying to imply that the goal is to harken back to some non-existent past when everything was perfect, nor to suggest that there is no humanizing mathematics going on in the world. To conclude this note, rehumanizing mathematics is asset-oriented and aiming at intentionally bringing joy and humane-ness into the schooling of mathematics.

The framework Gutiérrez (2018) outlines to rehumanize mathematics includes eight overlapping and interlocking dimensions: (1) participation/positioning, (2) cultures/theirstories¹², (3) windows/mirrors, (4) living practice/futures, (5) creation, (6) broadening mathematics, (7) body/emotions, and (8) ownership. It should be noted that her framework is intended to be used especially for students who identify as Black, Indigenous, Latin*, LGBTQ+, or womxn¹³ because the system has previously failed these students (Gutiérrez, 2018, p. 2). To date the written descriptions of these dimensions can only be found in a brief format in Gutiérrez's book *Rehumanizing Mathematics for Black, Indigenous and Latinx Students* (2018). More extensive details have been added based on presentations (2018) and the summer Rehumanizing Mathematics Workshop at the Park City Mathematics Institute (2021) led by Gutiérrez.

The dimensions provide categories for pedagogical moves, structures and tasks that mathematics teachers can implement as they work toward rehumanizing their classes and are described from that perspective. The framework is not a list of concrete moves or strategies that can be enacted to rehumanize a mathematics class. Instead, the framework can be thought of as a mapping space for thinking about practices from the eight dimensions. A teacher could consider pedagogical moves, structures or tasks that connect to or align with the dimensions, but the dimensions do not prescribe those practices. For example, one could argue that people do not need emotions or their body to do mathematics, but the rehumanizing framework provides a different narrative that we need to recognize and draw upon the body and emotions in doing mathematics. With that said, the Body & Emotions dimension does not prescribe how to

¹² Gutiérrez uses theirstories in place of histories to explicitly include facts from all peoples of any genders.

¹³ Womxn is intended to include cis and trans women and the broad fluidity of female-identifying gender.

accomplish that goal. Additionally, the eight dimensions are intended to be applied in their entirety and not in a piece-meal way, as concepts and practices within each dimension overlap with other dimensions. In other words, focusing on only one or two dimensions does not follow the intention of the framework, which is specifically designed to incorporate all eight dimensions with the understanding that no dimension is untouched by the other dimensions.

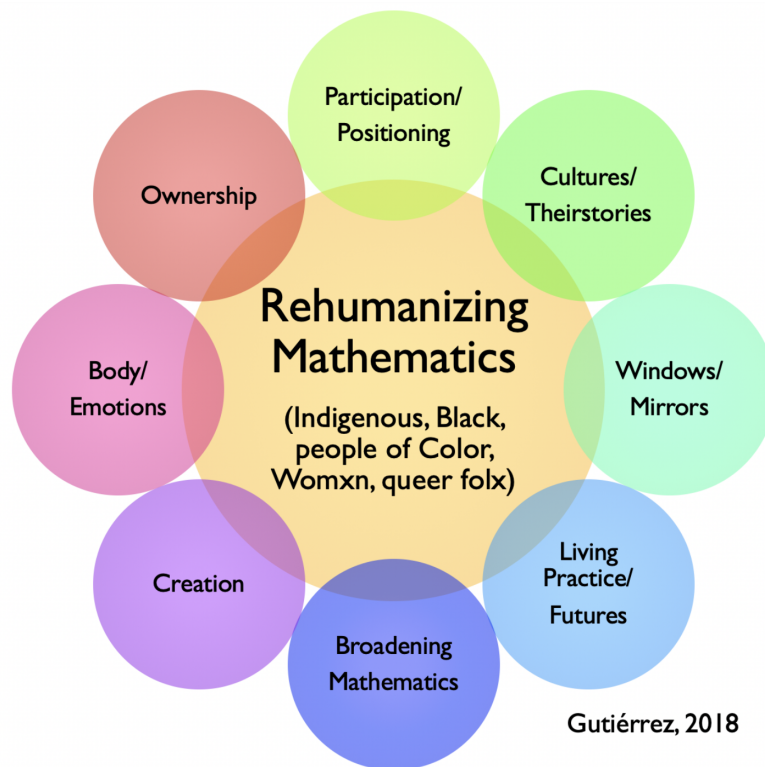


Figure 2. Rehumanizing Mathematics graphic (Gutiérrez, 2018).

In the graphic above (Figure 2), one could imagine that the middle, binding section upon which the dimensions are built is “love and care” (Gutiérrez, 2021), a concept mentioned or alluded to throughout the chapters of *Rehumanizing Mathematics for Black, Indigenous, and Latinx Students* (2018) (e.g., see the chapter by Joseph & Alston). Love and care provide the foundation that underlies the eight dimensions; without the enactment of love and care in

teaching moves, practices and course structures, students will not experience the mathematics class as rehumanized. In other words, if all eight dimensions of the rehumanizing framework are attended to in only transactional ways, students are not likely to have a rehumanized experience. The basis for this framework is relational, and love and care is a necessary component of being relational (Gutiérrez, 2021), even though the enactment of love and care might be difficult to measure. This implied foundation for the rehumanizing framework is also aligned with work by other scholars focused on caring, liberatory justice and dignity (e.g., Gargroetzi, 2020; Hackenberg, 2005; TODOS Podcast with Seda & Brown, 2021).

Gutiérrez's presentations and PCMI workshops (2019, 2020, 2021) have featured mathematicians and reported on others who are working to rehumanize their mathematics teaching and the specific ways they have done this. For example, in 2019, I was one of the invited guest speakers who was featured in the PCMI Rehumanizing Mathematics Workshop for the work I had started to do around rehumanizing assessments (MacArthur, 2019). Even so, very little work has been published that makes this work accessible to the broader public. Research studies need to help fill this void by reporting on specific practices and how they are received or felt by students (e.g., mathematical learning outcomes, connection to self and home communities, feelings of belonging/joy, etc.).

Lastly with regard to the rehumanizing dimensions, it should be stated explicitly that many of the moves, practices, and course structures that align with the rehumanizing framework dimensions have individually been investigated and validated by other researchers, prior to and outside the context of this framework. While describing each of the eight rehumanizing dimensions next, I have included references to some of that other research. What is unique about

the rehumanizing framework is the intended completeness of putting these dimensions together into a cohesive framework.

The *participation and positioning* dimension asks teachers to reposition themselves and students away from the traditional view of teacher as the expert and students as vessels into which teachers pour their knowledge. It asks teachers to position students as experts for each other, which in turn changes the power dynamics in the classroom and boosts their mathematical identities. Students in such environments would seek approval and evaluation from themselves and other students rather than relying only on the teacher for such feedback. This dimension is perhaps the easiest entry point for teachers, because its focus overlaps greatly with many other calls for active or engaged learning strategies, with attention to equity, to be employed in the classroom (e.g., Abell et al., 2017; Bressoud et al., 2015; Chao et al., 2016; CBMS, 2016; Freeman et al., 2014; NCTM, 2014), and thus there are ready-made resources available. As mentioned earlier in this chapter, Leyva et al. (2021) also lobbied for participation and positioning to be attended to in order to dismantle racialized and gendered norms. However, if teachers are only focused on this one rehumanizing dimension without attending to any other dimensions, they are likely attempting to address only access and achievement, not rehumanization in its full form (Gutiérrez, 2021).

The *cultures and theirstories*¹⁴ dimension aligns with teacher moves that acknowledge and center differing ways for people in the world to do mathematics. Implementing culturally relevant pedagogies (Aguirre & del Rosario Zavala, 2013; Greer et al., 2009), introducing ethnomathematics (e.g., Borba, 1990; d'Ambrosio, 1985) into classes, and highlighting various

¹⁴ Theirstories is intended to replace histories, and to indicate by the choice of language here that it is about all peoples, not just men.

algorithms used in different cultures would be included in this dimension. Additionally, leveraging students' mathematical ways of knowing and recognizing that those ways of doing mathematics are valid would be included in this dimension. The NCTM brief on equity-based teaching (Chao et al., 2016) incorporates recommendations for teachers to attend to diverse cultures and power structures in the mathematics classrooms, which attends to the ideas in this dimension.

The ability for students to see themselves in the course content and to see their cultural ways of mathematical knowing presented in the class would feel validating and rehumanizing, which leads into the next dimension of *windows and mirrors*. These are used as metaphors to indicate that students can see through a window into a different perspective than their own and look into a mirror to reflect back their own mathematical thinking, and were first discussed with regard to curriculum by Style (1996). There is a relational component to this dimension as well, in that students are seeking to understand themselves mathematically and also to understand and relate to others in mathematical ways. Research has been published that utilizes windows and mirrors constructs to analyze student-to-student and teacher-student interactions (e.g., Dominguez, 2016) or provides effective teaching strategy recommendations aligned with this dimension (e.g. Chao et al., 2016). Moreover, if these rehumanizing moves are taken up in the classroom, then students could have an appreciation for another's mathematical viewpoint, rather than just a critique of their work, which is aligned in spirit with the Common Core Standards for Mathematical Practice (Common Core State Standards Initiative, n.d.).

The next dimension of *living practice and futures* was originally labeled as living practice and then further expanded to include futures (Gutiérrez, 2021). This dimension shows how mathematics is not static, but rather as “something in motion” (Gutiérrez, 2018, p. 5), i.e.,

ever-evolving. Ethnomathematics scholars argue similarly that mathematics is dynamic, rather than rigid (d'Ambrosio, 2001), and laden with cultural concepts and practices. Using mathematics to understand and transform the world belongs in this dimension, which many other scholars have written about under the umbrella term of social justice mathematics (e.g. Bartell, 2013; Frankenstein, 1997; Freire, 1993; Gutstein, 2006; Skovsmose, 1994). With that said, Gutiérrez argues that social justice mathematics does not go far enough because it still assumes the classical form of mathematics will continue, i.e., that it will be a tool for reading the world and seeing injustices and seeking justice. This Living Practices & Futures dimension, on the other hand, emphasizes the need and power to create a different form or practice of mathematics in the future. Attending to this dimension provides students with ways to envision how the school mathematics they are learning will be brought into their lives and their future in meaningful ways for them, and about recognizing the futures they are trying to create. It also addresses ways students can imagine meeting their community needs in the future. Teacher moves that answer student questions about how mathematics can be used in different ways for the student's own purpose to restructure a different reality belong in this dimension. It may be helpful to keep in mind that the Cultures & Theirstories dimension has a heavy focus on the past and present, whereas the Living Practices & Futures dimension has a strong focus on the future and what kinds of mathematics we are constructing and building, rather than solely on how does the mathematics fit in with supporting our futures.

Broadening mathematics sees mathematics in other spaces, such as art, history, music, etc. The Journal of Mathematics and the Arts and the Journal of Humanistic Mathematics serve as examples of journals that publish articles by scholars mixing art, music and mathematics in their research and/or teaching (e.g. Haas, 2012; Shapiro & Huber, 2021; Shrestha, 2018). Cheng

(2015) even explores how mathematics can be likened to cooking in her quest to have the reader broaden their view of what mathematics is and is not. This dimension expands our thoughts about what counts as mathematics to possibly include other varieties of mathematics to be included in the curriculum, rather than only the traditional algebra and geometry. The emphasis in traditional mathematics classrooms on the general case as the gold standard might be an example of non-broadened mathematics. In this scenario, broadening mathematics would look for ways that specific examples could be used, rather than the general case, as acceptable arguments or looking for situations where we rely on examples rather than the general case. Having students learn how to pose mathematical problems, in addition to solving problems they are given could also fall in this dimension.

Creating mathematics can be defined as the process of students discovering a mathematical fact that is new, or at least new to them, and that has value for them. It is also less about following an already established algorithm and more about students inventing their own algorithm or ways to tackle a mathematics problem (e.g. Barajas-Lopez & Bang, 2018; Bunton et al., 2018; Pickreign & Rogers, 2006). Students could experiment with known theorems, change one condition, and then explore what consequences arise from that change, thus giving them first-hand experience with what Gutiérrez calls rule-breaking. An example of rule-breaking might be exploring different definitions of length that would allow students to reach different answers when asked about the distance between two points. Teachers could help students understand the axiomatic approach of mathematics and then encourage them to play with the axioms to see what happens. Activities in this dimension would also probe at the ethics of creating mathematics and how that is related or aligned to students' internalized values. One

example of work being done in this area includes creative work by STEM majors in doing supported undergraduate research (Mateja, 2008).

Bringing the *body and emotions* into mathematics classrooms is the next rehumanizing dimension. To attend to this, teachers can ask students to consider doing mathematics from an intuitive or emotional lens rather than solely from a logical perspective. Activities in this dimension might address questions about how the mathematics used in the classroom can be embodied or experienced through other senses than the written form, like through listening or acting out. Using manipulatives that are tactile or using a visual image to draw on students' memories or lived experiences can be another way to embody the mathematics being used. A study focused on improvisation in the mathematics classroom (McCloskey & Tanner, 2019) certainly uses constructs that could fall within this dimension because it involves the use of intuition and emotion. Another example that would lie in this dimension is work on embodied cognition in mathematics classes that use gestures and body movement as part of an interactive learning environment to improve instructional activities and learning (e.g. Abrahamson et al., 2021).

Ownership is the last of the eight rehumanizing dimensions. Doing or playing with mathematics even after class time, when it is done for the joy of it, would fit in the ownership dimension. Having the sense of accomplishment of doing something mathematical is ownership, especially when students can imagine how it can be beneficial for more than themselves. This dimension is not about individuals; rather it is about mathematics being done in collaboration with the communities in which students live. The first dimension, participation and positioning, is more about what happens inside the institutional space, whereas ownership focuses on what happens outside of that space. How will the student do mathematics in their community? Their

stewardship of their mathematical knowledge has personal meaning to them as they carry it out into the world as contributing members of their communities, similar to courses that use a realistic mathematics education emphasis (Gravemeijer & Doorman, 1999).

Wrapping up this dimension's description, I provide a final note about the term ownership here. There is a likely misinterpretation, for most Americans, of this word which needs to be cleared up. The word ownership can easily be interpreted within a settler colonialism framework. However, all of the rehumanizing dimensions are intended to be interpreted and used in relation to others and to self. In this way, ownership here does not mean something that a student owns for their own cavalier use. Instead, stewardship might be a better name for this dimension as it implies a sense of taking care of that which is owned (Gutiérrez, 2021).

Although individually each of these distinct constructs embedded as dimensions in the rehumanizing framework is beneficial for research and teaching, Gutiérrez (2018) intentionally put these different elements together to form a cohesive framework. Her premise is that each dimension on its own is necessary to rehumanize the mathematics classroom, but not sufficient. Thus, it should be stressed that the overriding goal with this rehumanizing framework is for both teachers and researchers to deliberately attend to all eight dimensions in some way, even if done iteratively or sequentially over a given time period. The dimensions are not mutually exclusive and the overlapping nature of the rehumanizing dimensions is part of what makes the framework comprehensive. Concluding this description of the rehumanizing framework, one theme that cuts across all the dimensions is the idea of breaking rules. Rule breaking shows up as a practice in several dimensions, including Living Practice & Futures, Broadening Mathematics and Creation.

To date, no research has been published that explicitly seeks to test the rehumanizing mathematics framework while providing feedback from students. My research study seeks to fill

that hole in the field by investigating how one researcher (myself) attempted to concretize specific practices of the rehumanizing mathematics dimensions as well as how students from groups who have been historically marginalized experience or imagine those practices. The results of my study will thus inform teachers about how to design their mathematics courses in ways that have the potential to feel rehumanizing to students in meaningful and thorough ways. Additionally, this study has the potential to uncover to what extent undergraduate STEM-intending majors confirm the claim that all dimensions need tending to in order to feel rehumanizing to students.

Conclusion

In this chapter, I have reviewed some of the bodies of research in which this study is situated and introduced the rehumanizing framework guiding the study. The goals of equity and a sociopolitical stance are embedded within the rehumanizing framework and were a springboard for its creation. To date, there is very little research published that uses or explores the rehumanizing framework in its entirety. This dissertation study addresses that gap by answering questions regarding how college calculus students perceive or imagine what moves, practices, and course structures would feel rehumanizing, and what is most salient for them within the dimensions of the rehumanizing framework, in the context of their college mathematics courses. Further, this study centers the voices of students from historically marginalized groups, i.e., from non-dominant groups, thereby addressing possible issues of power, privilege and justice within mathematics learning environments. These findings have the potential to impact the teaching and learning of calculus for future STEM majors, specifically for Black, Latin*, Indigenous, LGBTQ+ and women students. Furthermore, this research is the first to test the framework with

student perspectives, which may help to flesh out nuanced details of the framework or illuminate new aspects of its dimensions.

CHAPTER THREE

METHODS

Introduction

The research reported on in this dissertation investigates undergraduate Calculus 2 students' perceptions and experiences of rehumanizing in their college mathematics classes. The rehumanizing framework (Gutiérrez, 2018) is relatively new, and as such, research is needed to flesh out the details about how this theory can be applied in teaching practices at various grade levels and based on student perspectives. Additionally, this research project intentionally aims to center the voices of students from groups who have been historically marginalized in mathematics to be sure they have the opportunity to influence collegiate teaching in ways that students will experience as humanizing, which is operationalized later in this chapter. These purposes align with calls for research to advance equity in mathematics education as previously discussed in Chapter 2 (e.g. Adiredja & Andrews-Larson, 2017; Gutiérrez, 2013; Martin et al., 2010). To that end, I am addressing the following research questions:

What classroom structures, practices and pedagogies do undergraduate Calculus 2 students perceive as rehumanizing in their college mathematics classes?

- a. In particular, what are the perceptions of students from historically marginalized groups (in STEM) from various races, ethnicities, LGBTQ+ statuses, and/or genders? And how do these perceptions compare to overall perceptions?
- b. In what ways does examining student perceptions contribute to the existing rehumanizing framework?

Study Design and Rationale

In this section, I discuss the research design and provide a rationale for choices made in the design process. General descriptions of the intended settings and participants, information on recruitment methods, and a brief overview of data collection methods are provided. First, I describe and justify the particular study design used – a transformative mixed methods design.

Transformative Mixed Methods Design

A mixed methods approach, namely collecting and analyzing both quantitative and qualitative data, with an emphasis here on qualitative data, was used to explore the research questions. Mixed methods research has been argued to be particularly useful when describing experiences that cannot be fully captured by using only quantitative or only qualitative data (Creswell et al., 2003). The research questions for this study need data with both breadth and depth to be answered, which is fitting for a mixed methods design.

More specifically, my study used a fixed mixed methods design because the “use of quantitative and qualitative methods [was] predetermined and planned at the start of the research process” (Creswell & Plano Clark, 2011, p. 54), and then carried out as planned. Further, I am using a transformative mixed methods design. Creswell and Plano Clark (2011) state that mixed method studies that use a transformative-based framework or “advocacy and emancipatory worldview” (p. 99) are denoted as using a transformative design. “A transformative-based theoretical framework is a framework for advancing the needs of underrepresented or marginalized populations” (p. 96). They go further to state that “it involves the researcher taking a position, being sensitive to the needs of the population being studied, and recommending

specific changes as a result of the research to improve social justice for the population under study” (p. 96). Recall from Chapter 2 that the rehumanizing mathematics framework was designed from a sociopolitical stance and is intentionally developed to inform systemic changes to mathematics education to be more inclusive of students from historically marginalized populations. Therefore, a transformative mixed methods design precisely aligns with the theoretical underpinnings and goals for this study. A transformative mixed methods design entails making all research design and implementation decisions with the social justice framework as the guiding principle, in this case the rehumanizing framework (see Figure 3).

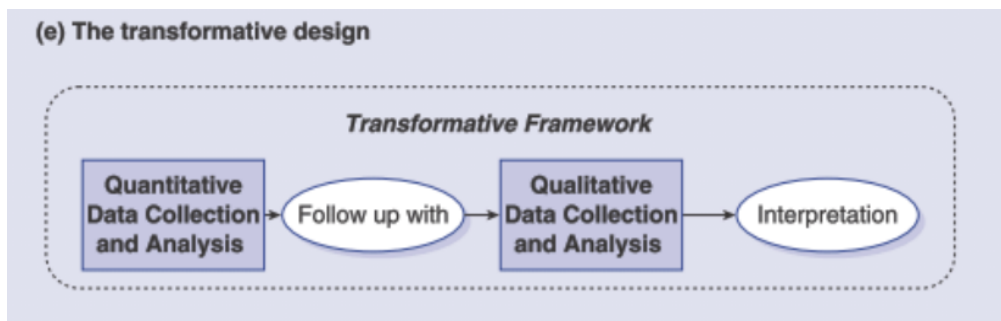


Figure 3. Transformative Design graphic from Creswell and Plano Clark (2011, p. 70).

Creswell and Plano Clark (2011) suggest several decisions that must be made for a sound mixed methods study, including the: (1) level of interaction between the quantitative and qualitative data, (2) priority of the qualitative vs. quantitative strands, (3) timing of data collection, and (4) timing and implementation of data mixing. Because the qualitative data collection was dependent on the quantitative data collection phase, my study has an interactive level of interaction, i.e., not an independent level of interaction. The quantitative data are mainly being used to answer the overarching research question, whereas the qualitative data are used to answer part (a). Then, the entire data corpus is being used to answer part (b). Consistent with a

transformative design, quantitative data were collected and analyzed to inform qualitative data collection. With regard to priority, there is greater emphasis on the qualitative data in this study. The quantitative data are used to explore differences of responses between groups of students. The qualitative data are used to provide a rich narrative of how students view teaching practices, structures and pedagogies that fall within the rehumanizing dimensions, as well as teaching moves that might be outside that stated framework. This is a sequential study because no further quantitative data were collected after the first stage, and the second stage of data collection was purely qualitative. Mixing can occur at “four possible points during a study’s research process: interpretation, data analysis, data collection, and design” (Creswell & Plano Clark, 2011, p. 66). For my study, mixing certainly occurred during design, where the qualitative component was informed by the quantitative, data analysis and interpretation. More details about mixing the data are described in the Data Collection and Data Analysis sections of this chapter.

Overview of Study Design

Consistent with the transformative mixed methods design described by Creswell and Plano Clark (2011), this study first collected primarily quantitative survey data and then qualitative interview data. Collecting the quantitative survey data was a necessary starting point for a couple reasons. The overarching research question asks broadly what college Calculus 2 students view as rehumanizing in their undergraduate mathematics classes and thus data from a more representative sample of Calculus 2 students was needed to investigate and identify potential patterns of answers. Preliminary analysis of the quantitative data informed who qualitative data were collected from and how data collection protocols were adapted. The survey also contained two essay questions, however, the qualitative data on the survey were not

analyzed to inform the rest of the qualitative methods. (Instead, the survey essay questions were later analyzed as part of the qualitative methods.) Second, qualitative data was collected through a series of interviews with the focal sample of students identified from the survey results, because rich descriptions of students' experiences are required to answer the more nuanced research questions. Thus, the quantitative data allowed patterns to be identified, while the qualitative data then provided more detail to explore those patterns in depth and answer the research questions. As such, this mixed methods approach increases the potential of this research to shed light on anything that might be missing or not fully described in the rehumanizing framework, and thus contribute to that existing framework, especially from the perspective of STEM-intending college calculus students.

Because my goal is to seek information directly from students to uncover patterns of thinking regarding humanizing pedagogies, I needed to hear from lots of students, especially those in groups who have been historically marginalized in STEM. This necessitated doing interviews of many students to have enough voices to find recurring themes. Additionally, both quantitative and qualitative data were required from a wide range of students so I could analyze and determine if there were significant differences and to determine if the curb-cut effect¹⁵ would apply here. For these reasons, doing a case study or a phenomenological study were ruled out, for example, and this mixed method transformative design was chosen. Moreover, the reason that only one round of interviews were conducted, as opposed to two rounds of interviews, for example, is because there was nothing noteworthy that seemed necessary to probe further in

¹⁵ The curb-cut effect was named when the benefits to a wide range of people were noticed after curbs were cut out of sidewalks to allow people in wheelchairs to navigate their own transportation more easily. So although the intended benefits were targeted to one group of people, many other people also benefited, like parents pushing baby strollers, kids riding bikes, elderly people with bad knees, etc.

another interview. In other words, there was enough repetition of themes in the interview and survey data that gathering further data with this group of students was not warranted. As an alternative approach, I could have observed students in their mathematics courses to witness their lived experiences which would provide richer descriptions of in-the-moment experiences that would couple researcher observations with student voices. However, my goal was not to compare or to describe student experiences in conjunction with my own observations, but to re-voice students' own perceptions.

One key benefit of using the transformative design for this study is that it seeks to empower the research participants, which in this case is achieved by elevating and centering the voices of students who are not often visible in mathematics education research. As discussed in more detail in Chapter 2, the sociopolitical and relational foundation of the rehumanizing framework calls for researchers and educators to teach in ways that are emancipatory and empowering, particularly for students who have historically been ill-served. Advocacy is at the center of both transformative design and the rehumanizing framework.

Settings and Participants

In this section, I provide information about the institutions where data were collected, as well as a description of how calculus courses are implemented at each institution. Lastly, I describe the process for recruiting students as research participants.

Institutions

For this research, all data were collected from students at two western, public, United States R1 institutions in the 2021-22 academic year. One of the institutions is large (pseudonym

of Canyons Bluff State University, or CBSU) and one is medium-sized (pseudonym of Highlight State University, or HSU). Both CBSU and HSU are predominantly white institutions (PWIs). HSU has a total student population of about 16,700 and CBSU is larger with a total student population of about 32,800. For the 2020-21 academic year, about 65% of CBSU's students identified as white, and for the 2019-20 academic year, about 84% of HSU's students identified as white.

Given the fact that this research is precisely attending to equity concerns, which are frequently experienced at PWIs, collecting data from such institutions fits within the transformative design. Additionally, results of this study will likely be applicable and beneficial for a wide range of students at all institution types, as has been seen with the curb-cut effect in various other studies (e.g., Johnson & Fox, 2003; Mate, 2022), making the concept somewhat ubiquitous (e.g. Blackwell, 2017). The curb-cut effect asserts that investing in one group, typically the most vulnerable group in a particular setting, can have positive impacts that support the well-being of everyone, thereby helping to create a just and equitable environment. This is similar to what some call “universal design for learning” where educators create curriculum designed to flexibly serve all students, including those with disabilities (e.g. Rose & Meyer, 2006). In this study, the notion of the curb-cut effect (or universal design) centers students from marginalized groups in STEM.

Due to past and current connections within the respective mathematics departments, I had access to Calculus 2 courses and students at both universities. To be clear, convenience and institutional characteristics were the main reasons I selected these institutions. This access made it possible for me to make a human-to-human connection with students, an important element of this study given my intention to center humaneness in mathematics teaching. Calculus 2 students

are the focal group for this study because all STEM majors require Calculus 2 at HSU and CBSU (as is true at most post-secondary institutions), and thus this is a reasonable mathematics class to access STEM-intending students. Both institutions have well-regarded engineering and science programs. Also, both mathematics departments teach calculus classes that primarily serve engineering, physics, and other STEM departments, as well as preparing their own mathematics and statistics majors.

Calculus at HSU and CBSU

HSU offers one calculus track with an honors section. This calculus sequence serves engineering students as well as a large number of students in other science and mathematics majors. The Calculus 2 courses are taught in small to medium class sizes, about 25-60 students in each class, by tenure-line or teaching faculty.

At CBSU, there are two main tracks of calculus, including a “regular” calculus track and an engineering calculus track. The regular calculus track is the traditional calculus sequence that has been taught at the institution for many decades. These calculus courses are taken by a variety of students, including engineering, physics, computer science, mathematics, biology, and chemistry majors; whereas the engineering-oriented calculus courses are typically taken by strictly engineering majors. The engineering calculus track covers the same content as the regular calculus track overall, but it was specifically designed to serve engineering majors, implementing a greater emphasis on application problems and presented in an order that is preferred by the engineering college. It is worth noting that at CBSU, engineering majors, including computer science, comprise the bulk of the students in both calculus tracks because those are the primary majors that require calculus. Both tracks are necessary to accommodate a variety of needs for the

large numbers of engineering majors, including transfer credit, scheduling needs, and later-than-entrance major decisions. The honors calculus courses are typically small and only taken by students who wish to major in mathematics and get an honors designation on their diplomas. Calculus classes range in size from 25 to 200 students.

At CBSU, classes are largely taught as traditional lecture-style courses by tenure-line faculty, teaching-track faculty, post-doctoral faculty or seasoned graduate student instructors (GSI), meaning GSIs with two or more years of teaching experience. The engineering calculus courses also have a required discussion section each week, run by a graduate student teaching assistant (GTA). Typically the GTA running the discussion session has fewer than two years of teaching experience.

Calculus 2 classes at both institutions are taught by the mathematics departments and are coordinated (i.e., supervised) by a mathematics faculty member, with varying levels of tightness in their coordination. The regular calculus track courses at CBSU are more loosely coordinated, whereas the engineering calculus track courses at CBSU and the regular calculus track courses at HSU are more tightly coordinated. Coordinated sections at both CBSU and HSU indicate consistent content coverage, similar pacing, and at least some common final exam questions across all sections. Tighter coordination efforts of classes include additional uniformity, like all section teachers using the same notes or same exams or same homework assignments. Coordination efforts are in line with the Progress through Calculus reports (Bressoud & Rasmussen, 2015; Bressoud et al., 2015) and are intended to ensure some level of common experience for students across sections of that course.

For fall 2021, there were a total of 634 students enrolled in the three different versions of Calculus 2 at CBSU. At the HSU there were 287 total students enrolled in Calculus 2. Thus, a

total of 921 students were enrolled in Calculus 2, between the two institutions. All 921 students were invited to participate in the study.

Recruitment Design

Institutional Review Board (IRB) approval was obtained from each participating university separately, along with additional legal documentation regarding the sharing of data between research partners at both institutions.

Surveys were provided to students by first gaining permissible access to them via their instructors and/or course coordinators/supervisors. In order to answer the overarching research question, all Calculus 2 students were invited to participate in this survey. The analysis of the survey data is intended to aid in recognizing patterns of perceptions of structures, practices and pedagogies in mathematics classes for a wide variety of students.

I provided a personal invitation to participate during the first few minutes of almost every section of Calculus 2 at both institutions. In this time, I explained the purpose of the research study and provided a handout with information. I made it known explicitly that the intention is to elevate and center the voices of students regarding what they might find beneficial about their college mathematics courses, with the hope that their experiences and voices can impact university-level mathematics teaching decisions in the future. The general wording used to verbally invite students to participate in the quantitative stage is included in the Appendix, along with the handout. The goal with these introductions was twofold. First, relating to the calculus students in a personal way and thus becoming human to them, as opposed to simply emailing them an invitation which might seem sterile, is in line with the spirit of the rehumanizing framework. This is because the rehumanizing framework, at its core, is about connections both to

people and to students' lives outside of school mathematics. Second, personalizing and explaining the research may have solicited higher rates of participation and helped students feel more comfortable with their participation and what they were being asked to do. At that time, I also communicated that some students would be invited to participate further in the qualitative stage.

With that said, there were three instances where meeting with a class in person to invite participants did not work out. For example, at HSU, one Calculus 2 course was offered at the exact same time that I was teaching a different course which meant I did not visit that class in person. For this case, I sent a few-minute video invitation for students to fill out the survey. As another example, at CBSU, there was one section of Calculus 2 that was a fully asynchronous online course, which meant that the recorded video invitation was the only way to reach students. Finally, at CBSU, there was another section of Calculus 2 that was a synchronous online course, taught in Zoom, which meant that my visit was online rather than physically in person. Table 1 provides information about when my in-person classroom visits took place or that a video introduction was sent.

Institution	Course #	Day of my visit
HSU	Calculus 2 Section 01	NONE (sent video)
HSU	Calculus 2 Section 04	Monday, 11/29
HSU	Calculus 2 Section 07	Wednesday, 12/1
HSU	Calculus 2 Section 10	Wednesday, 12/1
CBSU	Calculus 2 Section 01	Friday, 11/19
CBSU	Calculus 2 Section 02	Monday, 11/22
CBSU	Calculus 2 Section 03	Tuesday, 11/30
CBSU	Calculus 2 Section 04	Monday, 11/22
CBSU	Calculus 2 Section 05	Monday, 11/22
CBSU	Calculus 2 Section 06	Thursday, 11/18
CBSU	Calculus 2 Section 08	Tuesday, 11/23
CBSU	Calculus 2 Section 90	NONE (sent video)
CBSU	Honors Calculus 2 Section 01	Monday, 11/22
CBSU	Engineering Calculus 2 Section 01	Tuesday, 11/23
CBSU	Engineering Calculus 2 Section 02	Friday, 11/19
CBSU	Honors Engineering Calculus 2 Section 01	Tuesday, 11/23

Table 1. Schedule of visits to Calculus 2 classes to invite students to participate in the survey.

Although instructors at both institutions had the choice to offer their students some incentive for filling out the survey, such as a small amount of extra credit or an extra dropped low quiz score, most instructors did not offer any incentive. I did not collect student id numbers or university email addresses in the survey, so if instructors offered an incentive, it had to be at the class level. For example, if 80% of the entire class sent in their completed survey screenshot, then the whole class of students received some small benefit. Students could open the survey link where the first question was about informed consent. Whether or not they consented to the survey, they were given a completed survey screen. At least one instructor at HSU did offer such

an incentive for their students, in two sections of Calculus 2. This incentivization was approved by the IRB office at each institution.

After the first round of survey invitations to students were completed, I sent the video invitation to all Calculus 2 instructors to provide to their students. One week later, I sent one last reminder to all instructors, asking them to give the survey information to students with a reminder that I would be closing the survey by the end of that week. The survey was officially closed by Monday, December 12, 2021.

Data Collection

In this section, I provide more details about the data collection process, including the creation of the instruments and protocols used.

Survey Instrument

The first layer of data collection was in the form of a survey offered to all Calculus 2 students from both participating institutions. The survey data, along with student consent to participate, was gathered electronically via Google forms, using an institutional, secure Google account that meets privacy and confidentiality regulations required by federal law and was approved by the IRB. Survey questions were of three general types: Likert-scale, short answer (demographic) and essay questions.

The quantitative section of the survey included 24 Likert-type questions based on the rehumanizing framework. There were eight scenarios, one for each rehumanizing dimension (see Table 2), each with three Likert questions. The goal of these questions was to understand how students rank different dimensions with regard to the humanizing-ness of that dimension, using

the scenario as a stand-in for its dimension and using different proxy words rather than humanizing in the Likert questions.

These scenarios were first created by me during and right after participation in a two-week rehumanizing workshop led by Gutiérrez (2021). Feedback was sought by workshop participants, as well as from Gutiérrez. Following the workshop, I piloted the scenarios with four previous Calculus 2 students, which provided small edits to the scenario wording. In particular, I switched to the “imagine” language used here after the pilot survey was completed. I then finalized the scenario wording in consultation with four other qualitative research scholars.

Rehumanizing Dimensions (Gutiérrez, 2018)	Survey Scenarios
Positioning/Participation This dimension involves recognizing hierarchies in classrooms and society and shifting the role of authority from teacher/text to other students.	Imagine that your calculus instructor invites you to work on calculus problems with your neighbors at least a few times per class for rough draft thinking, i.e., to begin producing solutions that you would be able to revise throughout the lesson. The instructor also recognizes and builds on ideas and strategies used by students, allowing their questions and knowledge to guide some of the class time. Class time always includes discussion between students and teacher.
Cultures/Theirstories This dimension acknowledges students' funds of knowledge, algorithms from other countries, the history of math, and ethnomathematics.	Imagine that every week in your calculus course, the instructor spends a few minutes in class to discuss a current-day Indigenous, Black, Latinx, female or LGBTQ+ mathematician and showcase a bit of their work. A write-up and web links are also provided for each highlighted mathematician so you can read more about these people and their mathematical work on your own time.

Table 2. Description of Rehumanizing dimensions with corresponding survey scenarios.

Windows/Mirrors For this dimension, students can come to see themselves in the curriculum and also others or a new way of viewing the world. Students can be taught to appreciate (not just critique) the view of others.	Imagine that your calculus course is structured in a way that allows you to see a variety of ways to solve the same problem by sometimes seeing how other students in the class think through the problem and sometimes having your own work highlighted.
Living Practice/Futures This dimension underscores mathematics as something in motion. It includes debates, rule breaking, divergent answers, and doing mathematics for one's own purpose.	Imagine that several times throughout the semester, through both (a) in-class activities or problems and (b) a project assignment, you get to see and work on mathematics problems that you personally think will impact or apply to your future career or interests.
Broadening Mathematics This dimension expands the view of what mathematics is (algebra, geometry, etc.) and makes room for other forms of mathematics that can allow students to see more qualitatively.	Imagine that several times throughout the semester your instructor provides opportunities for you to practice doing mathematics outside of the traditional curriculum and to pose mathematical questions you want to explore. For example, they might spend a class day discussing and having students bring examples of how art is connected to mathematics.
Creation This dimension can encourage students to invent new algorithms or forms of doing mathematics that are consistent with their own values.	Imagine that as a regular practice, your calculus instructor poses questions that allow you to play with the mathematics and algorithms you're learning and provide a supportive space for you to create your own algorithms. For example, you might be asked to use examples and patterns to find a formula for the nth derivative of a given function and compare your answers with your peers for similarities and differences.

Table 2 Continued. Description of Rehumanizing dimensions with corresponding survey scenarios.

Body/Emotions By attending to emotions, individuals are encouraged to be more in tune with themselves and less likely to succumb to pressures to ignore their senses and "just pretend" in order to do school mathematics. Mathematics would conjure up feelings of joy.	Imagine that a few times during the semester, your instructor invites the students to participate in an improvisational mathematics activity or some other activity that involves you moving around. For example, you might work in small groups of students, getting up from your seats to do a card-matching activity, matching printed graphs of functions to their derivative graphs.
Ownership When students feel they are doing mathematics for themselves and not for others, there is a sense of play or expressing oneself through mathematics. One sign is when they choose to continue to grapple with mathematics problems long beyond the school bell or when they pose new questions.	Imagine that your instructor frequently invites all students to bring mathematical problems to them that come up in other classes or in your outside communities to work on both in class and for students to continue working on outside of class. Additionally, with the consent of you and the other students, the instructor updates the course structure and curriculum of the course to include such mathematical problems as they come up.

Table 2 Continued. Description of Rehumanizing dimensions with corresponding survey scenarios.

For each scenario, students were asked to answer the following three questions.

- A. I would likely feel valued and an increased sense of belonging.
- B. I would likely feel a sense of connection between mathematics and my life.
- C. I would likely feel supported in my learning.

Answers to the Likert questions were required for students to complete the survey. These questions served as proxy questions to get at the heart of the intentional outcomes from rehumanizing efforts within a class. Using the same three questions for each scenario enabled the analysis of responses to be compared across dimensions and to gather information about which

scenarios were more or less compelling than others for this sample of students. Each scenario served as a snapshot of one of the rehumanizing dimensions, which meant that I used the survey scenarios to get information from students about their feelings of which rehumanizing dimensions were most important to them. Having the same three questions for all scenarios in the survey was important because the survey is not a validated instrument for measuring rehumanizing perceptions. In fact, no such instrument currently exists that measures the rehumanizing construct or the impact of rehumanizing practices.

Since rehumanizing is not a word that is in the typical college student's lexicon with regard to mathematics, proxies must be used in eliciting responses from students that will target their feelings of experiencing mathematics as rehumanized. One outstanding question, then, is how will students internalize or feel that mathematics classes are humanized? In other words, how will students experience the effects of rehumanizing efforts and thus what Likert survey questions should be asked on the survey instrument? As Gutiérrez (2018) points out, rehumanizing mathematics seeks to "recouple [mathematics] with connection, joy and belonging" (p. 4). When students feel they are in a humanizing space, they can "feel whole as a person...while participating in school mathematics" (p. 1) which includes feeling fully supported in their learning.

Because sense of belonging is an area of vast scholarly work, a brief exploration into belonging literature is warranted here. One definition of belonging comes from work done by Hurtado and Carter (1997) and it includes " 'fitting in' on campus, perceptions of the warmth of interpersonal relationships, and feeling unpressured by 'normative' differences between [students] and the environment" (p 325). Strayhorn (2018) further states that "true belonging is not about fitting in; it's about being authentically oneself, flaws and all" (p. 9). These definitions

align with the love and care element discussed in Chapter 2 that is a foundational piece of the rehumanizing framework as well as work done by Baumeister and Leary (1995) in which they conclude that all human beings need to feel a sense of belonging. Engagement, persistence, and a student's relationship with their instructor are all strongly correlated with their sense of belonging (e.g. Strayhorn, 2018; Trujillo & Tanner, 2014; Wilson, et al., 2015). Additionally, a student's perception that the material they learn is "valuable, useful or important" (Trujillo & Tanner, 2014, p.10) for their future or somewhere in their life outside the classroom is strongly correlated with their sense of belonging. Essentially, students want to know their ideas are valued and that they are important as human beings in their learning environment. This is especially true where a student is "prone to feel alienated, invisible, (pre)judged, stereotyped, or lonely" (Strayhorn, 2018, p. xiv).

Thus, the three Likert questions aim to operationalize what a rehumanized mathematics classroom would feel like or be internalized for students. Feeling valued and a sense of belonging is called for explicitly in the rehumanizing framework, as quoted above. Having students feel supported in their learning squarely addresses the achievement and outcomes aspect of equity, which is the foundation of the rehumanizing framework. Finally, connections between mathematics and life outside of school are built into the cultures & their stories (dimension 2), living practice (dimension 4), broadening mathematics (dimension 5) and ownership (dimension 8) rehumanizing dimensions.

Next, identity and demographic data were collected in the survey, including gender, race or ethnicity, major, and LGBTQ+ status (see Table 3). This section of questions was intentionally placed after the eight scenarios to help lessen the possibility of stereotype threat, since previous studies have shown that answering identity-related questions first can impact the answers to later

questions (e.g., Spencer et al., 2016). Given the literature regarding how undergraduate calculus courses are racialized and gendered spaces for students (e.g. Leyva, 2021; see Chapter 2 for further details), the order of survey questions needed to be considered in order to minimize stereotype threat and reduce the risk that the survey itself makes identity salient in an artificial way.

These demographic questions (see Table 3) were open response questions to maximize the freedom students had to answer as they saw fit, regarding their own identities. Answers to these questions on the survey were not required. However, it was the hope that most, if not all, participating students would fill out this information as it is indeed important to the research itself since the desired focus of this study is to center voices of students from groups who have been historically marginalized in mathematics. The in-person method used to recruit study participants where I explained the purpose of the research to students potentially helped ensure authentic answers from students and was in line with the transformative and relational nature of this study.

Demographic and Identity Survey Questions
Gender
Race and/or Ethnicity
Major
Sexual Orientation
Do you identify as transgender or agender or nonbinary?
Are you willing to be interviewed for this research project to discuss your survey answers in more detail? Interviews will be conducted in one to two months from the time of this survey. Each interview will last between 20 and 60 minutes. If so, please provide your a. preferred name _____ b. personal pronouns _____ c. email address or phone number for text message (depending on your preference). _____

Table 3. Demographic and Identity Survey Questions.

The identity questions were asked as open-ended responses, rather than giving specific categories to choose from. This was done intentionally to allow students to self-identify in whatever way felt best for them. This certainly created data that was more varied than having only a handful of predefined categories, and thus required time to sort and clean the data. However, the time involved to do this extra work was tolerable and a reasonable trade-off in order to maximize students' ownership and freedom over how they identify. Additionally, since the framework for this transformative study centers students' voices and agency, it was crucial that these demographic questions provided the most freedom and ownership to students as possible.

Finally, the survey also had three essay-style questions, where students could give open responses about their experiences with and attitudes toward rehumanizing calculus or other mathematics classes. The three questions are listed in Table 4.

Open-ended Survey Questions
Please list at least one thing that college mathematics instructors could do (or already do) that would contribute to your sense of belonging in mathematics class, build connections to your life outside of class, and support your success as a student.
Please list at least one thing that college mathematics instructors could do (or do already) that would diminish your sense of belonging in mathematics class, make mathematics feel unrelated to your life outside of class, or adversely affect your success as a student.
(Optional) Is there anything else you'd like us to know or that we forgot to ask?

Table 4. Open-ended Survey Questions.

These open-ended questions were admittedly triple-barreled, meaning that there were possibly three separate layers to the question. For example, on the first question, a student might address something their instructor could do that contributes to their sense of belonging without mentioning anything about supporting their success or connections of mathematics to their life. In that vein, a student might not explicitly address any of the three elements of the question, but instead respond to something tangential that helps them feel positive in their mathematics class. This was by design. In analyzing the data, it was noteworthy to see which aspect(s) of the question compelled the student to write something meaningful for them.

The Likert questions for each scenario presented in the survey were given with seven possible answers, as shown in Table 5.

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

Table 5. Likert question possible answers.

The benefits of using a 7-point scale is that it can provide more accurate results than a 4 or 5-point scale, and can more easily be modeled as a continuous variable, rather than a discrete variable (Finstad, 2010), which was helpful for creating the random forest (discussed in the Data Analysis section below). Seven options for agreement are distinct enough that participants can choose an answer that reflects their true feelings.

Interview Protocols

After the survey data were collected, I considered the consent to be interviewed responses along with demographic data to find a group of Black¹⁶, Indigenous, Latin*, LGBTQ+ and/or women students to invite for an interview. Thus, the survey responses served as the basis for selecting a purposive sample (Creswell & Poth, 2018; Devers & Frankel, 2000; Patton, 1990) of interview candidates. Purposive sampling might also be called deliberate sampling. It is a type of non-probabilistic sample chosen deliberately, rather than randomly, when certain characteristics are intended to be studied. Purposive sampling is the most commonly used and accepted sampling strategy for qualitative research because the sample size is much smaller and the data collected from each participant is of greater depth. This type of sampling is also preferred to answer the research question on how certain identity groups of students view rehumanizing

¹⁶ Although the intention was to include Black student voices in this research, there were no survey responses from Black students.

mathematics, and it is in line with the transformative mixed methods design for this project, as well as the sociopolitical stance that the rehumanizing framework is built on. Indeed, Gutiérrez (2018) explicitly states the need to gather “evidence from those for whom we seek to rehumanize our practices that, in fact, the practices are felt in that way” (p. 3-4). This design is also in line with a study done by Leyva et al. (2021) with college calculus students to catalog ways they feel racialized and gendered in their mathematics classes. Having a few voices from different demographic categories helps address issues of intersectionality and has the potential to yield both similarities and differences among participants. Results of how this goal was realized (or not) are included in Chapter 4 of this dissertation.

To look for the pool of students from the desired groups this study focuses on, namely students who identify as Indigenous, Black, Latin*, LGBTQ+ and/or women, answers to the essay questions were reviewed within that subgroup of students to see if there were any enthusiastic responses that highlighted a student’s particular interest in being interviewed. To do this work, I first created a spreadsheet of survey responses from those students whose demographic information fit at least one of the focal groups for this research. I next looked at their open-ended responses and contacted first the students who showed a strong desire to be interviewed. For example, when asked if there was anything else the student wanted me to know, Alberto stated “As a minority and a student who does not consider mathematical concepts to come easily to him or intuitively, I have many ideas and thoughts about many parts of [the] educational process of learning math. If given the opportunity I would love to chat more in an interview.” Due to this enthusiastic response, Alberto was invited to be interviewed. Additionally, even if students did not express a strong desire to be interviewed, through their comments, I selected students for interviews if they agreed to be interviewed and had identities

that fit my research goals. For example, because I had so few students in the Indigenous or Latin* demographic categories, I invited each student expressing such an identity to be interviewed.

Due to the fact that there were no Black students who filled out the survey, their voices are unfortunately completely missing from this study. There were also very few students, only eight in total, who fit in the Indigenous or Latin* umbrella category. There were 40 students who listed some identity that fits within the LGBTQ+ category, and 49 students total identified as women. Overall, a subgroup of 29 students were identified as possible interviewees. Between December 18, 2021 and January 14, 2022, a total of 27 students were invited to participate in an interview from the identified group of possible interviewees. A few students responded with some interest and then did not follow up to set a time to interview. A few students did not respond at all to the invitation for an interview.

To invite students to be interviewed, I sent emails or texts, depending on which information and preference was stated by the student in their survey response, to about ten students. After receiving positive answers to my invitation, I set up several virtual interviews that were conducted and recorded in Zoom. The covid pandemic was surging at this point in time, so it made the most sense to conduct virtual interviews for ease of scheduling as well as to minimize travel and risk of exposure. I kept track in the spreadsheet who I had contacted and/or interviewed as well as how many times I contacted them. After the first six interviews were finished, I contacted another set of students for interviews and conducted more interviews. I continued in this fashion until all 20 interviews were completed. Students were contacted at most three times to see if they would like to be interviewed. The first interview was conducted on December 16, 2021, and the final interview was done on January 19, 2022. The only interview

done in person was at HSU with Finley on January 19th. All other interviews were done in Zoom. Each interview lasted between 40 to 75 minutes, was audio recorded and then each interview was transcribed verbatim.

The interviews were semi-structured, meaning interview prompts were prepared ahead of time with additional possible probing questions, and any key points that came up during the interviews were also explored spontaneously (Seidman, 2006; Weiss, 1994). In this way, detailed feedback was gathered from students regarding their experience with college mathematics courses and how those experiences felt humanizing or not for these students. Interviewees also had the opportunity to clarify and elaborate on the findings from their surveys. The individual interview protocols for each interviewee are included in Appendix A. Each interview contained five sections of questions, namely (1) Basic Information and General Experiences, (2) Survey Responses, (3) Role of Identity, (4) Humanizing, and (5) Wrap-up.

Semi-structured interviews are set up to handle variance in interview data and the probes that allow some leading by the interviewee. Such varied responses actually help attain the goal to explore what was more salient for the students within the rehumanizing framework. Thus, it was expected that slightly different data would be collected in each interview due to the nature of the follow-up questions to each participant's survey responses. For example, it could happen that one student had a lot to say about the body and emotions dimension question from the survey and little to say about the ownership dimension, which another student wanted to focus exclusively on participation and positioning. Interviews were used to elicit more detailed and individualized descriptions from the students to paint a fuller picture of what they view as rehumanized practices within their college mathematics classes.

One additional technique that was implemented in these interviews was to have some of the prepared interview questions provided to the student during the interview, either as a link for them to access electronically if the interview was in Zoom or printed on a sheet of paper if the interview was in person. At the appropriate time in each interview session, i.e., right before I asked the follow-up questions regarding their survey responses, the participant was given a few minutes to read over those interview questions, along with the survey questions as a reminder, and process their thoughts. Specifically, the students were given the Survey Responses section of questions from the interview protocol, a template of which is copied in Table 6. (The specific Survey Responses section of one such interview is included in the full interview protocol in Appendix A.)

This technique was in line with the caring underpinnings of the rehumanizing framework in the sense that it helped students remain calm and gave them an idea of what to expect for that section of the interview, allowing them to form some of their thoughts to help them articulate their ideas. When the interview resumed, I asked if there was any question that they deemed as the most important to them or most compelling for them to talk about first. The intention was to possibly shift the power dynamic to ensure that the student felt their voice was truly being centered and that they had some control over the sequence of talking points, which aligns with the ownership and participation/positioning dimensions of the rehumanizing framework. It additionally had the potential to yield more information about what they felt was most important, which specifically addresses the research questions. As it turned out, all interviewees preferred to go through the survey follow-up questions in sequential order as written.

From Interview Protocol:

Survey Responses

Now I would like to transition to discussing your survey responses. I have those responses here and would love to ask you a few questions about them. And, if you aren't sure why you said something or responded in a particular way and don't feel you can elaborate on the previous response, just say so; that's no problem at all.

Note: The questions listed in this section are more conceptual at this point, in order to get a feel for the types of probes I'll ask during the interview. To see the actual survey follow-up questions asked during the interview, see the full information in the Appendix.

1. In your survey, I noticed that you marked scenario X as more positively than scenario Y. I'm curious if you can explain why X feels more compelling for you than Y?

Follow-up question:

-What would make scenario Y better for your learning or help you feel more valued and empowered?

2. In your survey, you marked these four scenarios really positively. Can you describe how you would feel as a student experiencing these scenarios in a classroom?

Follow-up questions:

-How would that increase your learning in the classroom?

-How would this help you feel more connected to your peers and/or your instructor?

-Would this help you feel empowered and if so, why?

-In what way would this experience impact your feelings of persistence in your chosen STEM major?

-In what way would this experience impact your confidence?

3. In your survey, you marked these two scenarios really negatively. Can you describe how you would feel as a student experiencing these scenarios in a classroom?

Follow-up questions:

-How would this impact your learning in the classroom?

-Would this help you feel less connected to your peers and/or your instructor, and if so, why? What could make it better for you?

-In what way would this experience impact your feelings of persistence in your chosen STEM major?

-In what way would this experience impact your confidence?

Table 6. Template for survey follow-up questions asked in the interview protocol.

From Interview Protocol:
4. In your open-ended response, you said that X would contribute to your sense of belonging in the class. Can you expand on this sentiment? <i>Possible probes- What if this learning experience was implemented a bit differently, how would that impact your feelings of belonging? Can you recall a specific example when you experienced something similar to this in a mathematics class?</i> 5. You also said that Y would adversely impact your success in the class. Can you explain why and how you would feel and respond to that situation? <i>Possible probes- What would need to be changed about that situation in order for you to feel positively impacted? Can you recall a specific example when you experienced something similar to this in a mathematics class?</i>

Table 6 Continued. Template for survey follow-up questions asked in the interview protocol.

To create the survey follow-up questions for each interviewee, I created a spreadsheet that contained all the survey responses (one per row) of the interviewees. I color-coded the survey responses with one color per scenario, i.e., for that scenario's three Likert questions. The most positive scenario ranking by that student was color-coded as the darkest green. Then subsequent positive answers were color-coded varying shades of green. More overall neutral answers, per scenario, were coded as some sort of light yellow, and, the most negative scenario responses were coded as some shade of red, with the brightest red being for their most negatively-ranked scenario (see Figure 4). This allowed me to quickly and visually find more positive, neutral and negative rankings for the scenario and I filled in the survey follow-up questions accordingly. For example, I could tell which scenario was ranked most positive by a

student, which then allowed me to fill in survey follow-up question #1 in Table 6. Additionally, if I noticed patterns for a given student, then I could probe that further during the interview. For example, if a student answered Agree or Strongly Agree on every single question, I could ask them about the reason for that pattern.

Strongly Agree	Strongly Agree	Strongly Agree	Agree	Agree	Agree	Somewhat Agree	Agree	Somewhat Agree	Neutral	Somewhat Agree	Somewhat Disagree	Agree	Agree	Agree
Somewhat Agree	Neutral	Neutral	Disagree	Disagree	Neutral	Agree	Agree	Agree	Somewhat Agree	Somewhat Agree	Somewhat Agree	Agree	Agree	Agree
Neutral	Neutral	Neutral	Somewhat Agree	Neutral	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Agree	Somewhat Agree	Agree
Somewhat Agree	Neutral	Neutral	Strongly Agree	Somewhat Agree	Strongly Agree	Neutral	Strongly Agree	Agree	Strongly Agree	Agree	Strongly Agree	Agree	Somewhat Agree	Strongly Agree
Agree	Strongly Agree	Neutral	Agree	Strongly Agree	Agree	Somewhat Disagree	Somewhat Disagree	Neutral	Disagree	Disagree	Disagree	Neutral	Neutral	Neutral
Somewhat Disagree	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Somewhat Agree	Agree	Agree	Agree	Agree	Disagree	Disagree	Disagree	Somewhat Agree	Agree	Agree
Agree	Agree	Agree	Agree	Somewhat Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Neutral	Agree	Agree	Agree	Somewhat Agree	Agree
Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree

Figure 4. Sample color-coding of the survey data for interviewees that was used to create the survey follow-up interview questions.

During each interview, I engaged with the student by listening intently and taking researcher notes on paper (with a pen). Primary focus remained on the student interviewee throughout the interview. When it seemed appropriate, I shared appropriate small pieces of information about myself or experiences in order to build rapport and help the student feel comfortable sharing about their experiences. For example, in one interview, I shared that I had also been in the military when a student discussed their time in the U.S. Navy. On the other hand, I did not share my own experiences in college mathematics courses, since that might bias a student's answer. All questions from the protocol were addressed by each interviewee, and appropriate probing questions were used as needed. Additional questions were sometimes asked during the interview to clarify a salient point the student brought up or to investigate further about something the student mentioned that was worth elaborating on. For example, in one interview, a student talked about how they did not like it when mathematics classes felt political,

which prompted me to probe them further about what that word meant to them or how that had been enacted in their previous experience.

Researcher Notes

During and right after all interviews, researcher notes were written regarding anything that seemed noteworthy or unusual and to summarize the key points (Creswell & Poth, 2018), which is sometimes called reflexive note-taking. These notes also contained in-the-moment ideas about how the data from different interviews aligned or countered each other. Additionally, the notes occasionally contained ideas about themes that were appearing or notes about other data that might be helpful to collect in future interviews or studies. All such thematic notes and summaries took into account the theoretical framework and research questions that guide this study. Finally, any email conversations that took place while scheduling interviews and member-checking were kept as data when the student added further comments or elaborated on more recent experiences that, to them, seemed relevant to this research. These researcher notes were then used during the data analysis process to help triangulate between all data sources.

Data Analysis

In this section, I describe the data analysis process, including analysis of both the quantitative and qualitative data. Recall that there is a much heavier emphasis in this study on qualitative data than quantitative data.

Quantitative Data

Demographic data collected on the survey were cleaned and circle graphs, aka pie charts, or frequency charts were used to display the data and understand the sample. Cleaning the

demographic data for gender, race and/or ethnicity, major, sexual orientation and trans status involved collecting students' open-responses and sorting them into categories. Two examples of this process include combining responses of "male" and "man" into one gender category of "Man," and collapsing student identities of Hispanic, Latino or Latina into one category called "Latin*." In total, there are five such charts, one each for Gender, Race and/or Ethnicity, Sexual Orientation, Trans or Non-binary Status, and Major. More detailed descriptions of how each category of data was cleaned is provided in Chapter 4, along with the actual charts.

To prepare for the next level of quantitative data analysis the survey responses were divided into two groups, named focal and dominant groups. The focal group consisted of all responses where the student self-identified as being a woman or in the LGBTQ+ community or as Native American, Latin*, Asian, or as a combination of two races, which were then categorized as Mixed Race¹⁷. The dominant groups contains all responses from students who identified as white, cis-man and heterosexual. This step was done in line with the rehumanizing framework and the research questions for this research because students in the focal group are those from historically marginalized groups in STEM fields. The goal is to center the voices of the focal group of students described here.

Descriptive statistics, including mean, median, mode and standard deviation, were calculated for each Likert question. Also, the mean and standard deviation values were computed for each scenario, using averages across all three Likert questions for that scenario. These statistics were first computed for all survey participants and then for each of the two groups, meaning the group-aggregated values.

¹⁷ There were no Black students who filled out the survey, which is why they are missing from this list.

For each of the 24 Likert survey questions, a histogram was created to display the distributions of responses between the dominant and focal groups. Then each of the Likert survey questions was analyzed using a chi-square test to examine any differences in distribution of responses between the focal and dominant group. The null hypothesis was that there is no difference between the two group distributions. This analysis sheds light on which scenarios or which of the Likert questions were significantly different between the focal and dominant groups.

To add more nuanced information about which of the rehumanizing dimensions, as operationalized through the scenarios and/or Likert questions, were most important for deciding from which group, i.e., focal or dominant, a student's response was from, I use classification trees. Essentially, the chi-squared tests showcase which Likert questions were answered in significantly different ways between the focal and dominant groups. The classification trees showcase which Likert questions, in order, were most compelling for predicting the group a particular response came from.

Classification trees can be used to visually display a set of if-then statements, when the end decision is binary in nature, which is the case here since the end decision is whether the response came from a focal or dominant group student. In particular, classification trees are helpful in creating and representing the fewest number of hyper-rectangular¹⁸ regions to partition the hyperspace represented by all variables in a dataset to probabilistically correctly bin the responses from a sample of responses. A different way to see the usefulness of classification

¹⁸ In mathematics, “hyper” is used as a prefix for spaces that have more dimensions than three. For example, in two-dimensional space a circle is defined as “the set of points that are equidistant from one fixed point called the center.” In three-dimensional space, we typically call that a sphere and in higher-dimensional space, we call it a hyper-sphere.

trees is that they can answer a question like “What is the probability that a randomly selected student’s response came from a member of the focal group given certain responses to one or more Likert questions?” In my classification tree, I use all 24 Likert questions to make a decision about which group, i.e., focal or dominant, that student’s response came from, so the final binary decision at the end of each tree branch is the group. This means the data the tree uses lives in 25-dimensional space, with 24 input variables (one for each of the 24 Likert questions) and one output variable, namely the group (focal or dominant).

Figure 5 (Bijkerk, 2018), shows a much simpler example of a partitioning of data with only two input variables, along with its classification tree. Note that I cannot provide such a partitioning example with my survey data because there are 24 input variables, not two, which means there is no way to visually represent the partitioning in two-dimensional space. I provide this figure because it is useful in the conceptual understanding of classification trees.

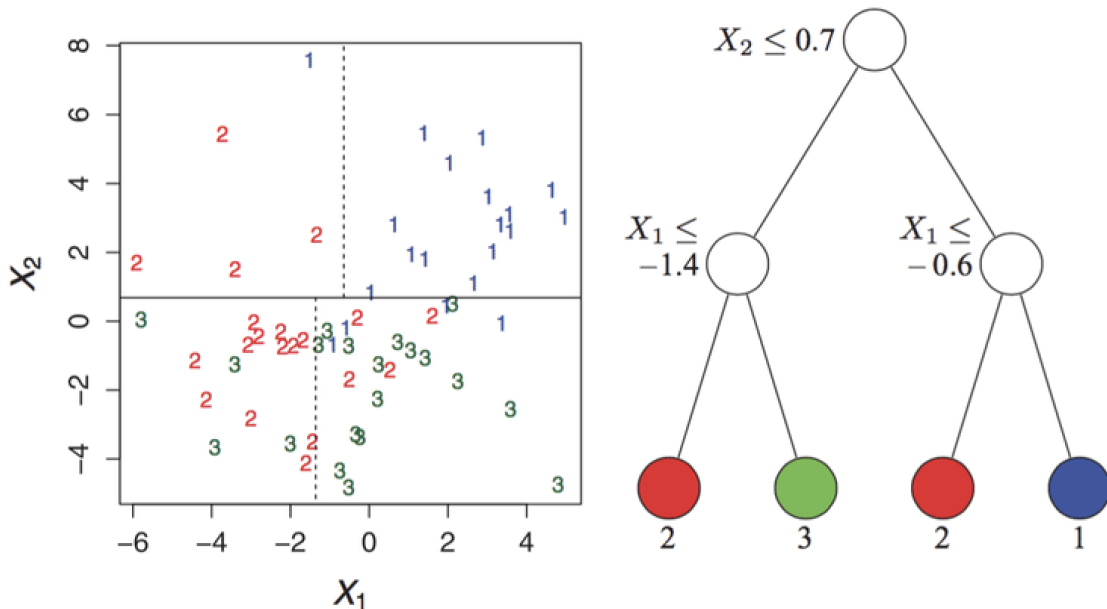


Figure 5. A visual representation of partitioning along with its classification tree for two input variables, X_1 and X_2 , and the output variable of 1, 2, or 3 (Bijkerk, 2018).

To explain the connection between the partitioning graph (on the left) and its tree (on the right), notice that the horizontal line segment drawn at $X_2 = 0.7$ corresponds to the first (top) node of the tree. If a response or data point has the characteristic that $X_2 \leq 0.7$ is true (false), then it travels down the left (right) side of the tree to the next level node. The dotted vertical line segments in the partitioning graph correspond to the next two tree nodes one level down from the top. In each of the rectangular regions in the partitioning graph, there is a preponderance of one output value. For example, in the top right rectangle, it is dominated by an output value of 1. The bottom right and bottom left rectangles appear to be not quite as homogeneous as the top two rectangles, but it does look like the bottom left rectangle is dominated by an output value of 2, as is indicated in the bottom left final branch of the tree. Thus, each node in the tree indicates the best place to divide the partitioning region into a smaller rectangle in order to maximize the homogeneity of output values in each rectangle. It is important to note that to get this partitioning graph, the order of the lines drawn has implications for being able to make accurate predictions. Finally, the bottom-most nodes in the tree describe which output value is dominating the corresponding rectangle in the partitioning graph.

With this foundational knowledge regarding the usefulness and conceptual nature of classification trees, I created an overall classification tree in R using all 24 Likert questions as input variables and the group, either focal or dominant, as the predicted variable. This allowed me to see which Likert items had the best predictive power to determine the group a student's response came from. This was a way to tell which scenarios were indeed ranked differently for the two groups of students as well as the ordering of importance based on when each partitioning took place. I next created three additional classification trees, one tree corresponding to the Value

& Belonging questions, another for the Connection questions and a last tree for the Supported Learning questions. Thus, in each of these trees, only eight input variables (one for each scenario) were used and the output variable was still the predicted group.

Qualitative Data

The bulk of the data collected for this study are qualitative in nature, including the essay-style questions on the survey and the transcribed interview data, as well as researcher notes. Each of the 20 interviews were audio recorded and transcribed verbatim. The preliminary step for analyzing responses to the open-ended essay questions from the survey and the transcribed interviews was to read through the entire data corpus to build familiarity. Then, the interviews were coded using NVivo software.

Deductive Process. Table 7 shows the process used for the deductive coding process of the interviews that is described in more detail below. Sections of the interview protocol, include

1. Section 1–Basic information/General experiences
2. Section 2–Survey Responses
3. Section 3–Role of Identity
4. Section 4–Humanizing
5. Section 5–Wrap-up.

Also, the sample interview protocol is included in Appendix A for reference.

<i>Deductive Coding process for each interview</i>
Go through <u>section 2</u> (survey responses; questions#7-13 in the sample interview protocol) plus the answer to <u>question #21</u> and code the student's answer or partial answer into the 8 dimension codes + All Dimensions code, e.g. 1-Participation & Positioning, 2-Cultures/Theirstories, etc. as needed. The only way something gets coded as All Dimensions is when the student says something that is related to all the survey questions or scenarios.
Go through <u>section 1</u> (Basic information) and look for anything that can go in the scenario themes (like the student said something about positioning and participation before I even prompted them about that in the survey follow-up questions).
Go through (a) <u>section 4</u> questions (Humanizing) and (b) <u>section 5</u> (Wrap-up) questions (#16-23) and (c) <u>question #12</u> (Humanizing; from the survey follow-up section) and bucket into the Humanizing parent theme and the Love & Care parent theme accordingly. <u>Notes:</u> A. ALL full answers for question #16 go into the Humanizing→Definition code, i.e., Humanizing Definition was a code within the Humanizing theme and that code had further sub-codes. B. All full answers for #17 and #20 go into the Humanizing parent theme. C. All full answers for #19 (and its offshoot questions) go into the Love & Care parent theme. D. For questions #22 and 23, the student's answer may or may not be coded. If they said something relevant to any of the parent themes, then it was bucketed accordingly.

Table 7. A description of the deductive coding process for each interview.

The interview coding process was first deductive, i.e., top-down, in that a priori themes were used for the different sections of interview question responses, as described in more detail below. Following that process of bucketing data into the parent themes, codes were created and defined within each theme as needed in NVivo. The unit of analysis was a fragment or entire answer to an interview question, often including the question along with the answer in order to maintain context. For example, if a student's response to a question focused solely on scenario 3,

then that was coded for Windows & Mirrors. However, if their response to an interview question addressed scenario 3 first and then they segued into discussing scenario 1, then the first part of their response was coded for Windows & Mirrors and the next part of their response was coded as Participation & Positioning. Additionally, there were times when a student was addressing two or more themes at once. For example, if a student was discussing the benefits of both scenario 8 and 2 in their response to an interview prompt, it got double-coded as being in both the Ownership and the Cultures & Theirstories themes.

For the first level of deductive coding, there were 11 parent or a priori themes altogether. These included one theme for each of the eight rehumanizing dimensions (8 parent themes), another theme labeled All Dimensions (1 parent theme, described below), as well as Humanizing (1 parent theme) and Love & Care¹⁹ (one parent theme) themes. In the next three paragraphs, I describe how the interview question responses were bucketed into each of the parent themes.

All interviews were first coded for section 2, i.e., the Survey Follow-up, interview questions and the question toward the end of the interview that asked specifically if there were any of the eight survey scenarios that felt more or less humanizing to the student. For these questions, student responses were bucketed into one or more of nine parent themes, namely the appropriate rehumanizing dimension themes (eight of them) plus a ninth theme sometimes utilized here, which I called All Dimensions. For example, if a student was saying something about all of the scenarios at once, like “all of the scenarios would support student learning,” then that response was coded as All Dimensions. This step was done for all interviews.

¹⁹ Recall that Love & Care was discussed in chapter 2 as the basis or glue that binds together the eight rehumanizing dimensions.

Next, section 1 questions from the interview, namely the Basic Information and General Experiences questions, were deductively coded into the eight rehumanizing dimension themes plus the ninth All Dimensions theme, as appropriate. For example, if a student mentioned something that related to one of the rehumanizing dimensions when prompted about how their mathematics class experiences have been, then it was coded as such. More specifically, a quote like the following would get bucketed in the Participation and Positioning theme: “I got together with some students in my Calculus 2 course who I sat next to and formed a study group. We worked on problems together and that collaboration helped me.”

Transcripts of responses to section 4 (Humanizing) and 5 (Wrap-up) questions from the interview protocol were coded next, as follows. All answers to the question “Since ‘humanizing’ might not be a word we typically use to describe mathematics classrooms, I’d first like to ask you, thinking broadly, what would it mean to you, or what would it look like, for a mathematics learning experience to be humanizing?” were put into the Humanizing Definition theme (which was a sub-code for the Humanizing parent theme). All answers to “I’m curious how important relationships with your instructor and peers are for you in your college mathematics courses?” as well as answers to the follow-up probes for this question were coded as Love & Care. All answers to (a) “Can you think of any specific mathematics experiences you’ve had thus far in college that you would describe as humanizing?” and (b) “Based on your own experiences, do you have any recommendations for instructors, for the university, or for other students regarding practices that would make mathematics learning experiences more humanizing?” were coded in the Humanizing theme. Finally, for the two final wrap-up interview questions, i.e., Section 5, a student’s response was coded only if it related back to one of the eleven parent themes.

From this deductive coding process, I bucketed the qualitative data into meaningful themes that reflected the eight rehumanizing dimensions, as well as more general themes, like humanizing and love & care which form the foundation of the rehumanizing framework (Gutiérrez, 2018). Thus, the output of this deductive process was the bucketed data, which was then used as the input for the next layer of coding.

Inductive Process. After the interview data was coded into parent themes, the second iteration of coding was a more inductive approach, i.e., bottom-up, going through the data within each theme and creating codes as needed, like child codes within each parent theme. The creation of the sub-codes was based on the content of students' full or partial responses that allowed me to find chunks of data that fit together, i.e., sub-codes were created both as a data condensation task and as a method of discovery (Miles et al., 2014). Figures 6 and 7 show the code trees with parent themes represented by rectangles and their sub-codes are shown attached to its corresponding parent theme, in rectangular-shaped-with-curved-corners boxes. The connectors are not meaningful in where they are attached to each parent theme. The connectors only show which parent theme that sub-code belongs to.

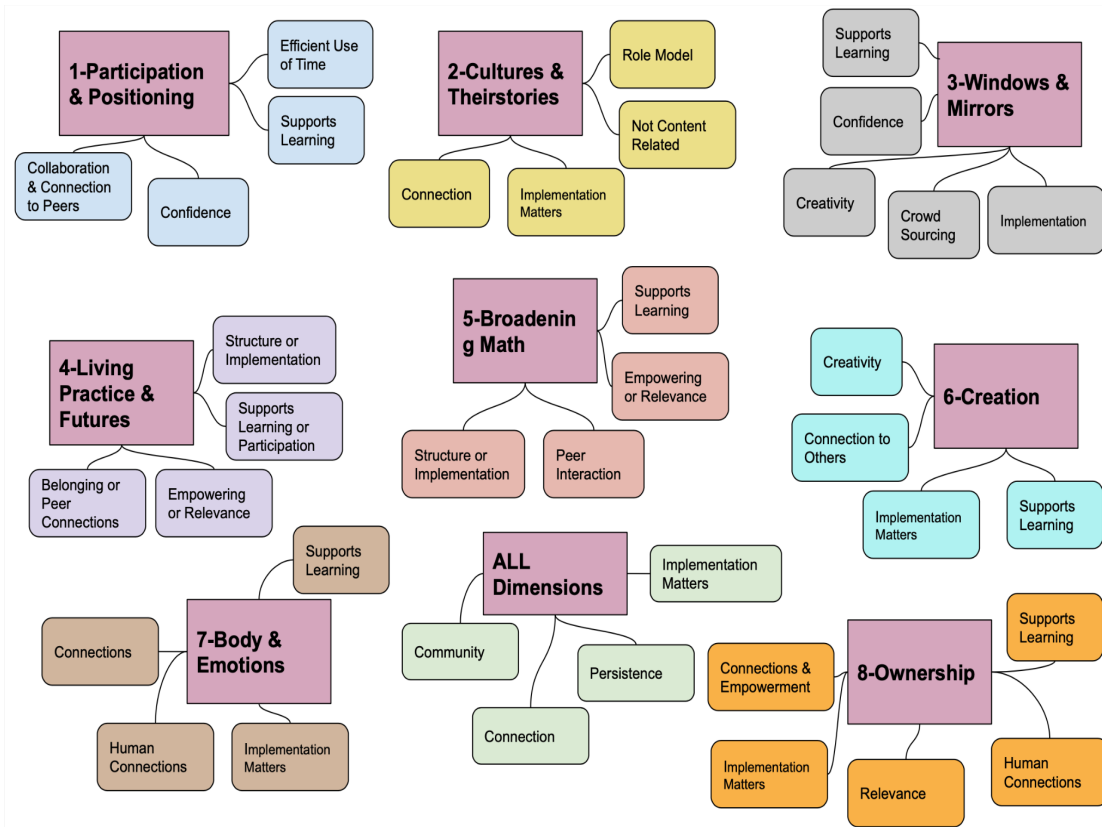


Figure 6. The code tree for all eight rehumanizing dimensions as well as the All Dimensions parent themes.

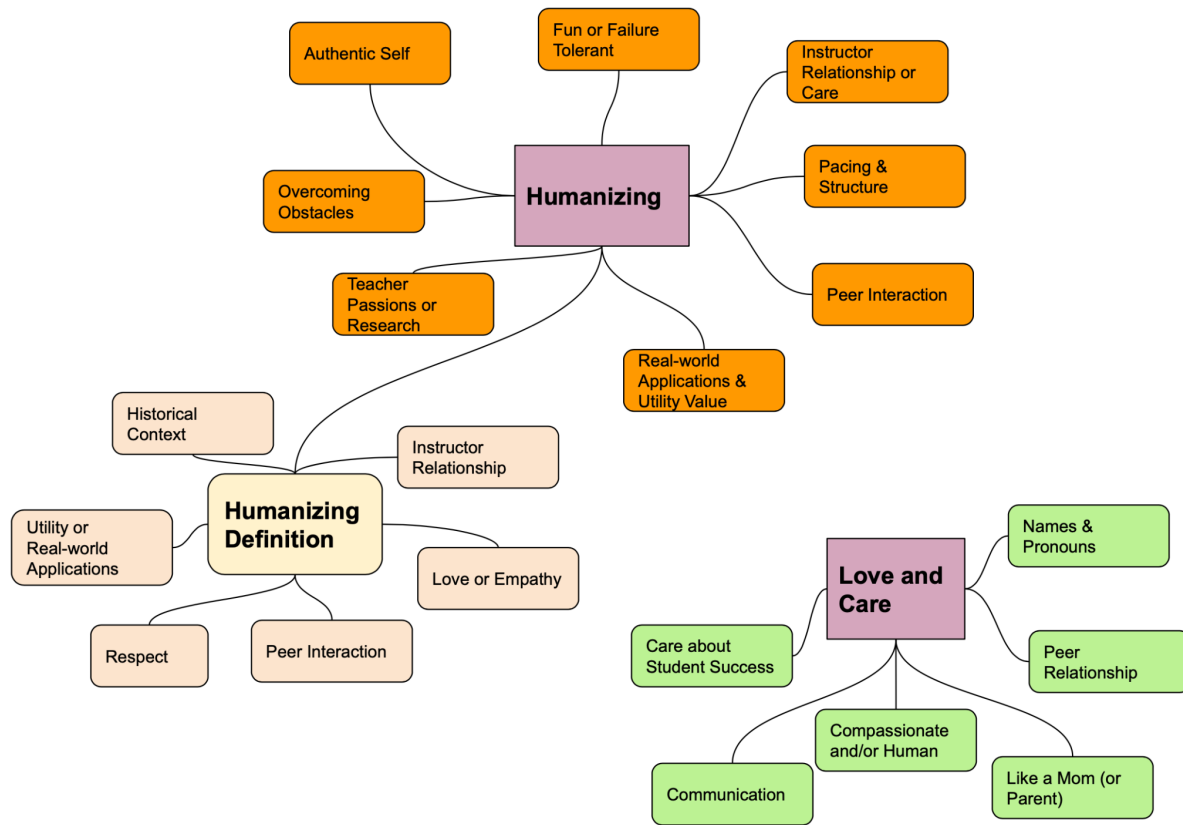


Figure 7. The code tree for the parent themes of Humanizing and Love and Care, along with their sub-codes.

Figures 8 through 19 show the code books for the parent and child codes as well as a description of each code and example quotes that would fit within the sub-codes.

Name	Description	Examples
1-Participating-Positioning	Parent Theme—for the rehumanizing dimension with this name.	
Collaboration & Connection to Peers	A few different things contribute to this code: 1. Collaboration is perspective-expanding 2. Collaboration can be done in ways that each person contributes part of the whole picture/concept 3. Collaboration is like “we’re all in this together” mentality. These can be either positive or negative references. Or the student mentions how this scenario impacts their connections to peers in some way.	- I just really don’t like working in groups in calculus. - I feel like learning with your peers and like working through a problem collaboratively is—is a good way to learn. - I get to share my knowledge or I get to share my thinking with other people and they—they can—they can, um, let me know what they think and like we discuss it together. So it’s like having that connection, I just like it.
Confidence	Confidence in themselves or their abilities to persist in STEM is impacted by this scenario.	Because if you could teach it then you learn it way better and then you feel a little bit more confident in it because you’re like, oh, I taught this person about it so I can—I can do it on the test by myself.
Efficient Use of Time	Student comments on how this scenario is either an efficient or inefficient use of time in the class in order for students to learn.	And I feel like it’s a—a good use of time to help better, uh, help me understand the material, uh, by doing it instead of just, uh, seeing, uh, seeing it on the board.
Supports Learning	Mentions that this scenario helps or hinders their learning or mathematical understanding (or both helps and hinders).	I think it improves my learning as well just because I’m able to explain a concept to someone else that maybe I don’t totally understand, but after I’m able to explain it to someone I’m like, oh I get it now.

Figure 8. Code book for rehumanizing dimension 1, Participation and Positioning.

Name	Description	Examples
2-Cultures-Theirstories	Parent Theme—for the rehumanizing dimension with this name.	
Connection	The student mentions something about this scenario that makes them feel connected 1. To peers—Like we’re all in this together. 2. To the environment—maybe meaning class/peers/life. 3. To the instructor.	I think the one, the first one about highlighting, you know, Black, LGBTQ, um, Latinx people, that would help me feel more connected to my peers because I know I’m not the only one in the room.
Implementation Matters	How the teachers does this matters to the students and could have positive or negative results.	I don’t feel spending a certain amount last time is necessary for that. Maybe make the, uh, those resources available online and just mention it instead of explaining things
Not Content Related	Noting that this doesn’t “fit” within a math class because it’s not math specific or not part of the curriculum. But it might still add joy or interesting tidbits. Or someone might be neutral or negative about this.	That would be very interesting. But I feel like when I go to like calculus class I want to learn calculus more than like—like I—I would—I’d be interested in taking like a math history class, I just feel like it’s a little bit off topic in that class.
Role Model	Students get to “see” mathematicians like them, i.e. not like white cis men. This may be positive or negative. This may also not be mentioned explicitly but implied, like by mentioning the marginalized status of the mathematicians would be impactful or how it’s inspirational to know about how others have overcome adversity.	- along with the one of learning about, uh, Black or Latinx or LGBTQ, uh, mathematicians, I think also just learning about ordinary people who have used math in a way to overcome adversity, um, is also very humanizing. - even if they’re fictional they show minorities in math and I feel like that’s very empowering.

Figure 9. Code book for rehumanizing dimension 2, Cultures and Theirstories.

Name	Description	Examples
3-Windows-Mirrors	Parent Theme—for the rehumanizing dimension with this name.	
Confidence	Mentions (with or without prompting) whether or not hearing/seeing/knowing different ways to do a math problem impacts their confidence.	• So usually when that happens, when they consistently show that student's work and how good they are, I feel like it kind of hurts other people's confidence because they're like, oh, I'm not as good as that person who's being shown right now. • I think it would definitely boost my confidence.
Creativity	Mentions the artistic or creative aspect of doing math in different ways.	• that is one of the coolest things about math because it feels like art
Crowd Sourcing	Helps relieve pressure from any one student to see multiple ways to do the same problem. Or the pressure possibly hurts students in some ways. This could be positive or negative for the student.	• I like seeing things from a lot of different perspectives because then it helps me understand like what's going on and like how things work.
Implementation	Ideas on how a teacher can implement this scenario so it benefits students.	• if like you have a different way of solving it instead of like going through and teaching that in the classroom, if they—if that student wants you to go over it or other students want you to go over that, like doing that outside of the class time, like during an office hours meeting, and like with class participation.
Supports Learning	Mentions that hearing/seeing different math perspectives helps or hinders their learning or mathematical understanding (or both helps and hinders).	• It just gives me like a bit too many options to figure out how I would do the problem. So I'm not really practicing any one more than the other, so I'm not really getting good at any of the different ways. • Seeing a variety of ways to solve one problem I think could be helpful.

Figure 10. Code book for rehumanizing dimension 3, Windows and Mirrors.

Name	Description	Examples
4-Living-Practice-Futures	Parent Theme—for the rehumanizing dimension with this name.	
Belonging or Peer Connections	Their sense of belonging or connections with peers would be impacted by seeing connections with math and other subjects/fields of study.	• I guess a problem with applications that I also have an interest in, um, then I think that could definitely help me connect to them.
Empowering or Relevance	This scenario feels empowering or inspirational or particularly relevant in some way.	• when I feel like I understand the applications in my life of math, um, and it makes me feel more empowered and more, um, inspired to continue learning and growing in math when I can see how it relates to what I'm going to be doing in my life.
Structure or Implementation	The instructor's role in setting up the connections between math and other things is important.	• I need the professor to say, here's the connection. And then I'm able to go, oh, okay.
Supports Learning or Participation	They notice that connections to other fields of study are important or helpful for their learning and/or boost their participation in class.	• it would let me see more applications of calculus related to chemical engineering or just other aspects of life. And I think I just in general learn much better when I can see direct applications, when it's less abstract.

Figure 11. Code book for rehumanizing dimension 4, Living Practice and Futures.

Name	Description	Examples
5-Broadening-Math	Parent Theme—for the rehumanizing dimension with this name.	
Implementation or Structure	Student recognizes that how this is implemented in class makes a difference or they have ideas on how to implement or structure this in the class.	A lot of the time I feel like it wouldn't be employed as it should
Peer Interaction	They mention something (positively or negatively) about peer interaction related to this scenario.	it gives me that potential to connect with peers and the instructor by, uh, working on stuff with them.
Relevance or Empowering	The student feels this scenario is (or is not) relevant to their lives or major and/or feels empowering (or not). Or they might say it supports their learning in other classes (not necessarily in their math class).	- Like I feel like that's just not the curriculum, so like why would we do that in that class? - applying those concepts for the future is like—like applying those and like, um, outside the classroom, like really—it's really good.
Supports Learning	The student feels that their learning (or others' learning) or participation in the math class is supported or boosted by this scenario.	if I practice things where it applies then you would be, um, really helpful for me to understand.

Figure 12. Code book for rehumanizing dimension 5, Broadening Math.

Name	Description	Examples
6-Creation	Parent Theme—for the rehumanizing dimension with this name.	
Connections to Others	The student mentions something about this scenario that makes them feel more connected to their instructor or peers.	I think scenario six would be really helpful for me to be more connected to both my professor and my peers,
Creativity	The student mentions the creative nature of this scenario or how it sparks their imagination and brings joy. Or they note how they're not interested in this sort of creativity because they like the more traditional view of math.	- And scenario six, oh yeah, I just really want to learn how to do algorithms. I want to learn how to break those so bad. Um, they sound really cool. - I really like to do creative work. I mean, I—I'm a scientist so I like that.
Implementation matters	The way the teacher implements it or when it gets implemented or how often it's done makes a difference to the student. Or maybe they have ideas on how to improve this scenario.	they would be fun but like maybe not something that I'd want regularly, because I feel like if that was happening like every week it would feel like—like a little bit out of the focus of the class
Supports Learning	The student mentions something about how this scenario will support their learning or help them have deeper understanding of the mathematics.	I think it could be really helpful actually understanding those concepts now, um, to play around and create and compare with other students.

Figure 13. Code book for rehumanizing dimension 6, Creation.

Name	Description	Examples
7-Body-Emotions	Parent Theme—for the rehumanizing dimension with this name.	
Connections	The student mentions that this would impact their connections to other math content, other classes, other perspectives or just broadly.	I think just the increased interactivity would make it easier to like build those connections or see things in different ways that you can't see when it's just a lecture.
Human Connections	The student says something (positive or negative) about peer interactions related to this scenario or that they would feel more connected to peers and/or instructor.	also getting that feedback from like peers, like in scenario seven and yeah, just also makes it like more personal to people.
Implementation matters	The way the teacher implements it or when it gets implemented or how often it's done makes a difference to the student. Or maybe they have ideas on how to improve this scenario.	- that kind of stuff could feel gimmicky, - I think I'd be a little bit afraid of like taking away too much from the lecture if that makes sense.
Supports Learning	The student comments on how this scenario helps them learn or understand the mathematics better (or worse).	it just adds another layer of understanding to the problem because you have like a physical activity you can match with what you were doing.

Figure 14. Code book for rehumanizing dimension 7, Body and Emotions.

Name	Description	Examples
8-Ownership	Parent Theme—for the rehumanizing dimension with this name.	
Connections and Empowerment	The student mentions how this scenario would help them make connections between their class mathematics and their life outside the classroom, either in their lives or in their major. They might also mention how this empowers them and gives them some ownership.	I think it'd make me more confident in working because the—the problems that I've run into outside become more directly applicable.
Human Connections	The student mentions how this would impact their connections to other humans, peers and/or instructors.	I think that by allowing students to bring questions and problems to work on it kind of encourages class participation a little bit more
Implementation Matters	The way the teacher implements it or when it gets implemented or how often it's done makes a difference to the student. Or maybe they have ideas on how to improve this scenario.	problems that students bring in might not always be the best example of how to do that, or like not nece —not the best example, but doesn't represent the course material the best, is what I mean. So someone would have to probably like moderate those, pick through them.
Relevance	The student point out how they value and see importance of the relevance of mathematics in the classroom to their lives outside the class and how this scenario would help them see the relevance.	I just kind of like it because it really applies it to the real world, like how you're actually going to use the problems you learn in class as well.
Supports Learning	This scenario would make the student feel supported in their learning or it would boost engagement, participation or interest in learning.	I can take problems that I run into and have help in solving them and it just brings in this involvement that has always been really strong for my learning, personally.

Figure 15. Code book for rehumanizing dimension 8, Ownership.

Name	Description	Examples
ALL dimensions	Parent Theme—From instances when the student referenced all the scenarios from the survey.	
Community	The student mentions community, teamwork or seeing things from different perspectives as benefits of these scenarios (or good teaching) in math classes. OR they mention something that shows concern for the community in the class, i.e. beyond themselves personally.	- I think that when I was going through each of these scenarios I felt like there was always one—like I could see it helping someone I knew, each scenario helping someone - teamwork, working with other people, even when you have those, uh, partners who are not invested, you know, that is something that you learn to navigate through and that's something that will come up again in a job or something.
Connection	The student mentions how these scenarios (or good teaching) connects them to various things, like other classes or other ideas or other characteristics in life that help them be successful and achieve their goals.	having the professor connect math to other areas or careers...that would be enough of a connection that I would be like, this is worth doing well.
Implementation Matters	The student mentions something about their concerns about implementation or makes a recommendation about implementation.	depending on the professor and also the students in the class, the class size, um, a lot of it is just very dependent. So while I really liked some, some of them I thought, oh, this would be really tricky to implement in the class.
Persistence	The student says something about how these scenarios or good teaching in math classes helps with persistence or never giving up.	there are so many great things about math that will help me everywhere. Like never giving up.

Figure 16. Code book for the parent theme of All Dimensions.

Name	Description	Examples
Humanizing	Parent Theme--What the student said would be humanizing for them in a math class.	
Authentic Self	The student mentions something about bringing their whole or their authentic self to math class. Or they might mention how the teacher knowing and using their preferred name and personal pronouns feels helpful.	if I can't feel like I'm bringing my whole self into the math class it doesn't really—it doesn't feel like it's a detriment to me. It's just something that I could have that would help me that I'm not getting.
Fun-or-Failure Tolerant	The student equates or relates the “fun”-ness and/or having a failure-tolerant (one where mistakes are encouraged and/or totally acceptable) in math with being humanizing. The implication is that the instructor needs to create that fun and/or failure-tolerant atmosphere.	- for math learning experience to be humanizing it would almost feel like fun...like enjoyable - So she's really good about making failure like not a bad thing because she's this extremely intelligent woman who recognizes like that she can make simple mistakes sometimes too.
Instructor Relationship-or-Care	The student mentions how their relationship or rapport or communication with their instructor impacted their motivation or confidence or persistence, etc.	for me it is having a relationship and like talking and saying, I'm confused. Please help me.
Overcoming Obstacles	The student mentions their own responsibility in creating a humanizing space for math, by doing more practice (which then brings deeper understanding) or other student moves to overcome some barrier that then contributes to their own success. OR they mention how beneficial it is to hear or know about other people's success in overcoming obstacles in math.	- Like a lot of in class examples feel most humanizing just because it's like giving you the practice, which I think in math is the main thing that helps you to just understand what's going on. - I would say it definitely makes it for—makes it feel more humanizing that, um, somebody came up with this to solve a problem.
Pacing and Structure	The student mentions specifically the pacing of class or feeling rushed. Or they mention something about the course structure, like some suggestion for what the teacher can do to make it more humanizing (like if a student says it feels to them that is about memorization and/or too performative).	- I do like the, the study hall stuff, like where it's not required for you to go...because like you don't have to go but it's extra help if you need it. - don't like rush the lesson and not thoroughly explain every step of that lesson that needs to be taught to them or skim over it just so that you can make sure you move on to the next one the next day.
Peer Interaction	The student mentions how important peer interactions or group work or group discussions are in math class to benefit their learning and to help them feel more humanizing (or confident or sense of belonging).	- I feel like when I did have moments working with other people, that it was so great as compared to Calc 1 that I wanted more of that. - it was able to cater a little bit different to everybody's learning types because you were able to kind of bounce off different people because you had a group that was fun.
Real-world Applications	The student specifically mentions that doing some sort of real-world applications would benefit their learning or positively impact their motivation or that they need the math they learn in class to be useful for their other classes and/or future career. They want to see the direct connection so that they see the utility value in what they're learning in class.	- More applications, the better. - This isn't some random stuff that we're just learning just because like it has an application for it. - I like to feel like it's going to be applicable when I leave college or, you know, like my experience in my class will be similar to when I leave college and go get a job
Teacher Passions-or-Research	The student says that the teacher sharing their research or math passions that showcase real-world applications feels beneficial or humanizing for them. OR they mention the teacher's passion for teaching.	- she goes to class she brings that excitement of like, hey, let's—let's study this and how she's like really motivated to teach. - my calculus teacher was telling me about what she does with calculus, with polar bears and I just thought it was so cool.

Figure 17. Code book for the Humanizing parent theme.

Name	Description	Examples
Definition	This is how the student defines humanizing when asked.	
Historical Context	In their definition of humanizing, the student mentions something about knowing about the history of mathematics or mathematicians or how it's relevant to mathematics they're learning now.	Just hearing more than a mention of a name related to a concept, um, I think those would really humanize the course.
Instructor Relationship	In their definition of humanizing, the student mentions something about their relationship with the instructor.	More direct contact between the student and the professor.
Love-or-Empathy	In their definition of humanizing, the student mentions something about a loving atmosphere or one that welcomes everyone in a way that they feel like they belong or they mention that empathy is required.	So more welcoming. I—maybe like—humanizing. To me the term just kind of sounds like it's relating to a broad amount of people or humans. Because there are different backgrounds from people and everything.
Peer Interaction	In their definition of humanizing, the student mentions something about group discussions or peer interactions.	I also think in a math classroom for humanizing it would be kind of socializing. And by that, I mean, definitely like working with each other, um, working through problems in different ways.
Respect	In their definition of humanizing, the student mentions something about respect or respectful behavior or an atmosphere where they feel good to truly be themselves and/or be accepted or where it is failure-tolerant.	- I think just acknowledging that concepts are difficult that are being learned. - I just like environments where it's easy to make mistakes and like, you're not going to be penalized for it
Utility-or-Real World Applications	In their definition of humanizing, the student mentions something about making math applicable to their lives or future careers or other classes or brings in real life applications so they can see those connections.	I guess sort of—for me I guess humanizing would be I guess where it's relevant to the real world.

Figure 18. Code book for the Humanizing→Definition.

Name	Description	Examples
Love & Care	Parent Theme--This code is to catch all the sentences from students where they were discussing how the love and care from their instructor impacts them (based on prompting in the interview).	
Care about Student Success	The student talks about how the teacher's caring for the student's success and/or learning impacts their learning and/or them and possibly explains what this care would look like.	when I feel like my instructor, uh, like cares about my success, that really helps.
Names & Pronouns	The student mentions how the instructor's use (or misuse) of preferred names and personal pronouns is important to their feeling cared for (or not).	- just knowing that like you feel appreciated in a classroom when a teacher knows your name, um, and like knows you exist and know you're there. That's always really nice. - he always knew my name.
Peer Relationship	The student mentions the importance (or lack of) of relationships with peers.	- in terms of relationships with others in the class, I don't feel for myself like as motivated to have relationships with my peers as I do my professor. - But I think it's super important to have a good group of friends in your math class that you can kind of go to for understanding and to like learn through.
Communication	The student discusses how important communication between the teacher and student is. They might even give examples of types or timeliness of communication (including communicating about grades) that is impactful.	I think it's important to like have an open line of communication with your professor.
Compassionate and-or Human	The student talks about how their relationship with the teacher is best if the teacher is compassionate or makes themselves human to the students in some way. Or they might discuss how the power dynamic is different because it's not only an authority-dependent relationship.	I noticed that when you have a teacher that is super nice, super kind, super supportive, motivated, and that type of thing, they allow you to feel more comfortable and allow you to just succeed better in the class because you feel more comfortable and you're willing to ask questions, ask for help
Like a Mom (or Parent)	The student discusses how they would feel cared for if their instructor did things that felt like what a loving mom would do or they reacted to the teacher the way they would react to a parental figure.	- I just wanted to impress her and I wanted to like do my best work for her because I cared about her opinion. - She was almost like a mom in a way.

Figure 19. Code book for the Love and Care parent theme.

After coding the interview data and creating the code book along with its instructions, another doctoral student used this information to also use NVivo to code four (20%) interviews, with IRB approval. She started with just the transcripts of the four interviews and coded using the instructions, not knowing how I had coded them. Then, she sent me those coded interviews which I uploaded into NVivo and compared with my coding of the same interviews. We met three times in Zoom to discuss the process, answer questions and then to resolve any differences that were found. As a result, there were a few codes that got collapsed. For example, in one rehumanizing dimension, there was a code for real-world applications of mathematics, i.e., mathematics that were relevant to a student's life outside the classroom or to their potential future career, and another code for utility value and those were combined into one code because each of us had interpreted them with some overlap.

The goal in using both inductive and deductive coding was to ensure that all themes were accounted for in the data. As will be explained in more detail below, the survey essay responses also did not add any further themes or codes, indicating that nothing seemed "missed" while coding. By that I mean that it was not necessary to do another layer of inductive coding to find themes which were outside the rehumanizing framework because the data in the interviews and surveys fit within the parent themes described above. Additionally, when reporting the results of the coding process in the findings, I looked at what themes emerged from overlapping components of the dimensions, not on specific codes.

Survey Data. Next, the survey open-ended essay questions from all participants were analyzed. First, the survey essay questions were compiled into six different files, three files for the dominant group responses and another three files for the focal group responses. One file each

was for the focal (or dominant) group answers to the survey question “Please list at least one thing that college mathematics instructors could do (or already do) that would contribute to your sense of belonging in mathematics class, build connections to your life outside of class, and support your success as a student.” Then, one file each was for the focal (or dominant) group responses to the survey question “Is there anything else you’d like me to know or that I forgot to ask?” One file each was for the focal (or dominant) group answers to the survey question “Please list at least one thing that college mathematics instructors could do (or do already) that would diminish your sense of belonging in mathematics class, make mathematics feel unrelated to your life outside of class, or adversely affect your success as a student.”

All six of those documents were then coded in NVivo using the code book for the Humanizing sub-themes that were created from the interview data. The Humanizing parent theme was chosen for these essay responses in order to determine (1) if the three proxy Likert questions used in the survey captured the essence of humanizing and (2) if there were any new sub-codes that arose from the survey responses that did not show up from the interview data. Note, those last two files of responses did not provide much insight into answering the research questions because the focus with this research is on what feels rehumanizing to students, not what feels dehumanizing or negative. Thus, not much from the last two files was coded. While coding the survey responses, attention was also paid to the possibility of new themes emerging from the survey data that may not have shown up in the interview data. This possibility was not realized, as the code book was sufficient to analyze the open-ended survey responses.

After the first round of coding all open-ended survey responses was complete, I coded the survey responses again. Specifically, I coded only the responses to the question asking about positive things, bucketing each response or partial response into one of six bins, namely

Belonging, Supported Learning, Connection, Belonging-Implied, Supported Learning-Implied, and Connection-Implied. This was done to address the triple-barreled nature of that essay question. This analysis then allowed me to see what attribute(s) of the question, i.e., belonging, connections or supported learning, were most attended to by students and if there was any difference between the focal and dominant group responses. The results of this analysis were used to contribute empirical evidence to support the rehumanizing theoretical framework.

At the end of the coding process, the frequency of codes emerging from the data was examined as well as the number of students whose responses fell into each sub-code. This information proved valuable to get a sense of what was most compelling to the participating students or what felt particularly relevant to answer the research questions. Specifically, examining the presence of themes by students' group/identity associations was also considered, because that data might provide information about themes that are compelling to certain subgroups of students at these PWIs. Noticing the patterns that showed up across all the data helped to answer the research questions and was helpful in identifying possible areas of future research.

The combination of deductive and inductive coding, with both the interview and survey data, along with the analysis process will help unpack students' perceptions of what is rehumanizing as well as what characteristics of or why certain teaching moves positively impact them. The overall analysis then serves to answer the research questions, illuminating teaching strategies and structures that can be used to work toward a goal of rehumanization and to contribute further evidence to substantiate the theoretical framework.

Blending Quantitative and Qualitative Analyses

In this transformative mixed methods study, which is sequential in nature, the quantitative results from the first phase informed how the qualitative data in the second phase were collected. Further, after completing both quantitative and qualitative analyses, discussion of conclusions drawn from both sets of findings were interpreted together to more fully address the research questions. The quantitative findings were used to determine which scenarios were perceived differently between the focal and dominant groups of students. Then, those differences were explained further using the qualitative findings, as was necessitated by my research questions. This blending of the findings also helped “decide to what extent the results uncover inequities and call for change” (Creswell & Plano Clark, 2011, p. 220) which is aligned with transformative design. Since the intention of the rehumanizing framework is to center the voices of students from historically marginalized groups, no interview data was collected from dominant group participants. However, the quantitative survey data, and the qualitative essay answers, served a valuable purpose in exploring differences and similarities across the groups. Indeed there was no way to answer questions about differences without such data. Additionally, having both quantitative and qualitative data allowed for comparisons between the findings. It afforded me the opportunity to attend to any findings that possibly opposed each other, and then the qualitative data was used to learn more about factors contributing to differences between groups.

Interviewee Mathematical Identities and Short Biographies

In parallel with the coding process, I wrote a two-to-three paragraph rich description of the identity of each of the 20 interviewees. I used data from section 3, i.e., Role of Identity, of

interview questions, and noteworthy identity-related information that might have been mentioned in other areas of the interview, as well as my researcher notes, to construct each interviewee's short biography. These identity descriptions included each interviewee's demographic information, their voiced salient aspects of their identity, especially as mathematics students, and other characteristics that provided information about their mathematics identity. I emailed the short identity and mathematics biography description to each interviewee, as a way to member check this data analysis piece. Three of the interviewees requested small changes to some of the wording; all other interviewees, except one interviewee (who never responded to my email requests), expressed satisfaction with what I had originally written. For the students who requested changes to their mathematical biography, I made appropriate changes and then sent the revisions to the students until they approved. These short biographies were important to include as findings specifically because it is aligned with the transformative design and rehumanizing framework in that it truly centers the interviewees as human beings, rather than research subjects. To appropriately adhere to the spirit of rehumanizing, it is crucial that every aspect of this research focus on treating and showcasing participants as whole human beings and not reporting their demographic identities in reductive ways.

Trustworthiness

Since the bulk of this study is qualitative in nature and transformative by design, the goal is to tell a relevant story from students' perspective that addresses the stated research questions, not to make predictive statements for larger populations of students. As such, claims of replicability are not relevant here, meaning this study may not be replicated with the same results elsewhere, but certainly it can be repeated. Instead, issues of credibility, dependability,

transferability, authenticity, and confirmability need to be considered (Creswell & Poth, 2018, p. 256). Attending to these five areas of trustworthiness can be used to “assess the ‘accuracy’ of the findings, as best described by the researcher, the participants, and the readers” (Creswell & Poth, 2018, p.259). Each trustworthiness category will be addressed one by one here.

Credibility is concerned with the fit of the data to the participants’ perspectives, meaning that the researcher took care to reconstruct the participants’ views in a credible way (Marshall & Rossman, 2014). To increase the credibility of this research, I checked that interview quotes were correctly used and representative of the participant’s intended meaning and received approval from all interviewees regarding the write-up about their mathematical identity and short biography. In all communication, the interviewees were given the opportunity to correct errors, approve quotes and clarify any misinterpretations. This also boosts the chances of truly centering student voices, which is a primary aim of this research.

Dependability describes how the research process itself and any conclusions made were logical and trackable (Lincoln & Guba, 1985). Additionally, dependability can be described as “accounting for changing conditions...and changes in the design created by an increasingly refined understanding of the setting” (Marshall & Rossman, 2014, p. 203). This is somewhat analogous to reliability in quantitative research, which would ensure that the results from a repeated quantitative experiment would be the same. In qualitative research, unlike quantitative research, it is unlikely that a different researcher would get the same results from a group of different students. However, my data collection process itself could be repeated, using the same survey instrument and interview protocol, meaning that the process is in line with dependability goals. Moreover, I have taken measures to have coherent and thorough instructions about the

coding and analysis process that could be handed off to another researcher to replicate this study elsewhere.

Transferability is attained when the researcher provides enough information that allows the reader to transfer research results to other settings or situations (Marshall & Rossman, 2014). Thick descriptions of the data aid in transferability. With that said, there are no claims here that the results of this study will necessarily transfer to other populations or university settings, even PWIs, although it is possible. However, rich descriptions of the data collection and analysis processes and the findings are provided so readers can make informed decisions about how transferable this research is for their own context.

Authenticity is based on a constructivist view of research, stemming from work done by Guba and Lincoln (1989), and “involves an assessment of the meaningfulness and usefulness of interactive inquiry processes and social change that results from these processes” (Shannon & Hambacher, 2014, p. 1). This can be achieved by a researcher’s effective communication of the participants’ perspectives and by documentation and analysis that provokes empathy and possibly action from the reader. To meet this goal, reflexive note-taking was employed during and after each interview. Additionally, researcher positionality/relationality and potential bias were stated explicitly (see Chapter 0) and reflected on repeatedly throughout the research process, with the aim to move toward a more neutral and authentic stance with the findings. Addressing the issue of social change that transpires from this study is not possible within the timeframe of the study. However, the aim in answering the stated research questions is indeed to impact teaching practice at the undergraduate level and publishing the results of this work will aid in accomplishing the social change aspect of this trustworthiness category.

Confirmability suggests the results of the study should be able to be confirmed or substantiated by others (Marshall & Rossman, 2014). To achieve confirmability, all data and coding documents were organized and securely stored for continued reference and as a chain of evidence that others could follow. A colleague doctoral student, who has experience with qualitative research, was consulted to review some of the data and confirmed that findings were aligned with said data. Specifically, the other researcher coded 20% of the interview data using my code book and procedure to be sure there was agreement about the overriding themes and codes, as well as the instructions on how to use the code book. This occurred after I have finished coding all 20 interviews. After comparing the results of our coding for those four interviews, there were two sub-codes that were collapsed because we had basically been using them interchangeably. Finally, verbatim quotes will be used to appropriately represent participants' input and to ensure that the results of the study align with the participants' intended perspectives and words.

Lastly, to address further concerns regarding trustworthiness, the findings across all data sources, including surveys, interviews and researcher notes, were integrated. The design of the study establishes triangulation through the multiple forms and sources of data collected and analyzed.

Limitations and Significance

This research is intended to contribute to our understanding of how students view and experience college mathematics classrooms as rehumanizing. Ideally, this research will benefit the academic community both theoretically and practically. In this section, several possible limitations and potential contributions are considered.

Potential Limitations

The results of this project are intended to add to a body of literature regarding teaching practices that students feel are humanizing and moving toward building equitable outcomes, especially for students from historically marginalized groups within STEM. It is also intended to elevate and center voices of students who are not frequently heard from. With that said, this study is not intended necessarily to be generalizable and the transferability of these results to other institutions or contexts could pose challenges. The institutions from which students were asked to participate in this study are both PWIs and R1 institutions. As such, it may be true that the student experiences reported on in this study are too dissimilar from other institutions for the results to be fully useful in other contexts, although it is likely that my results can be reasonably extended to application-driven calculus courses. This study is intended to highlight some student experiences as possibilities that may occur in other institutions and for other groups of students. In that way, the results will still benefit other educators as places to start, things to consider and ways that they can experiment with in their own classrooms to build rehumanized calculus spaces.

One additional challenge of this type of study is the building of trust between me and the interviewees. This was attended to in several ways, including using requested pronouns and adhering to their stated boundaries or requests, listening intently, generously compensating them financially for their time, and checking in with students who were interviewed regarding their short biographies to obtain their approval of what is being written about them. Although compensating students for their time could be considered authentic generosity and interest in the student, it is also possible that the student viewed this as a payoff. For example, it is possible that

the student viewed the payment as a way to get only data that I wanted to hear. Since the interviewees did not know me and did not actually have any such notion of what responses I might be hoping for, other than their true opinion, this possibility is unlikely. In this vein, I did repeat several times, both in the recruitment phase, in the survey and in the interview, that I wanted to hear students' honest answers. Some scholars also argue that interviewees could feel that payment cheapens the interview exchange as a transaction as opposed to entering into an authentic relationship with the researcher. To address this possibility, I did explain to interviewees that the purpose of paying them was to honor their time. Indeed, one student did refuse to accept payment, insisting that they had plenty of money and wanted to participate out of a desire to benefit future students and research in general.

The underlying assumption of student behavior in answering both survey and interview questions was that students answer them authentically, thoroughly and honestly. However, it is possible that students did not wish to divulge full information, for a variety of reasons, which means the data collected may not be complete from a student perspective. Not only might there be information students consider too private to share, but I had limited time, so the data are as complete as they can be within those constraints. Additionally, a few students did not share full demographic information about themselves, perhaps because they did not feel comfortable doing so, which could have impacted which students were interviewed and whose voices are elevated with this study. Finally, there were no Black-identifying students who participated in this research which means their voices are completely missing from this research. The potential negative impact of this cannot be overstated, especially given Gutierrez's original intentions and design for the rehumanizing framework. With that said, the diversity of the interviewees in the focal group provided a wide range of views making this research point in a direction that has

potential to encompass experiences of many different students, including Black students. I am also not trying to use my participants' voices to suggest they are representing all members of their identity groups.

At least one instructor at HSU offered an additional dropped low quiz score for students to do the survey, which positively impacted the response rate at that institution. To receive that benefit advertised by the instructor, at least 80% of the class sent a screenshot of the completed survey to their Calculus 2 instructor. Students received a completed survey notice even if they did not consent to actually fill out the survey questions, i.e., a survey was considered completed if the student got as far as reading through the consent form. This form of extra credit for students likely explains in part why a larger proportion of HSU students filled out the survey than CBSU students and thus, I may not have a representative sample from these two schools. However, both schools are PWIs and thus, the population of students were similar enough to override the impact of this potential limitation. Additionally, representativeness would not have been achievable from this study even with 100% participation in the survey. The goal of having a survey response sample that was fairly well-balanced between the dominant and focal group responses was indeed achieved here.

The rehumanizing framework is relatively new and the written expression of this framework is fairly small in the literature. As such, there is an added risk that this study has misinterpreted some pieces of the framework or emphasized parts of the framework in different ways than was originally intended by Gutiérrez. Steps were taken to minimize this risk, including participation in a two-week rehumanizing mathematics workshop led by Gutiérrez, as well as soliciting feedback from the participants of said workshop. Additionally, direct feedback was

provided by Gutiérrez for the rehumanizing framework section of Chapter 2 to ensure its authenticity.

Several of the survey scenarios contain double-barreled questions, meaning there is more than one element that the student's responses could be referring to. For example, in the Cultures/Theirstories scenario, a student's responses could be referring to the feeling they have from hearing their professor talk about mathematicians from diverse backgrounds in the class and may not be influenced at all by the web links the professor provides outside of class. Also, whether or not the scenarios capture the essence of each dimension is unvalidated. For example, the scenario for the Cultures & Theirstories dimension would possibly yield different reactions from students if it suggested that a guest speaker was invited for ten minutes every other week to promote theirstories instead of how the scenario is currently set up. Since the survey is not intended to be predictive or claimed to represent all students, but instead intended to be an entry to student thinking, this is an acceptable potential limitation for this survey. Furthermore, these survey answers were probed in more detail in the interviews that followed the survey data collection which is one way this potential limitation is overcome.

Finally, the proxy questions used in the survey to get at the heart of how rehumanizing efforts are perceived by students could miss the mark, meaning that the proxy questions do not accurately represent how students would experience or define rehumanizing. Also whether or not the survey scenarios captured the rehumanizing essence of each dimension is unvalidated. Overall, the survey is not a validated instrument for measuring a rehumanizing construct. The students may interpret the survey questions in unintended ways and this could have impacted the data in ways that the findings could be misaligned with student perceptions. These risks were minimized by having several researchers provide feedback on the survey items, piloting the

survey with students and soliciting feedback from Gutiérrez and the rehumanizing mathematics workshop participants. The survey pilot provided information about how the pilot participants interpreted the survey questions and how to make sure the questions were eliciting responses on what students could imagine in their mathematics classes, as opposed to what they had previously experienced. Due to its novel approach, the survey does also have potential to produce valuable results and to be used in the future by other researchers. This limitation was somewhat overcome by using the same common questions for each scenario in the survey.

Rather than measuring rehumanization, the structure of questions allowed measurement of what rehumanizing dimensions, if any, play a salient role for students. Additionally, these limitations were addressed with the data collection and analysis from the interviews, to uncover if indeed the proxy questions sufficiently captured students' ideas about what rehumanizing means to them along with richer descriptions of their perceptions of the scenarios.

Potential Significance

As mentioned above, because the rehumanizing framework is relatively new there has been little research to date using or expanding this framework to flesh out details of how it can help frame and understand student experiences. This study has the potential to contribute to the practical use of this theory and to make recommendations on how the theory can be adapted based on empirical results. The results of this research can also be used to operationalize the rehumanizing framework in ways that students understand. For example, the three proxy questions used in the survey to get at the rehumanizing essence were explored further with the interviews to verify whether or not students' ideas of humanizing match those represented in the survey.

More specifically, research in this regard is needed at the undergraduate calculus level where the stakes for students are high in their pursuit of a STEM degree because calculus can be and is frequently used as a gatekeeper to those majors. Thus a primary goal of this work is to provide researchers a more detailed description of what is rehumanizing for students from groups who have been historically marginalized in mathematics and are STEM-intending. This study also lays a foundation of knowledge about rehumanizing structures that can be investigated and/or implemented at HBCUs, HSIs, community colleges, etc.

The fundamental research question for this study is focused on detailing classroom structures, practices and pedagogies that students feel are rehumanizing. As such, one goal of this research study is to compile a list of perceived teacher moves that might help create more humanized classrooms for undergraduate students which could then have beneficial cumulative effects on students' futures. Thus, from a praxis point of view, the results of this research could impact educators and college teacher trainers in how they structure and run their calculus courses and how they train others. This in turn could positively impact undergraduate students pursuing STEM degrees, in particular it could produce desirable gains for students from historically marginalized groups within mathematics. More specifically, the scenarios created for the survey offer clear examples of practices that instructors can implement in their classes.

Even though this study will center the voices of students from groups who have been historically marginalized in mathematics, the likelihood that all students will benefit from this knowledge is high. Like the curb-cut effect mentioned earlier, ways to rehumanize calculus for some students will likely rehumanize calculus for students from other groups as well. Further, the rich mathematical identity descriptions provided for each interviewee, in conjunction with the research results, can impact the knowledge of both the mathematics education research and

teaching communities. Knowing about who our students are and what they value can help educators work with them more productively, providing strategies that will likely benefit everyone.

Finally, although gathering data only from PWIs could be considered a possible limitation, I argue that it simultaneously offers significance. This study is focused on elevating voices of students who have been kept at the margins, particularly at PWIs. Indeed, the emancipatory goal for this transformative research needs more attention at PWIs than at other minority-serving institutions.

Conclusion

This study provides an opportunity for STEM-intending college students from two R1, PWI institutions to contribute knowledge about what could make college calculus classes rehumanized. Specifically, the study centers the voices of students from groups who have been historically marginalized in mathematics, including Latin*, Native American, women and LGBTQ+ students. This in turn provides teacher moves that can be made by educators to rehumanize their undergraduate mathematics classes. Further, this study provides a fuller interpretation and expands the knowledge and understanding of the relatively new rehumanizing theoretical framework.

CHAPTER FOUR

QUANTITATIVE FINDINGS

Introduction

The goal of this chapter is to present the quantitative findings from the survey data, including demographic information of all survey participants and the results from analyzing the Likert questions. These quantitative findings address the overarching research question as well as part (a), which are:

What classroom structures, practices and pedagogies do undergraduate Calculus 2 students perceive as rehumanizing in their college mathematics classes?

- a. In particular, what are the perceptions of students from historically marginalized groups (in STEM) from various races, ethnicities, LGBTQ+ statuses, and/or genders? And how do these perceptions compare to overall perceptions?

The next chapter regarding the qualitative findings will further flesh out nuanced details in answering these research questions, and will also address the remaining research question.

I start with a description of the survey participants. Next, frequency charts depict the data from various demographic categories, including major, gender, race and/or ethnicity, sexual orientation, and transgender or non-binary status for all survey participants. Following that, the survey data were split into two groups, namely the dominant and focal groups (described in more detail below), and statistical analysis was done for each of the 24 Likert questions to determine if any differences were significant between the groups' responses. Finally, I present and interpret

classification trees to show which scenarios and Likert questions were most salient for the two groups.

Survey Participants

As mentioned in Chapter 3, surveys were offered to all enrolled Calculus 2 students at both CBSU and HSU. In total, 109 HSU students (about 38% of enrolled students) and 66 CBSU students (about 10% of enrolled students) started or completed the survey. There were 11 HSU students and 1 CBSU student who did not consent to the survey and thus did not answer the questions. Overall, there were 98 full survey responses collected from HSU students and 65 full survey responses collected from CBSU students, which totals 163 overall responses to the Likert questions. An additional 10 students did not provide all of the necessary demographic information in order to analyze the results meaningfully with the rehumanizing framework. Thus, in the end, 153 survey responses were analyzed in full.

I next present charts that showcase the demographic information of all survey participants, with a quick reminder that demographic information is important to the design and implementation of this study. The rehumanizing framework, and in turn my research questions, are specifically focused on centering the voices of students from groups that have been marginalized in STEM spaces. The particular groups of focus for this study are students who self-identify as people of color, women or in the LGBTQ+ community.

Students filling out the survey had a variety of STEM majors, as is depicted in Figure 20. The three most reported majors were Mechanical Engineering, Computer Science and Biology, which account for roughly 44% of the responses, with only three students stating that they had not yet declared a major. Although this graph is not necessary to answer the research questions

directly, it is important to include here as evidence that indeed the students who participated in this research were STEM-intending majors, which was the goal in recruiting Calculus 2 students.

Survey Results: Major

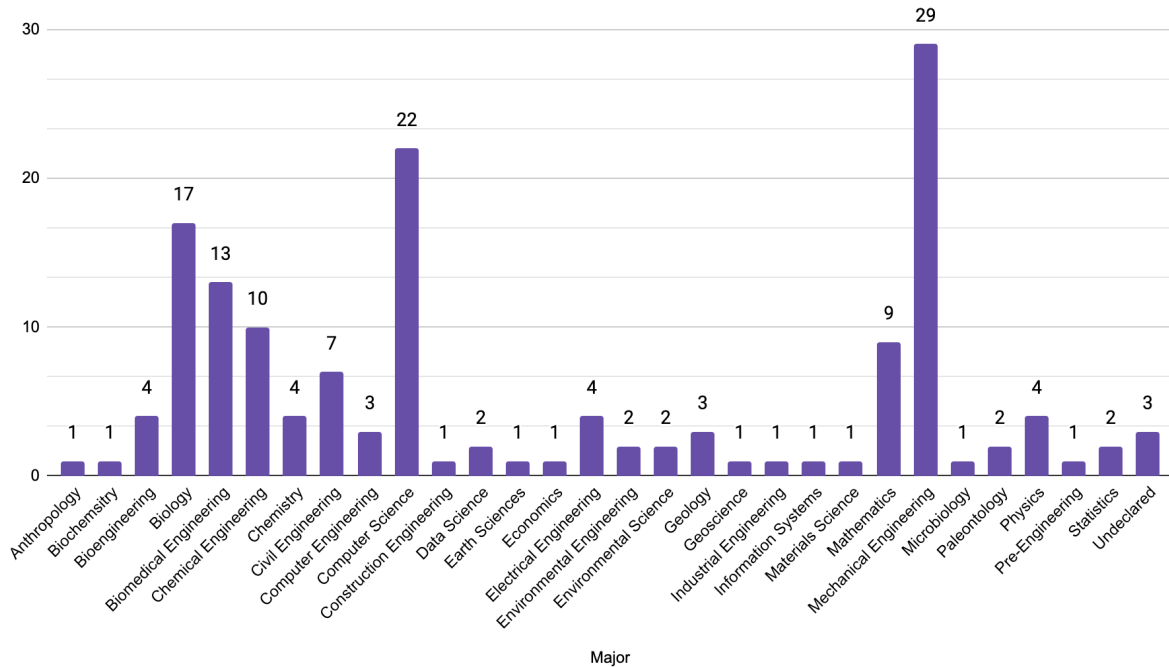


Figure 20. Majors of all survey participants, listed in alphabetical order.

The next two charts present the gender (Figure 21) and race and/or ethnicity (Figure 22) of the survey participants, which unsurprisingly depict a large portion of participants identifying as white men. This is not surprising because both HSU and CBSU are PWIs. In order to create these charts, I did clean the data since each student self-reported their identity information as a free response answer. For example, some men wrote their gender as male or Male or man. Each of those answers were grouped together as Man. There is one student who did not answer the gender question. Their survey results were kept for analysis because they had another piece of their identity that fit within the broad LGBTQ+ category.

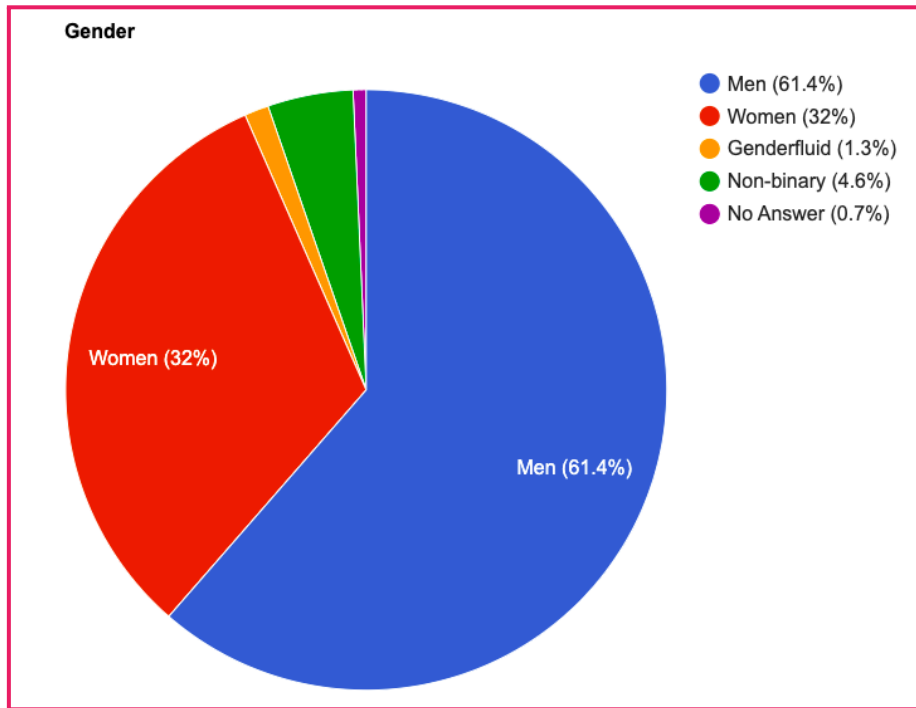


Figure 21. Gender of all survey participants.

To clean the student write-in responses to the race and/or ethnicity question on the survey, I had to collapse a few categories. For example, if a student self-identified as Hispanic (2), Mexican (1), Latino (1), or Latina (1), I grouped them in the Latin* category. The Mixed Race category contains students who self-identified as white & Hispanic (2), Asian & white (2), or white & Native American (1). For the white category, as labeled in Figure 22, students self-identified as white or Caucasian. In the Asian group, students either identified as Asian (3), Asian American (1), or Asian-Vietnamese (1). It made sense to collapse some of these self-reported labels for aggregate reporting of quantitative data. However, this approach was not taken when reporting on results of the interviews. The reasons for students choosing one label over another for the race and/or ethnicity survey question, like Hispanic or Mexican, is explored further and reported on for the interviewees in Chapter 5. (Note: Although the original goal was to include Black students, no such students participated in the survey.)

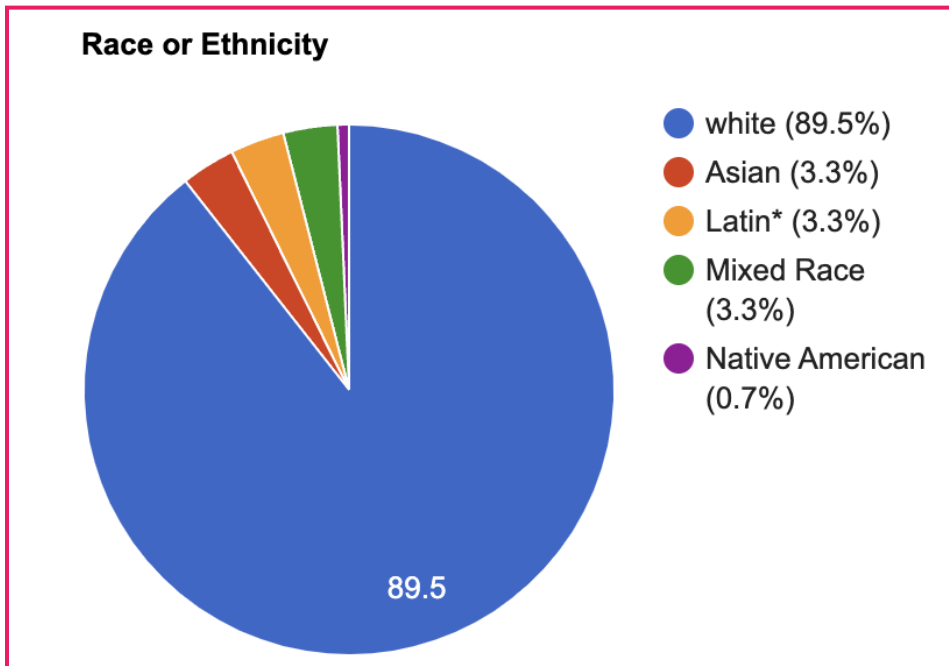


Figure 22. Race and/or Ethnicity of all survey participants.

Next, for the sexual orientation question, students again self-reported any answer they chose. To clean this data, some categories were collapsed. In the Ace or Asexual group, students answered this question as ace (1), acearo (1), or asexual (1). For the Heterosexual group, students either wrote an answer of straight or heterosexual. For the group labeled as Q in Figure 23, students either answered with Q (2), Queer (5) or Questioning (3). Although queer and questioning are not the same category, since Q can stand for either queer or questioning, this seemed the most reasonable way to group answers in this demographic category for aggregate reporting purposes because students who identify as either queer or questioning are included in the broader LGBTQ+ community and thus meet the criteria for the focal group of this study. Another noteworthy point in this demographic category is that there were three students who left this question blank, and were thus categorized here as No Answer. Their survey responses were

not removed from the data set, however, because one or more of their other demographic identities were in the focal group of students for this research.

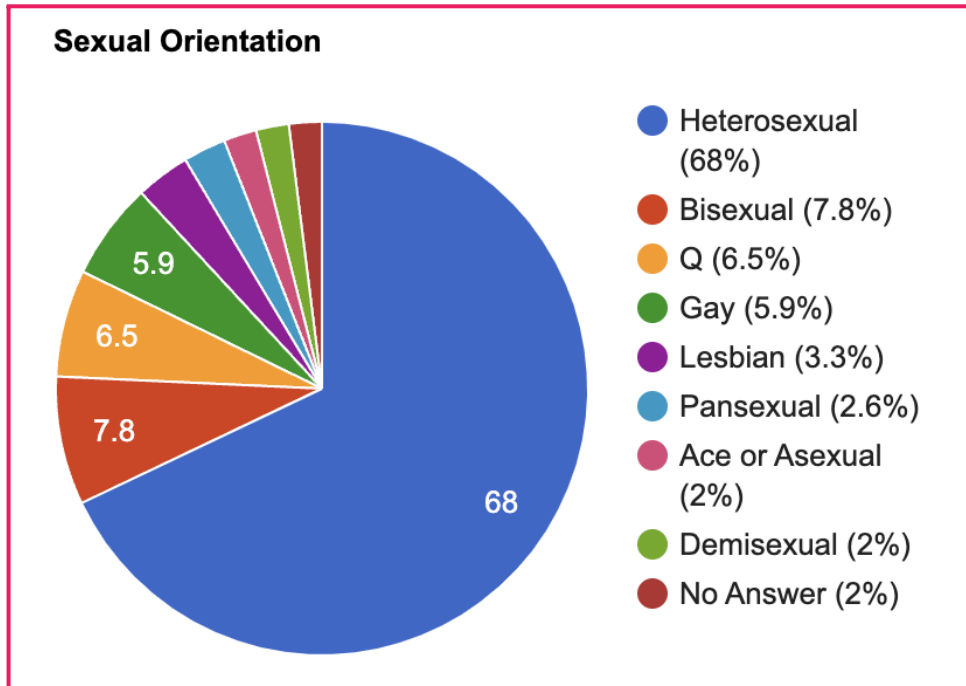


Figure 23. Sexual Orientation of all survey participants.

Finally, Figure 24 shows the results for the survey question that asked “Do you identify as transgender, agender, non-binary, gender fluid or something under the non-binary umbrella?” All students wrote in answers of either Yes, No or Maybe, so there was no need for any cleaning of this data. One final note here is that all of the Yes or Maybe answers to this question were for students who reported a sexual orientation and/or gender that would also be in the LGBTQ+ category. Thus, this particular question did not add nor remove any students from the focal group of students for this study.

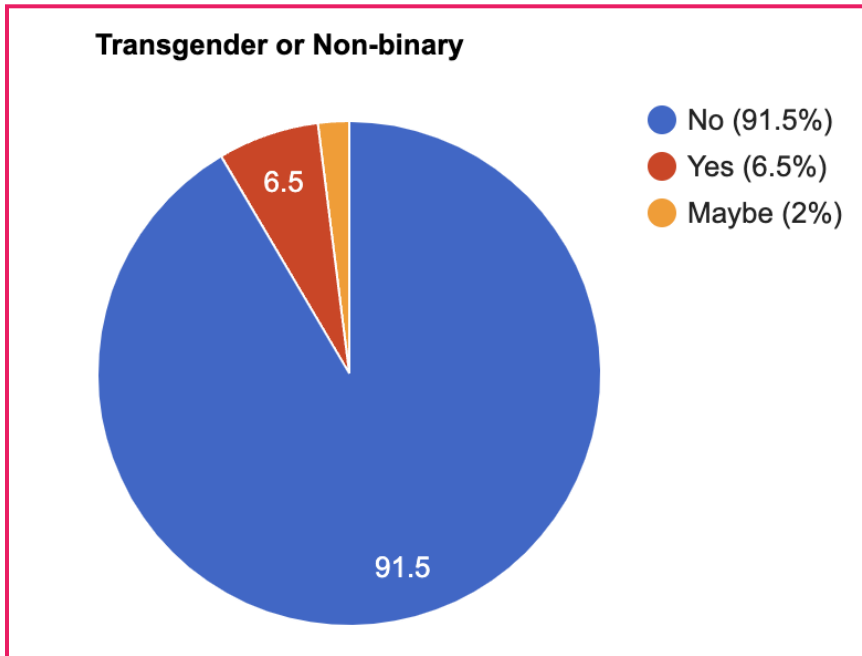


Figure 24. Transgender or Non-binary status of all survey participants.

Because the goal of this study is to focus on students who are from historically marginalized groups within STEM spaces, the survey data was split into groups before any analysis was done. I split the 153 full survey responses into two groups, namely the dominant group and the focal group. The dominant group consists only of survey responses from students who identified as white, cis-gender, heterosexual men. The focal group consists of survey responses from students who identified as being in the LGBTQ+ community, women and/or as what I have categorized above as Latin*, Native American or Mixed Race. In total, there were 80 students in the focal group and 73 students in the dominant group.

Survey Data Analysis

To analyze the Likert question data with the goal of answering the research questions stated at the beginning of this chapter, I first split the student responses into two groups,

dominant and focal, and compared the distributions of their answers. The histograms provide helpful visual representations and then chi-squared tests were used to determine if any of those differences were statistically significant. Then, classification trees were created to further examine which of the survey questions were most salient.

Histograms

For each of the eight scenarios on the survey, one per rehumanizing dimension, three Likert questions were asked. As a reminder, the same three Likert questions were asked for each of the eight scenarios. All Likert questions had seven possible answer choices, ranging from Strongly Disagree to Strongly Agree. For this analysis, the responses were turned into numerical data, with 1=Strongly Disagree and 7=Strongly Agree. The three questions were:

A: I would likely feel valued and an increased sense of belonging. (*In the analysis, this is often referred to as Value & Belonging or abbreviated as VB.*)

B: I would likely feel a sense of connection between mathematics and my life. (*In the analysis, this is often referred to as Connection or abbreviated as Cn.*)

C: I would likely feel supported in my learning. (*In the analysis, this is often referred to as Supported Learning or abbreviated as SL.*)

In Figure 25, histograms with all of the Value & Belonging questions are shown. For all scenarios except scenario 2, the distribution of responses is left-skewed, meaning that overall, most students tended to agree that an environment such as the one presented in the scenario would support their sense of value and belonging. Also, the dominant vs. focal group distributions for each scenario, except scenario 2, do not seem to be very different (visually). But, scenario 2 appears to be visually different from all the other graphs for this Likert question

because it is not left-skewed and the differences between dominant vs. focal group answers appear to be noteworthy.

Next, in Figure 26, the histograms for the Connection question on each scenario are displayed. Again, most of the distributions are left-skewed, with no visually large differences between the dominant vs. focal group distributions. Yet, again, there is a notable exception with scenario 2.

Finally, the histograms are shown in Figure 27 for the Supported Learning questions, one corresponding to each of the eight scenarios. The pattern is continued here in that almost all of the histograms are left-skewed with no visually apparent differences between groups. The pattern of scenario 2 being an exception is maintained here as well.

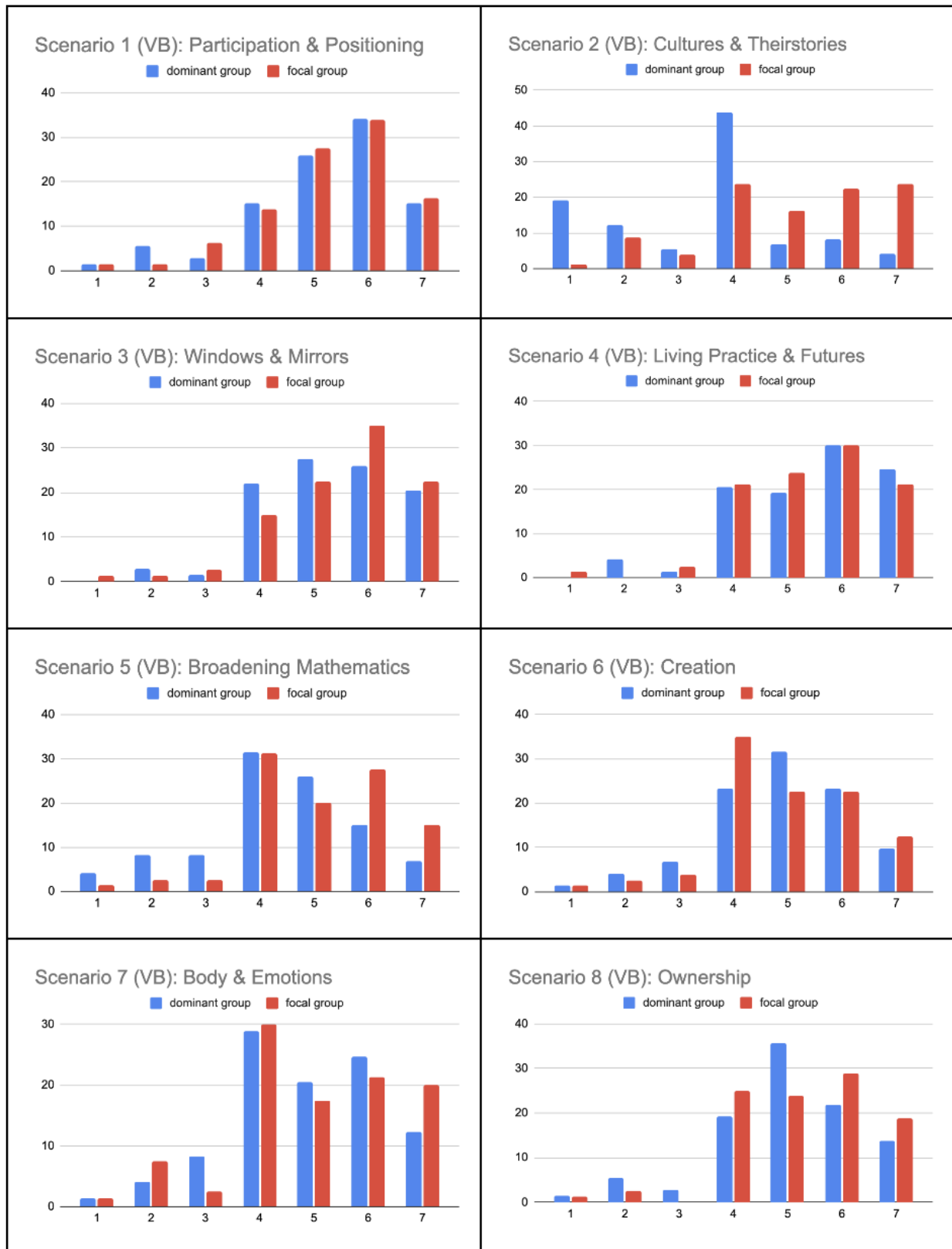


Figure 25. Histograms for the Value & Belonging question for all eight survey scenarios.

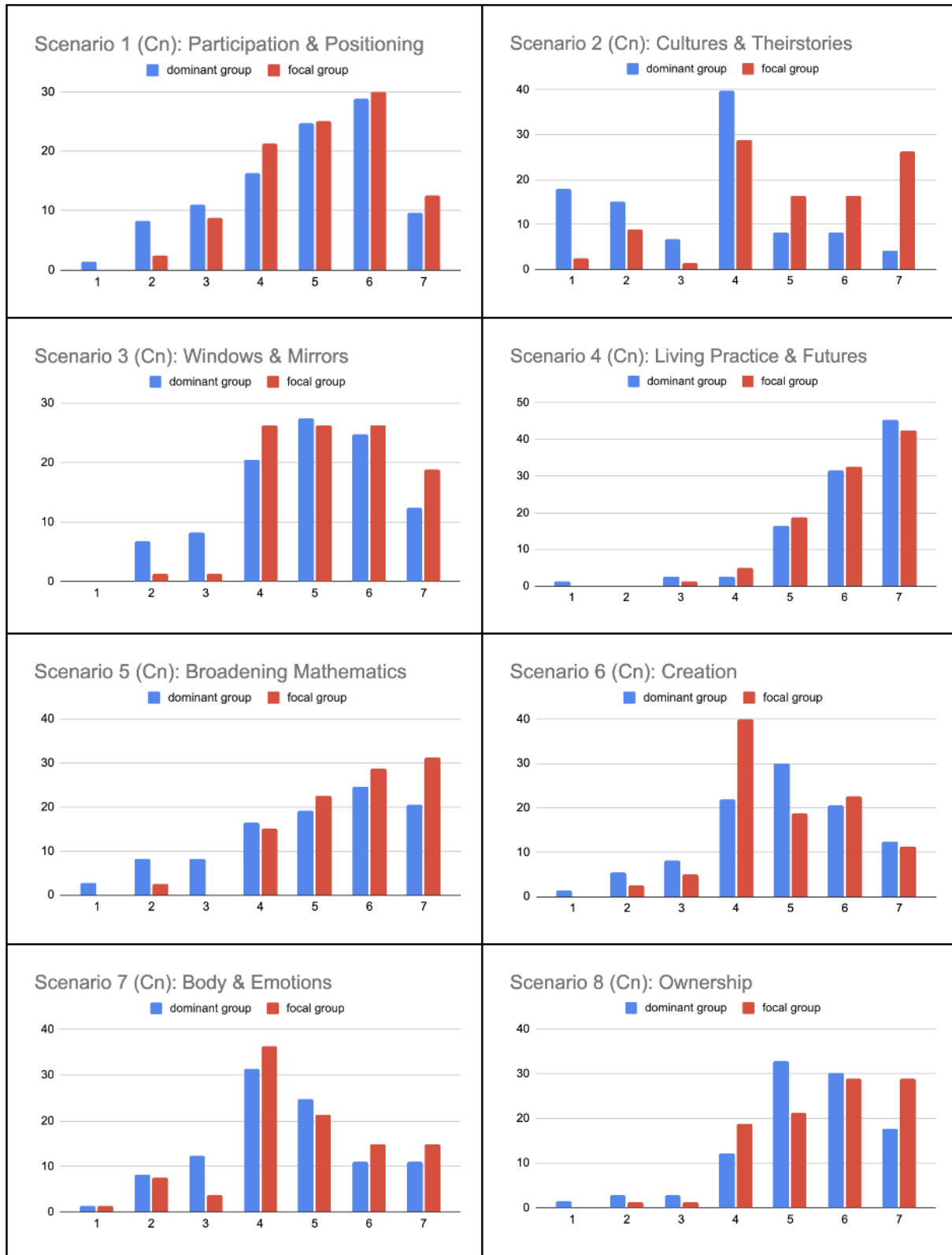


Figure 26. Histograms for the Connection question for all eight survey scenarios.

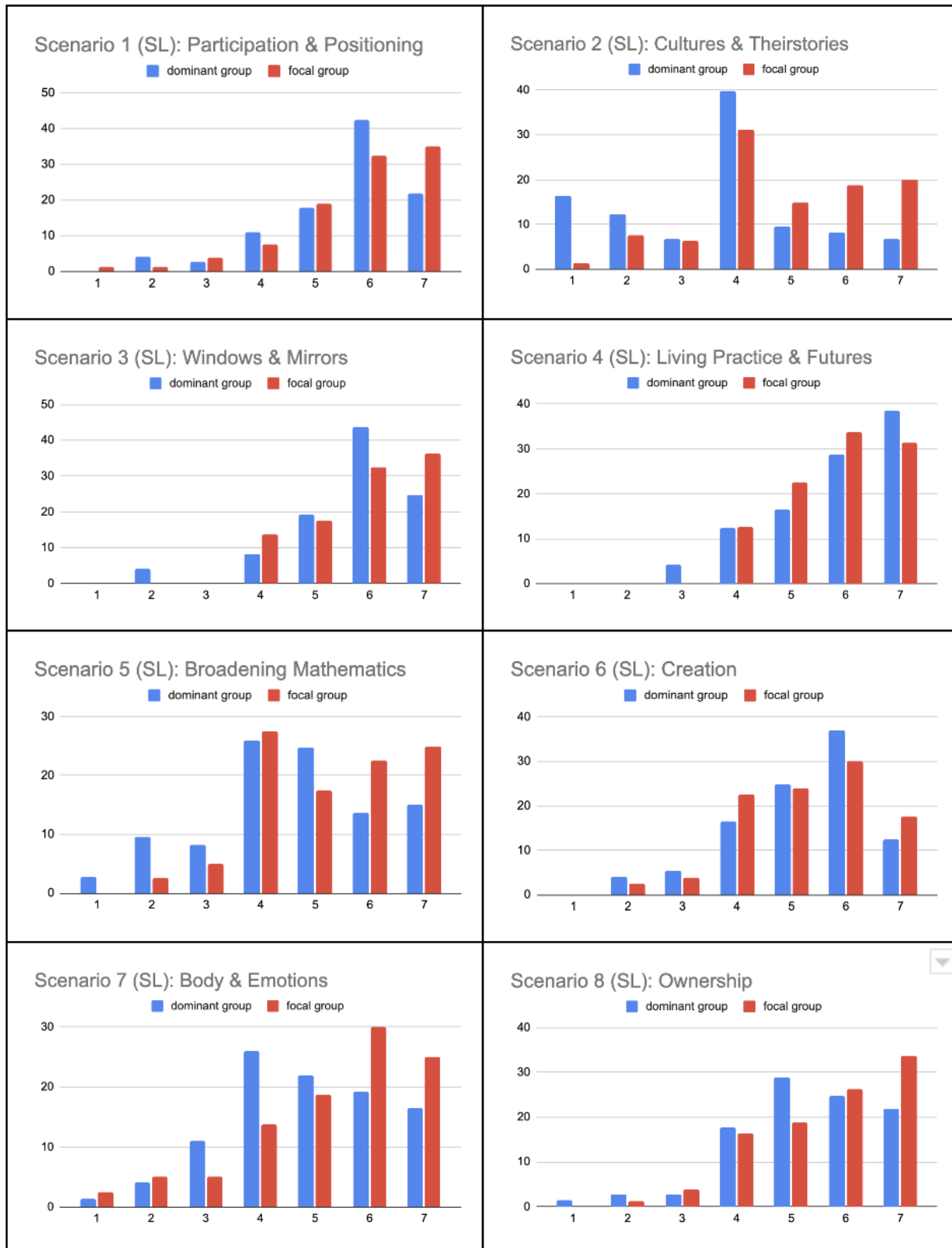


Figure 27. Histograms for the Supported Learning question for all eight survey scenarios.

Overall, the histograms suggest that students tended to agree that the environments from these imagined scenarios would promote their feelings of value and belonging, connections, and support their learning. In particular, the focal and dominant group responses were quite well-aligned for Scenarios 1, 4 and 6, except for the Connection question on Scenario 6. Further, Scenario 4 was the most agreed-upon scenario between the two groups, meaning that most students felt this scenario would positively impact their mathematics learning experience. Visually, scenario 2 seems a clear outlier for all three Likert questions, suggesting that the focal and dominant groups felt differently about how the teaching move in that scenario would impact them. However, visual inspection of histograms is not a sufficient way to analyze this data. Next, I share the results of the statistical tests that examine if indeed scenario 2 questions, or any of the other Likert questions, had statistically significant differences between the two groups.

Chi-Squared Results

To determine if the distributions between the two groups were significantly different or if their differences, per question, could be explained by chance, I used a chi-squared test on each of the 24 Likert questions. In other words, the chi-squared test was used to decide if the differences between the expected frequencies and the observed frequencies of responses between these two groups were statistically significant. In Table 8, I have reported the results of each of the 24 chi-squared tests. As expected from visual inspection of the histograms, all three Likert questions for scenario two were answered in significantly different ways between the two groups, with approximate p-values of 0.0000029 for the Value & Belonging question, 0.000029 for the Connection question, and a larger p-value of roughly 0.0019 for the Supported Learning question. Additionally, the Connection question for scenario five was also significantly different

between the two groups' responses, but with a higher p-value of roughly 0.038, so less than the often reported threshold of $p=0.05$. Finally, the Value & Belonging question for scenario five was not quite significantly different between the two groups, but perhaps worth mentioning that it was the only other question, out of 24, that had anything close to a significant p-value, meaning it was only slightly higher than a traditionally accepted p-value threshold of 0.05.

These results confirm the patterns discussed from the histograms above. Further, these findings indicate that, on average, scenario two is perceived differently between the focal and dominant groups of students. Specifically, the perceptions of students differ regarding the ability of scenario two to increase a sense of belonging, supported learning and connections to students' lives outside the classroom. In other words, the members of each group tended to feel differently about the effectiveness of those scenarios as being humanizing, where the focal group were more likely to agree and the dominant group were more likely to disagree. Similarly for the Connection question on scenario five, the dominant and focal group distributions are significantly different. However, that p-value was substantially higher than for all scenario two questions, suggesting that the differences between the two group's distribution of answers for the scenario five Connection question was not as stark as for scenario two questions. Although both groups, on average, tended to agree that scenario five would positively impact connection to their lives outside the classroom, the dominant group was slightly more likely to disagree with this.

Scenario & Qn	Chi-squared test result (from R)
S1VB	X-squared = 3.2353, df = 6, p-value = 0.7788
S1Cn	X-squared = 4.4525, df = 6, p-value = 0.6157
S1SL	X-squared = 6.0323, df = 6, p-value = 0.4196
S2VB	X-squared = 35.92, df = 6, p-value = 2.857e-06
S2Cn	X-squared = 30.716, df = 6, p-value = 2.871e-05
S2SL	X-squared = 20.862, df = 6, p-value = 0.001942
S3VB	X-squared = 4.0277, df = 6, p-value = 0.6729
S3Cn	X-squared = 8.6912, df = 5, p-value = 0.122
S3SL	X-squared = 7.3609, df = 4, p-value = 0.118
S4VB	X-squared = 5.0217, df = 6, p-value = 0.541
S4Cn	X-squared = 2.2163, df = 5, p-value = 0.8185
S4SL	X-squared = 4.8624, df = 4, p-value = 0.3017
S5VB	X-squared = 11.594, df = 6, p-value = 0.07168
S5Cn	X-squared = 13.317, df = 6, p-value = 0.03826
S5SL	X-squared = 10.498, df = 6, p-value = 0.1052
S6VB	X-squared = 4.2453, df = 6, p-value = 0.6435
S6Cn	X-squared = 8.695, df = 6, p-value = 0.1915
S6SL	X-squared = 2.5183, df = 5, p-value = 0.7737
S7VB	X-squared = 4.9131, df = 6, p-value = 0.555
S7Cn	X-squared = 5.0111, df = 6, p-value = 0.5424
S7SL	X-squared = 8.3038, df = 6, p-value = 0.2167
S8VB	X-squared = 6.7647, df = 6, p-value = 0.3432
S8Cn	X-squared = 6.8559, df = 6, p-value = 0.3344
S8SL	X-squared = 5.2688, df = 6, p-value = 0.5098

Table 8. Chi-squared results for each of 24 Likert questions, comparing the differences between the dominant and focal groups.

Classification Trees

I next present the overall classification tree for my data in Figure 28. Recall that a classification tree is a predictive algorithm displayed visually. In this case, it explains how the group, i.e., focal or dominant, that a student's response came from can be predicted based on their responses to the 24 Likert questions from the survey. Each node is created as a split in a predictor/input variable (a Likert question) and each node at the end has a prediction of whether that student's response was in the focal or dominant group. Recall, classification trees attempt to partition the data along input variables in order to efficiently locate responses with different output variables (i.e., which group the students' responses came from).

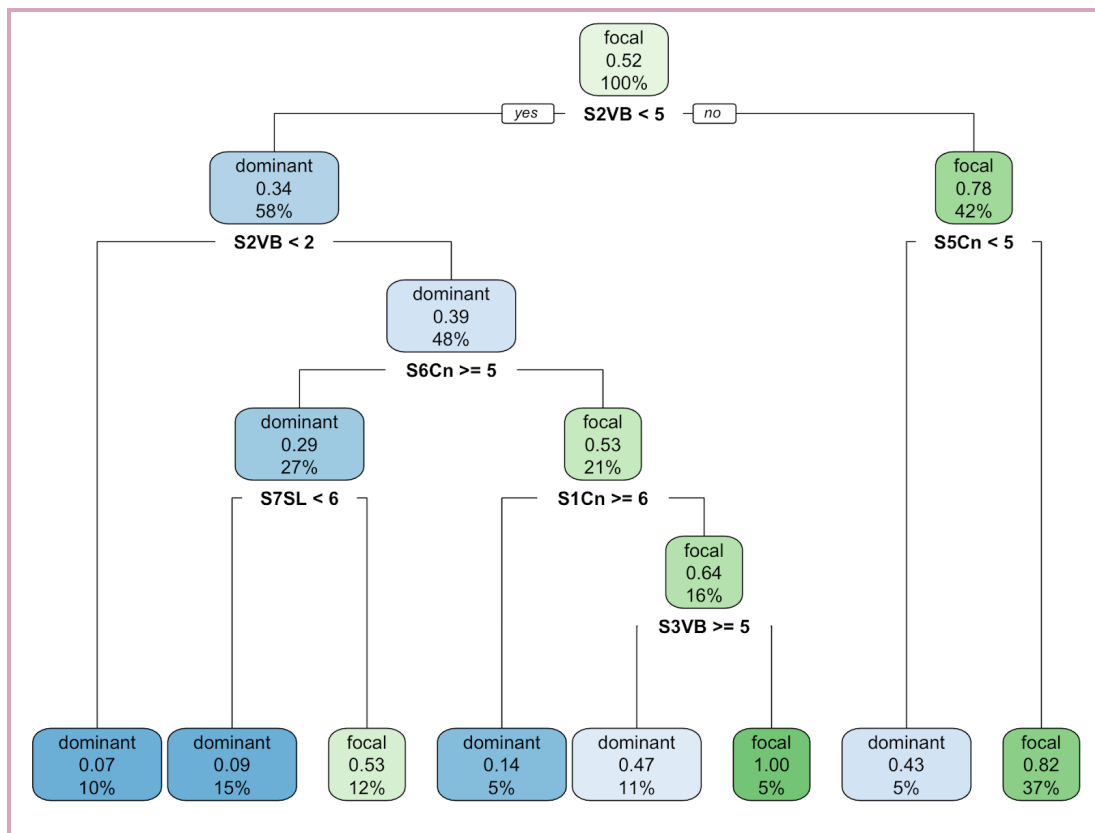


Figure 28. The classification tree using all 24 Likert questions as input variables and the output variable is the focal or dominant group classification.

In each node of this tree, the top label tells the predominant group represented in that node, which means the group that comprises most of the output values in that rectangular region in its corresponding partitioning graph. The top-most node reflects the entire sample prior to any partitioning. The next number in the node bubble gives the probability of being in that predicted group, and the bottom number in each node bubble tells the percentage of total observations that are accounted for in that node. The descriptor below each node tells which decision was made at that node. For example, in the very top/first node in Figure 28, it accounts for 100% of the data because it has not yet split and there is a 52% chance that a response in that group is from the focal group (because there were 80 out of 153 total responses in the focal group, which is about 52%).

In Figure 28, the first decision made for partitioning is based on the scenario 2 Value & Belonging question (S2VB in the figure). This means that the S2VB question has the highest likelihood of predicting which group a particular student response was from. From there, S5Cn, i.e., scenario 5 Connection question, is next most important. These two facts are not really a surprise since all of scenario 2 questions and the Connection question for scenario 5 had statistically significant different distributions for the two groups of student responses based on the chi-squared results. This tree, however, gives more information. For example, the bottom right node says that if a student answered greater than or equal to 5 (Somewhat Agree) for the scenario 2 Value & Belonging (S2VB) question AND scenario 5 Connection (S5Cn) question, then there is an 82% likelihood that they are in the focal group, and that node/category accounts for 37% of the total survey responses. This was the most compelling node since it accounts for, by far, the highest percentage of responses with a reasonably high probability, i.e., in its corresponding partitioning graph, the rectangle for that node has the largest area with fairly

homogeneous output values. The final tree node second from the left accounts for 15% of the overall data but with a strikingly low probability, which is not very compelling. The bottom tree node third from the right accounts for only 5% of the overall data, but with 100% probability, which means that all of the responses accounted for by that node are from students in the focal group.

Overall, the final rightmost bottom node that accounts for 37% of the data provides more nuanced data than the previous-stated chi-squared test results. From the histograms and chi-squared test results, we already knew that all Likert questions from Scenario 2 and the Connection question from Scenario 5 are significantly different between the focal and dominant groups. The classification tree goes further to state that we can predict, with reasonable accuracy, that if students answered Agree or Strongly Agree on Scenario 2 Value and Belonging question AND on Scenario 5 Connection question, then they are in the focal group (with 82% probability). Thus, for focal group students, these two scenarios are influential for a sense of belonging and connections outside the class. Finally, it is helpful to recall that a classification tree seeks to minimize the number of cuts/splits it makes so the order of the nodes in the tree is important which adds more information to chi-squared results because it says that Scenario 2 was most important. One final note worth mentioning is that although the Scenario 2 Connection question was also found to be significantly different between focal and dominant group responses, S2Cn does not appear as a node split decision in the tree. This suggests the likelihood that S2VB and S2Cn are indeed correlated.

If we add one variable to the data, namely that of “which school,” the classification tree produced is slightly different (see Figure 29). In this tree, it is still true that S2VB was the first

variable to split on and the left side of the tree is mainly intact, compared to the original tree in Figure 28. However, which school becomes a second-level node for splitting, essentially replacing the importance of S5Cn in the original tree. Here, I let HSU be represented by 1 and CBSU is represented by 2. At HSU, there were 55 dominant group survey responses and 36 focal group responses, whereas at CBSU, there were 18 dominant group and 44 focal group survey responses. Thus, the bottom right node in this new tree says that if a student answers Agree or Strongly Agree for Scenario 2 Value and Belonging question AND they are a student at CBSU then it is likely they are from the focal group, with this node accounting for 25% of the data.

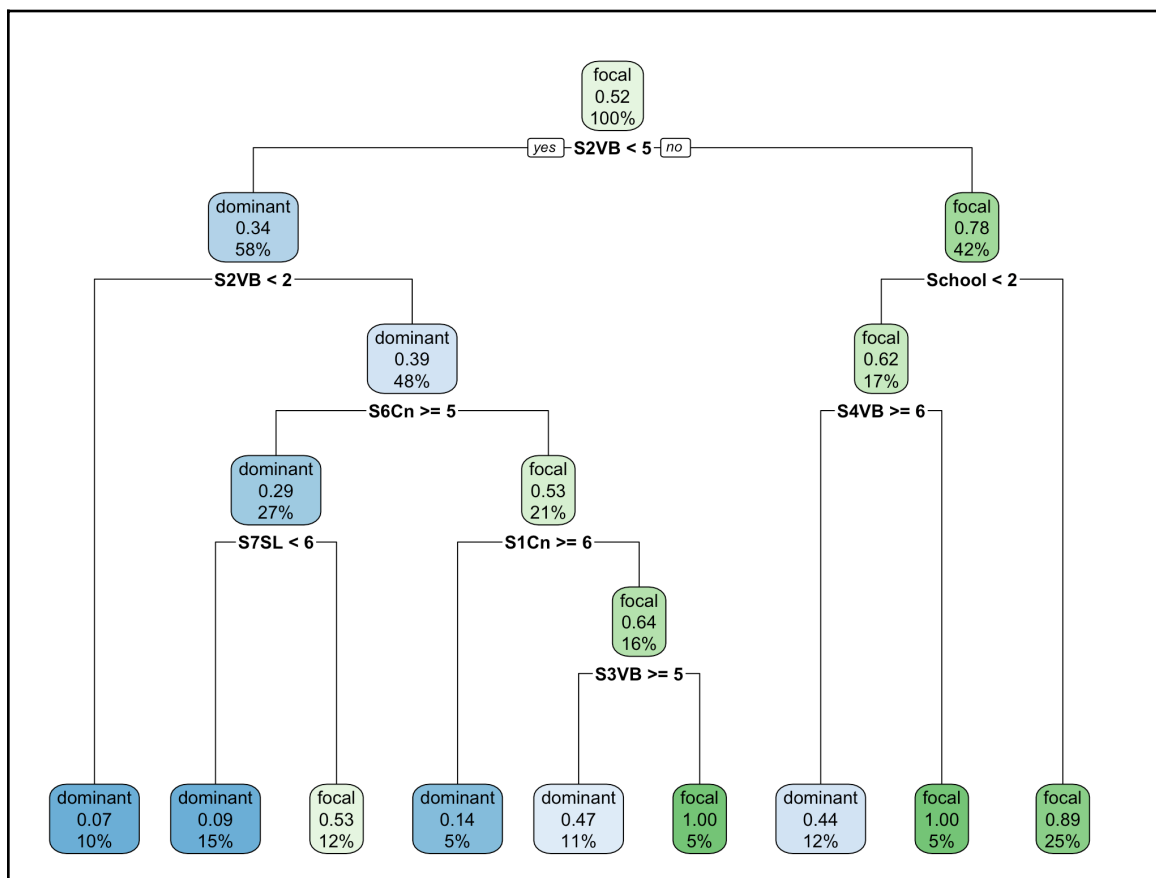


Figure 29. The classification tree using all 24 Likert questions and which school as input variables and the output variable is the focal or dominant group classification.

I next present three different sub-trees, one for each of the three Likert questions that were asked for each scenario, namely one tree corresponding to the Value & Belonging questions, another for the Connection questions and a last tree for the Supported Learning questions. Each of these trees have only eight input variables (one for each scenario), but the output variable is still the predicted group, i.e., focal or dominant. In Figures 30-32, it is evident again that scenario 2 was the most compelling predictor of which group a student's response came from for each of the separated trees. Another noteworthy fact to point out is that in all four trees, the overall tree and these three question-specific trees, it is hard to predict if a student's response was in the dominant group. For example, in Figure 30, the left-most bottom node in the tree classifies a response being in the dominant group if the their S2VB response was less than 2 (Disagree), but only with a 7% probability which is not a very strong statement. In fact, all of the bottom nodes categorized as dominant had probabilities ranging from 7% to 47% and nodes categorized as focal group had probabilities ranging from 53% to 100%, which is quite a contrast. This suggests that the focal group responses were less dispersed than the dominant group responses and easier to predict.

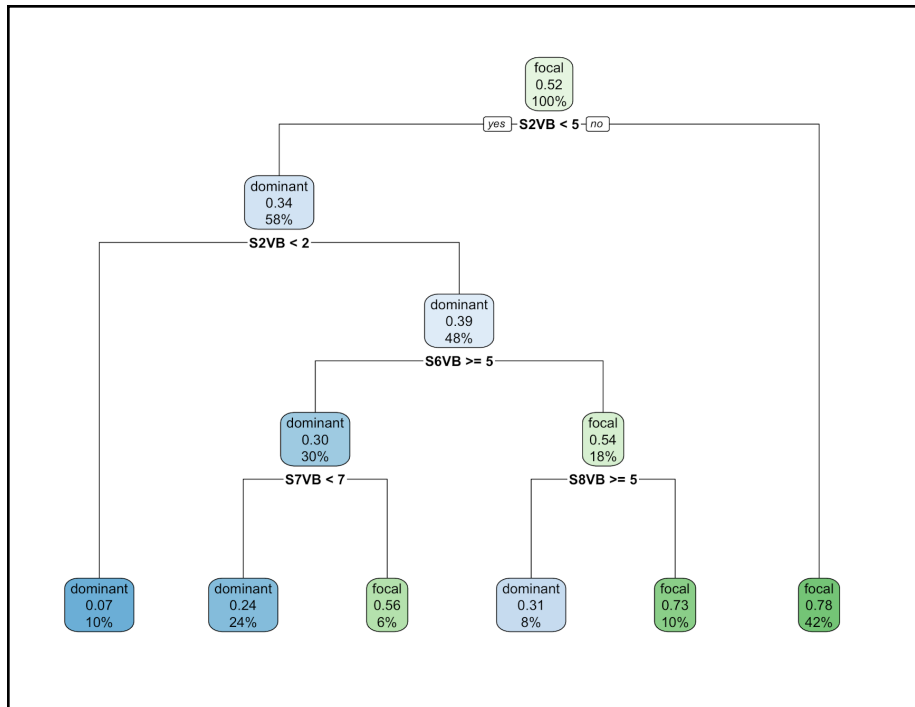


Figure 30. Classification tree for each of the Value & Belonging Likert questions.

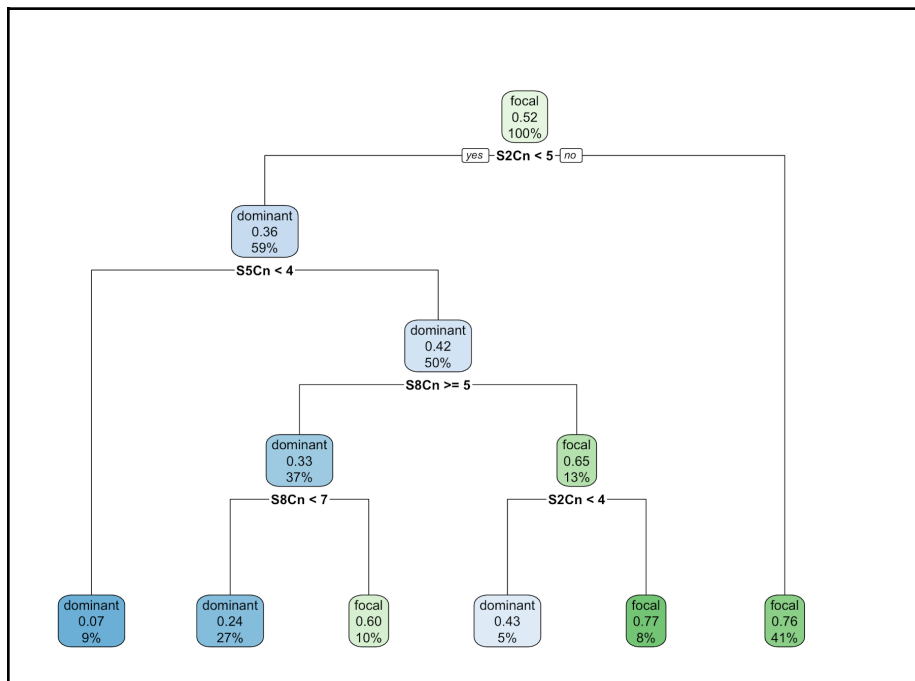


Figure 31. Classification tree for each of the Connection Likert questions.

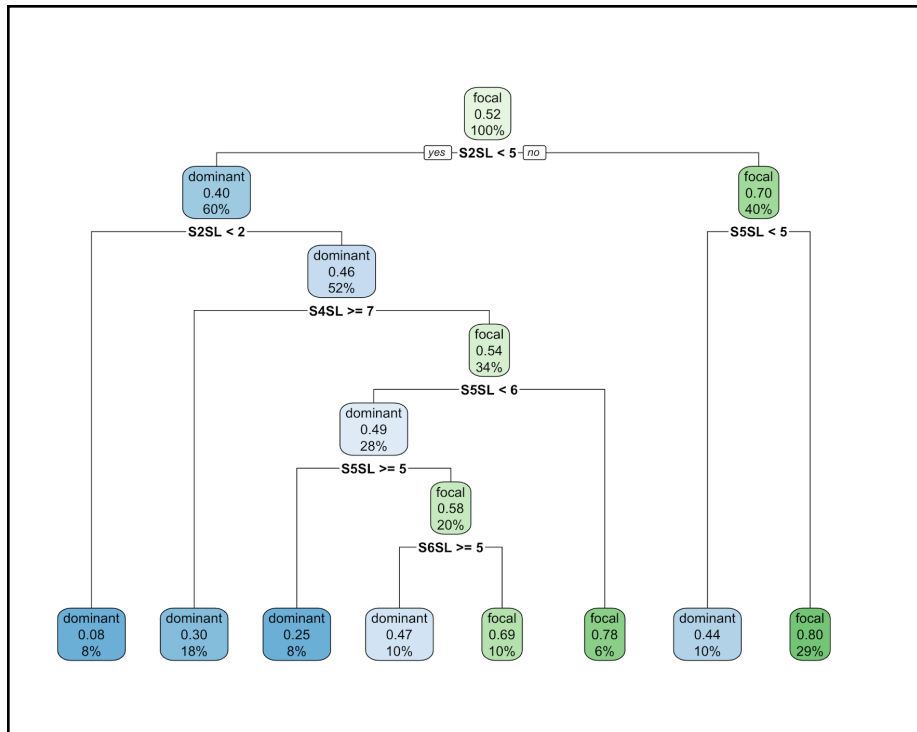


Figure 32. Classification tree for each of the Supported Learning Likert questions.

Summary of Quantitative Findings

The quantitative data analysis set out to answer, in part, what classroom structures, practices and pedagogies undergraduate Calculus 2 students perceive as rehumanizing. I used the scenarios on the survey to represent examples of rehumanizing practices that could be implemented in undergraduate mathematics classes and explored students' perceptions in terms of their feelings of being valued and belonging, supported in their learning and connecting mathematics to their lives. Overall, it is clear from the left-skewness of the histograms for all the Likert questions, except Scenario 2, that students generally find these scenarios representing the rehumanizing dimensions to be beneficial. Further, Scenarios 1 and 4 responses were especially well-aligned between the focal and dominant groups. Thus, teaching practices in all dimensions of the rehumanizing framework have the strong potential to contribute positively to Calculus 2

students' perceptions. From this analysis, it is additionally clear that the scenario corresponding to the Cultures/Theirstories rehumanizing dimension was most compelling, especially for the focal group of students, even when accounting for the university where students attend (recall CBSU had 44 students from the focal group and 18 from the dominant group, an imbalance which could have yielded more priority in the classification tree analysis). More nuanced information is provided in the next chapter, exploring the results of analyzing the qualitative data.

CHAPTER FIVE

QUALITATIVE FINDINGS

Introduction

Building on the quantitative findings from Chapter 4, here I present the findings from the qualitative data analysis. The bulk of the data come from the 20 interviews conducted with students in the focal group, but the open-ended essay questions from all survey participants were also analyzed and are reported on here. There were 80 students total in the focal group, as survey participants, which means 25% of them were interviewed for this study, creating a rich narrative used to answer the research questions. Those research questions are:

What classroom structures, practices and pedagogies do undergraduate Calculus 2 students perceive as rehumanizing in their college mathematics classes?

- a. In particular, what are the perceptions of students from historically marginalized groups (in STEM) from various races, ethnicities, LGBTQ+ statuses, and/or genders? And how do these perceptions compare to overall perceptions?
- b. In what ways does examining student perceptions contribute to the existing rehumanizing framework?

I start with a brief, demographic description of the interview participants. This is followed by more detailed descriptions of each interviewee's mathematical identity and short biography, to ground the relational and human-beingness focus of this study and its transformative framework. To set the stage for the qualitative findings from the interviews and survey data, I give a description of dominating overarching themes. Then, the qualitative

findings are separated into four main categories, including the definition of humanizing from the interviews, general humanizing teaching moves recommended and/or experienced by the interviewees, main themes emerging from the rehumanizing dimensions, and qualitative survey findings across dominant and focal groups. A report of the blended findings, pulling from the qualitative data to discuss the potential reasons behind the significant differences in Scenarios 2 and 5 between the focal and dominant groups observed through the quantitative analyses, is included within the rehumanizing dimensions section.

Interview Participants

Recall from Chapter 3 that 20 focal group students, i.e., students who identify as Native American, Latin*, LGBTQ+ and/or women, were interviewed based on their demographic information, willingness to be interviewed and possibly their enthusiasm about being interviewed that they wrote in their last open-ended survey question. The Venn diagram here (see Figure 33) showcases the demographic mixture of students who participated in interviews. The “women+” category represents students who identified as women, gender fluid or non-binary. All names listed are pseudonyms, which were primarily chosen by me, with two exceptions where students preferred to choose their own pseudonym. Students represented with purple-typed names were from HSU and students represented with black-typed names were from CBSU.

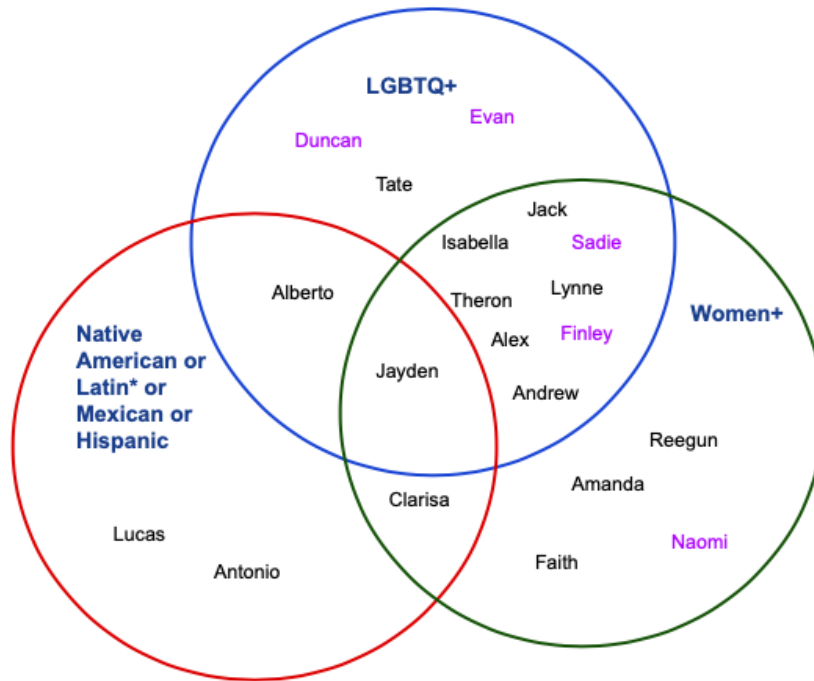


Figure 33. Venn Diagram representing demographic data for students chosen to be interviewed.

In Table 9, all interviewed students along with their demographic information as provided on their survey is provided. All data in this table is primarily as given by the student in their survey responses. However, there are a few updates made to this data based on interview data. For example, if a student originally wrote that their pronouns were either she/her or they/them in the survey and then later, in the interview, confirmed that they would prefer that all references to them in published research use only she/her pronouns, then that request is being honored here.

Pseudonym	Pronouns	Gender	Race and/or Ethnicity	Sexual Orientation	Identifies as transgender, agender, non-binary, gender fluid or something under the non-binary umbrella?	Major	School
Alberto	he/him	man	Hispanic	Gay	No	Games BS Computer Science Minor	CBSU
Alex	they/them, ze/zir	non-binary	white	Aroace	Yes	Computer Science with EAE emphasis	CBSU
Amanda	she/her	woman	white	Heterosexual	No	Biomedical Engineering	CBSU
Andrew	they/them	non-binary	white	Bisexual	Yes	Data Science	CBSU
Antonio	he/him	man	Mexican	Straight	No	Applied Mathematics	CBSU
Clarisa	she/her	woman	Latina	Heterosexual	No	Applied Mathematics	CBSU
Duncan	he/him	man	white	Gay	No	Bioengineering	HSU
Evan	he/him	man	white	Gay	No	Computer Science	HSU
Faith	she/her	woman	white	Heterosexual	No	Biology	CBSU
Finley	they/them	non-binary	Caucasian	Pansexual	Yes	Chemical Engineering	HSU
Isabella	she/her, they/them	woman	white	Bisexual	Maybe	Mathematics	CBSU
Jack	they/them	non-binary	Caucasian	Pansexual	Yes	Biomedical Engineering, Materials Science & Engineering	CBSU
Jayden	she/her	woman	white & Hispanic	Lesbian	No	Chemical Engineering	CBSU

Table 9. Self-identified demographic data for all interviewees.

Pseudonym	Pronouns	Gender	Race and/or Ethnicity	Sexual Orientation	Identifies as transgender, agender, non-binary, gender fluid or something under the non-binary umbrella?	Major	School
Lucas	he/him	man	Native American	Heterosexual	No	Chemistry	CBSU
Lynne	she/her	woman	white	Queer	Maybe	Mathematics	CBSU
Naomi	she/her	woman	Asian	Heterosexual	No	Computer Science	HSU
Reegun	she/her	woman	white	Heterosexual	No	Biology	CBSU
Sadie	she/her or they/them	woman	Asian & white	Demisexual, Biromantic	No	Mechanical Engineering	HSU
Tate	he/him	man	white	Bisexual	No	Computer Science	CBSU
Theron	they/them	non-binary (gender fluid)	white	Demisexual	Yes	Computer Engineering	CBSU

Table 9 Continued. Self-identified demographic data for all interviewees.

Mathematical Identities and Short Biographies of Interviewees

Because this research is human-oriented, each of the 20 interviewees is described here in more detail than providing merely their demographic information, as is listed in Table 9. After all of the interviews were transcribed, information from each interview transcript and its corresponding researcher notes document provided the basis for each of the following biographical descriptions. In each mathematical identity and short biography, I have written two to three paragraphs of information regarding the student's personal identity, as self-described to me, as well as pieces of their mathematical identities that came out during the interview.

After writing each biography, I emailed the interviewee to get their approval for their biography and for them to have the opportunity to suggest changes along the way, in case I described something inaccurately or incompletely. All students (except one, who did not respond to several email requests for approval) gave their consent via email for me to use their biography, as written here, to describe them and agreed that what is written reasonably represents them. Three reasons to get student approval for these biographies are (1) to be sure I am respecting and including these students who are pivotal for my research. Also, (2) the rehumanizing framework highlights the importance of elevating student voices as human beings first and foremost (Gutiérrez, 2018). Finally, (3) learning from students in the expressed focal group is the direct goal for the research questions investigated through this study. These biographies are intended to give a sense of each student as a human being and as a mathematics student, majoring in a STEM discipline. (Note: I have removed filler words, i.e., “like” or “um,” in the student quotes to make the quotes more readable and to be aligned with the interviewees’ wishes.) At times, I made inferences based on what students were saying, that were also guided by the rehumanizing framework and the purpose of the study. With that said, students signed off on these short biographies as accurately representing their thoughts and feelings.

Alberto

Alberto has been attending CBSU for two years to pursue his second bachelor’s degree, majoring in Computer Science with an EAE (Entertainment, Arts & Engineering) emphasis. He currently takes full-time coursework on top of working a full-time job. His degree program is the beginning of a career change from a successful dance career to a more scientifically oriented career, the timing of which was partially prompted by the employment challenges that came with

the pandemic. He self-identifies as a Hispanic, gay man, using he/him pronouns. His mom is from Puerto Rico and has always said their “family’s Hispanic,” which influenced Alberto’s use of Hispanic rather than Latino or Latinx. In his view, those labels are essentially “the same” and thus, given a choice, he chooses the label that aligns with family norms.

Alberto considers his family members as “best friend[s], all of them” which includes his partner, mom, dad, siblings and his dog. When asked what aspects of his identity are salient for his college experience, he noted that he returned to college to “have a good future with [his] partner and to be able to help [his] family if they need help.” He feels that his partner and family are a “bigger thing than [himself]” which motivates his academic focus and commitment. Additionally, being openly gay is important for Alberto’s college STEM identity. He feels it is “important to not hide the fact that [he’s] gay” because he “want[s] to be able to help people if they are in [his] classes.” By this he means that his aim is to be a role model for other gay or LGBTQ students so they have the freedom to not “have to hide who they are,” i.e., to support students bringing their authentic selves to mathematics and other STEM spaces.

Alberto had consistently vibrant energy and enthusiasm during the interview and it was clear from several comments that he wants to positively impact others, and wants his academic coursework to positively “connect” to his future career. For a long time, including during his first degree program, he had no confidence in his mathematics and science skills. He felt he was “not smart enough” or “manly enough” to belong with other STEM majors. But now, due to his age and maturity, he is more willing to “jump in” and give it his best to see how it goes. He has been happily surprised that he is succeeding and enjoying his “programming and math” classes much more than previously anticipated. Due to a supportive learning experience in his Calculus 1 course, he signed up to take Calculus 2 from the same instructor. He felt that the instructor

“believe[d] in [him] as a student and that made [him] want to do better and it made [him] believe in [him]self more.” Partly due to that instructor’s support, Alberto recognizes many characteristics of doing mathematics that apply to his life outside of class, including struggle, “teamwork” and “critical thinking skills.”

Alex

Alex self-identifies as a non-binary, white, aroace person, using they/them or ze/zir pronouns. Aroace is used here as a combination word for ace and aro.²⁰ Alex feels that ace and aro are “part of the same thing for [zir]. So it just makes sense to have them be one word.” Their preference is that I switch up the use of their two sets of pronouns, which is reflected in this write-up about them. Additionally, they identify as “neurodivergent with sensory processing disorder and dermatillomania,” alongside “other OCD tendencies” which ze believes has only a “neutral” impact on their success in computer science and mathematics. Ze is in zir sophomore year, majoring in Computer Science with an EAE (Entertainment Arts & Engineering) emphasis at CBSU. Their projected graduation date is in spring of 2024 and zir goal is to become a game designer after college.

For Alex, the most salient aspect of their identity in college so far has been the fact that ze is non-binary. They commented that people are “used to thinking, okay, everyone's probably either male or female, and so it kind of results in an invisible feeling.” Until Alex explains to others that they’re non-binary, they feel that people “don’t see [ze] as [ze] yet.” The erasure of this aspect of zir identity is all-too present, in their experience. When instructors take the time to

²⁰ Both of these words in the LGBTQ+ community are understood to be on a spectrum. According to the Trevor Project website, ace is short for asexual and typically means that a person “may have little interest in having sex, even though most desire emotionally intimate relationships.” Aro is short for aromantic and typically means that a person has little interest in romantic relationships.

use or ask for pronouns or if someone else uses they/them or ze/zir pronouns, indicating they are “probably not cis,” Alex feels “seen.” When instructors do not ever use pronouns, Alex does not necessarily feel a “negative impact,” but “more like a positive impact that [ze] could have that [zir’s] not getting.” Zir experience in college mathematics classes specifically, in relation to zir identity, is that pronouns are not typically brought up, like they are in a humanities class for example. Thus, in mathematics courses if pronouns are not addressed, the sense of invisibility persists.

Enjoying mathematics and “generally respond[ing] well to the way teachers teach” is a frequent experience for Alex. With that said, they feel that lecture-based classes are a missed opportunity for learning and “interacting with other people” is much better for thriving. Perhaps the quote that sums up Alex’s thinking regarding mathematics classes is the following: “when you go into a calculus class, you should feel not like you’re just a calculus student but like you’re a student who’s taking calculus.”

Amanda

Amanda is in her first year of college, majoring in Biomedical Engineering with a planned graduation date of 2025. She self-identifies as a white, heterosexual woman, using she/her pronouns. During high school, she took both concurrent enrollment and on-campus courses from a local community college, which included Calculus 1. Thus, she was able to take Calculus 2 during her first semester at CBSU. She feels university mathematics courses are “definitely different than high school” or “community college math” classes that she took previously because they are “a lot more independent” with “less help” or resources offered. In her experience, “talking wasn’t encouraged” in her university mathematics course, as it was

strictly lecture-based. However, for Amanda, interactions and the ability to ask and answer questions with peers and instructors, i.e., to have an “open line of communication,” are necessary for effective learning. She wants everyone in the class to be “able to struggle through the problems together, which ma[kes] it more cohesive,” because that “feeling of understanding” is “so amazing.”

When asked about salient aspects of her identity, Amanda mentioned that “being an engineering student” and “being a female in STEM is very important to [her] identity because [she] want[s] to succeed to prove” that she can “do hard things.” She also pointed out that “having that sense of belonging into the STEM community” was important to her. This is partly motivated by the fact that she has “definitely had people” tell her that she “shouldn’t be in a STEM field” because of her gender. Thus, being a woman in STEM feels incredibly salient to her. She wants to “prove that [she] understand[s] upper math,” especially as a woman, because that would “prove that [she’s] smart” and that motivates her. In her experience, “if you [are] in math or science, you [are] smart.”

Andrew

Andrew self-identifies as a non-binary, white and bisexual person, using they/them pronouns. They are a second-year college student majoring in Data Science at CBSU, planning to graduate in 2024. When asked what aspects of their identity are most salient as a STEM major in college, Andrew said that being non-binary is “definitely different” and has caused “a lot of awkward first conversations” with other people. For them, this aspect of their identity is a “very internal label,” meaning that “people don’t really look at [them] and think [they’re] non-binary.” It is an identity piece that needs to be explicitly stated since it is invisible to others, which allows

Andrew to hide this aspect of their identity if desired. Further, “being non-binary doesn’t hinder [their] ability to do math,” nor does it “hinder [their] ability to code.” They believe that some people “think it’s weird,” but in their experience, people with such beliefs “keep it to themselves” which makes their experience overall “not terrible.”

Since Andrew started college during the pandemic, their first year of coursework was primarily done online. They are grateful to be moving away from online learning to in-person classes where human interaction is more easily accessible. Their experience with mathematics and computer science instructors has been a “mixed bag.” However, peer interactions in their major have been “surprisingly positive,” only surprising because they view STEM majors as notoriously introverted and their experience is that their peers are more “social than expected.” In their major, they have had positive interactions with students who are “pretty focused” and committed. Students in their Calculus 2 course “were struggling,” so they worked together which helped Andrew’s learning and success. “Working with people is really important” to Andrew overall and contributes to their feelings of success.

Antonio

Antonio self-identifies as a Mexican, straight man using he/him pronouns. He prefers Mexican, not Latino or Hispanic, because he views them as different ethnicities and he is Mexican. He is a first-year student, majoring in Applied Mathematics at CBSU and planning to graduate in 2025. Antonio has three older brothers who all majored or are majoring in STEM fields, including Applied Mathematics, Computer Science and pre-med. He says that his “older brothers definitely impacted [his] decision” in choosing a major, especially seeing how their

STEM coursework “affected them.” His parents went into business (father) and teaching (mother), but Antonio always enjoyed mathematics and considered it his “forte.”

When asked what parts of his identity were most salient in college, Antonio gave two aspects, namely his membership in a fraternity and his Applied Mathematics major. His major is an important part of his college identity because he likes being “different” from his peers and standing out in that way. He wants to be his own person and not “just follow the crowd” because he “wants to make a name for [himself] in a different area other than what everyone else” does. His involvement with a fraternity is important to Antonio partly because he feels it is a great resource of “older guys in the fraternity who have taken the classes that [he’s] currently in and they can help [him] a lot.” Having that community of extra resources boosts his learning and comfort with college.

In both the open-ended survey questions and throughout the interview, Antonio expressed very interdependent views regarding mathematics and wants to see everyone succeed and learn. Unfortunately, in his Calculus 2 course, he didn’t really talk to his peers in class, mostly worked alone and “kept to [him]self.” He did participate in a group chat with other students where they helped with some homework questions. However, without peer interaction, he feels “stranded” by himself. He expressed interest in having instructor-led structured ways of interacting with peers during mathematics courses to “allow everyone to get to know each other and feel comfortable in the workplace.” This level of comfort with his peers would allow him to “have more resources to learn because [he’d] be able to ask [for] help from them.” Having other students as resources, in addition to the instructor, is important for Antonio because “the dynamic is a little better when you have peers.” Overall, he wants to feel “comfortable” with

both his teacher and other students so he can ask questions and “make mistakes.” For Antonio, this level of comfort necessarily leads to learning and success in mathematics courses.

Clarisa

Clarisa is a sophomore at CBSU, majoring in Applied Mathematics and planning to graduate in 2024. She self-identifies as a Latina, heterosexual woman, using she/her pronouns, and is also a first-generation college student. While growing up, her mom typically “worked three jobs” so her “grandma took care of [her]” and helped her with homework after school. Since her grandma only spoke Spanish (she grew up in Mexico and Clarisa grew up in the states), she could not help with any homework that had to do with English due to the “language barrier,” but she could help with mathematics. Clarisa has fond memories of her grandma teaching her mathematics. Additionally, her maternal grandpa is part Japanese and he would teach Clarisa “Japanese methods for math,” which she loved and thought were “really cool.” Thus, she grew up having a love of mathematics that was tied to familial relationships.

The most salient aspects of Clarisa’s college identity are being (1) Latina and (2) a “woman in STEM, particularly math, because [she didn’t] see a lot of people like [her]” growing up. She feels that if she had seen more STEM role models in her “own community,” then she would have “challenged [her]self a bit more” throughout her K-12 schooling “in order to do better in college.” She is motivated to study mathematics, as a Latina woman especially, because it is “what [she] like[s] to do” and so she can “apply that to other passions, like serving others” or “future goals or career interests.” She feels this is possible because “math is very broad.” Although the academic content in her major courses is enjoyable for her, she feels a bit like an

“outsider” in the mathematics major because there are so few “women and Latinos,” but “hopefully that will change in the future.”

Clarisa considers herself a “visual learner” and likes it when instructors are flexible and provide additional resources for learning, which has happened so far in her experience. Teachers who are “passionate” about what they are teaching and “prioritize math,” which means they “communicat[e] each step,” are most enjoyable for Clarisa. Having teachers share their research interests as well as asking students about their mathematical interests supports her learning and career goals.

Duncan

Duncan has been a student at HSU consistently since 2014 and is currently working on a masters degree in Bioengineering, graduating in spring of 2022, assuming his thesis is completed. His bachelor's degree was in microbiology, but since that degree did not require calculus, he has had to take Calculus 1 and 2 while in his graduate program. Duncan self-identifies as a white gay man, using he/him pronouns. In college, he feels “science is the biggest part of [his] identity.” He has always liked “to interpret things around” him, “explain[ing] things with math and science,” and he “cling[s] to professors that do the same.” He views everything he does is “because of science” and refers to himself as a “nerd in that aspect.” He specifically chose a graduate program in engineering, rather than a “sort of theoretical biology field” because he likes to apply mathematics in ways that explains the world around him and “increas[es] efficiency.” During the interview, Duncan expressed much joy when he explained how he gets to use differential equations in his thesis to model how bacteria grow and how that “affects the immune system, the healthy gut microbiome.”

Overall, Duncan's experience with his Bioengineering course instructors has been "great," mostly because the teachers are "super passionate about the topics" they teach. He recognizes that students are very motivated to learn in his classes and he appreciates teamwork. However, relationships and time with instructors seems much more important to him, in supporting his learning. Although he is a generally positive person, he said that his college mathematics teachers were "not the greatest at teaching." In one "high-level statistics course," there were not enough resources available for the students, including access to the instructor, which negatively impacted his learning. He is a "very visual" learner who requires lots of "practice" to learn and views himself as someone who does not "learn traditionally." He frequently needs a variety of explanations and perspectives to understand mathematics, which means he especially appreciates teachers who are excellent and timely communicators. Duncan actually went so far as to say that adjunct professors are the "best" because "their main focus is teaching" and not research, which makes them more "available" for students. For him, it is most important that college mathematics instructors "pay attention and adjust based on [their] students," i.e., to "care a little" which to him means to show passion and interest in their students.

Evan

Evan self-identifies as a white, gay cis-man, using he/him pronouns. He is in his second year of college at HSU, majoring in Computer Science and planning to graduate in 2025. For Evan, the most salient aspect of his identity in college and in mathematics is the fact that he grew up in a "small country town," that has a population of about 360 people. He feels this gives him an "advantage over most students" because he has had to do "physical work." That work ethic

benefits him as a computer science student. Additionally, growing up in a small town allowed him to have more “one-on-one time” with his teachers and to be highly involved in sports and clubs in high school. His high school academic and extracurricular activities, along with leadership experiences, “put [him] at an advantage in terms of life skills.” His ever-present interest in “science and math” combined with consistent K-12 teacher support “challenged [him] in school until college” which he feels is helping him succeed in college.

Evan’s STEM-major course experiences have been “good and bad,” but his Calculus 1 and 2 courses were both “great experiences” due to the teachers and course structures. He feels certain that all instructors “want to see [students] succeed,” even if the teaching techniques and/or explanations do not always work for him personally. Peer interaction in his college mathematics courses (which includes Precalculus, Calculus 1 and Calculus 2) has been “decent,” but the pandemic is dampening those opportunities. He appreciated that students in Calculus 2 were in “similar majors” which meant they could “relate” to each other “on most things.” Evan believes strongly that the primary purpose of college is to prepare students for their career, which he thinks aligns with “most people’s ideas about college.” To him, this means that students “should be working on problems that [they] would see in the field in [their] career[s]” or “at least getting exposure to that.” To accomplish this goal, he thinks that college instructors should be deeply interested in teaching and supporting student learning.

Faith

Faith is a first-generation college student at CBSU, majoring in Biology with an intended graduation date of 2025. She self-identifies as a white, heterosexual woman, using she/her pronouns. She earned an associates degree while in high school, by taking both concurrent

enrollment and on-campus courses at a community college. When prompted about salient aspects of her college identity, she commented that her identity is not “completely connected to school, but [she does] find a sense of pride in going to school for [her] family.” Making her “family proud” is a “good motivator” for her. She commented further that she has had “many opportunities that usually aren’t given to people,” like scholarships, which also motivate her to learn and succeed in college.

Faith refers to herself as a “visual learner” and enjoys “making the connection” between mathematics and other areas of her life, including other science classes like biology and chemistry, in order to “solidify” the concepts in her mind. Further, she “really like[s] knowing that in [her] future career, [she] will use” the mathematics learned in class. During the interview, Faith referred to her consideration of others several times. For example, she likes “bounc[ing] ideas off of somebody else” during group discussions in STEM courses in order to “see their perspective” because seeing “different sides” is helpful for her. She was also concerned that some teaching moves would work “for a certain type of person” but not work so well “for other people,” and that consideration influenced many of her answers.

Along those lines, Faith wants “politics” and “controversy” to be left out of mathematics courses, which she views should be “neutral” spaces. “The reason [she] love[s] math is because everything has a solution.” Although she has never personally had a mathematics course that was overly political, her concern is for herself and others regarding sensitive topics. When entering a mathematics class, she wants “to leave everything out the door,” meaning “all the problems and news,” and “just go in there and be excited just to learn.”

Finley

Finley is in their first year as a Chemical Engineering major, with a Materials Science minor, at HSU with a planned graduation date of 2025. They self-identify as non-binary, white, demisexual and pansexual, using they/them pronouns. The most important aspect of Finley's identity in college is their major. Also, they are currently only "out to [their] high school friends, one of [their] relatives" and the members of an LGBTQ-friendly campus club, but it is their "long term goal" to be out by the time they complete their degree program. Although they did not think any aspects of their identity were particularly relevant in their Calculus 2 class, they did not feel they could bring their whole authentic self into the mathematics classroom, because they "couldn't really appear how [they would] like to." They feel they would "probably" enjoy classes more if and/or when they can appear/present as they would like.

Although Finley is "not a very open or extroverted person," they have had "positive" peer interactions with students in their STEM courses because everyone they have "met and talked to has been friendly." They did feel that Calculus 2 was "challenging," partly because they have "never been the greatest math student." With that said, they enjoy learning and are especially motivated when they can see mathematics applications that connect to chemical engineering, physics or their life in some other way. In general, Finley "learn[s] much better when [they] can see direct applications, when it's less abstract." They are also interested in anything pertaining to history and "eager" to learn about "history" or "people" within mathematics, which specifically includes contributions made by marginalized mathematicians.

Isabella

Isabella self-identifies as a white, bisexual woman, using both she/her and they/them pronouns. Their request is that I switch up pronouns in writing, which is honored here. On the survey, when asked if Isabella identifies as transgender, agender, non-binary, gender fluid or something under the non-binary umbrella, she answered yes because they are “questioning.” This is their first year in college at CBSU, majoring in Mathematics with a planned graduate date of 2025. She feels that “being a woman” is the most salient aspect of her identity in college, especially as a STEM major. There are not as many women in their STEM classes as they would like which makes it “intimidating in a way.” They mentioned a concern about the prevalence of sexual harassment by men in college as part of that intimidation. Additionally, their experience is that too often students who are men “don’t think [she’s] smart enough to be able to be in that class or hear [her] opinion out or are really surprised when [she’s] doing well and understanding [the] material.” This is bothersome and makes her feel like she has to prove herself. Further, Isabella finds it “saddening” that there is a high likelihood that a man will be chosen over them for a future career job, even if they have the same credentials as the man. She is sure that “eventually it will change,” but to accomplish such a change, there needs to be “more women” in STEM fields to “normalize” the gender balance and attitudes.

As a mathematics major, Isabella sees the importance of “real world” examples in class that could shed light on “what you’d want to do as a career.” They view doing mathematics as primarily a “solo activity” but feel that “doing it as a group” increases learning because it is perspective-expanding, especially when learning “something new.” Thus, they feel that doing mathematics is “kind of both” a solo and collaborative endeavor. Her final thoughts in the interview were to stress that instructors not “rush through their lessons.” “Teaching and learning

can take time” and she wants to be sure that college mathematics instructors allow students enough practice and processing time to ensure their success.

Jack

Jack self-identifies as a non-binary, masculine-bodied, pansexual, white person, using they/them pronouns. They are majoring in Biomedical Engineering and Material Science Engineering, with plans to get a Master’s degree in Biomedical Engineering through a combined BS/MS program at CBSU, graduating with all degrees in about 2027. Their career goal is to use the materials science and engineering knowledge gained from their degree programs to “make prosthetics.” Before this college experience, Jack worked in the U.S. Navy for eight years as a nuclear submarine electrician. So, attending college at 28 years of age, with more life experience and maturity than many other college students, gives them a unique perspective. Additionally, they mentioned that personality-wise, they are “just not a very stressed person” and thus have equanimity in the face of typical college stress. My observations during the interview were aligned with this assessment as I viewed Jack to have a stable affect in general while answering questions.

The aspect of Jack’s identity that they find most salient for their college experience so far is their “time spent as a nuclear electrician on a submarine,” partly because their college costs are being covered by military benefits. Also, people in the scientific lab where they work have given Jack credit for being a “hard worker” due to their previous military experience. Jack went to college for a short time before going into the Navy, and they aim to have a more committed experience in college at this point. They discussed their intent to “actually talk a lot to [their] instructors and show up to every TA hour” in order to maximize their learning. Although they

have a strong ability to engage during all classes, including Calculus 2, they did mention a few times that they “dislike math” and are “not very good at it typically.” They are successful nonetheless as a student, due to their work ethic, interest in learning generally, focus on their studies, and dedication to their future career goals. Their disinterest in math is mostly centered around its lack of “real life applications.” In fact, the overriding theme from this interview was that mathematics classes need to have useful applications and real examples of such applications for it to feel helpful, interesting and humanizing for Jack.

Jayden

Jayden previously attended a different university in the southeast area of the U.S. during her senior year in high school and is now at CBSU majoring in Chemical Engineering. She plans to graduate in 2025. Jayden self-identifies as a white/Hispanic, lesbian woman, using she/her pronouns. When asked whether she preferred the term Hispanic or Latina, she said that her grandmother is from Guatemala and “uses Hispanic more when she talks about her experiences” and so Jayden “adopted that term as well” to be respectful of her family heritage. When asked about salient aspects of her identity in college, Jayden discussed her participation in an LGBTQ+-and-STEM-friendly club on campus which has felt “like a little community” to her. She said it was “really fun to meet people who are experiencing a lot of the same things” she is in college, like the “same major” and the “same issues at home,” such as coming out to her parents and family. She also works part-time, and thinks that “most college students work part-time.” This work “adds to [her] college experience” and “forces” her to have a “set schedule every day” which is helpful in keeping her organized.

Jayden has “always enjoyed math and science” and believes that her enjoyment of “math probably has a large impact” on her participation in and learning of mathematics. She feels that doing “long calculus problems” was like a “puzzle.” She likes to get “immersed” in her mathematics classes and wishes more mathematics courses took advantage of “study halls.” Many of Jayden’s other classes, including Physics and Chemical Engineering, have instructor-led or TA-led “study halls” which she finds incredibly helpful for her learning and to increase peer interactions, in and outside of class. The study halls are regularly scheduled sessions where students can get further help on concepts and/or homework, but “it’s not required for [students] to go.” She feels study halls are “structured” and a “good way to meet a lot of [her] classmates.” Lastly, she mentioned the importance of flexibility and kindness of instructors in working with students who suffer physical or emotional ailments during the semester, like what happened during final exams week one semester when the stress of coming out to her family caused an anxiety-induced migraine. She appreciated that her “professor actually care[d]” about her and her grades.

Lucas

Lucas self-identifies as a Native American, heterosexual man, using he/him pronouns. He started college at his hometown university and then transferred to CBSU, where he is currently in his third year of college, majoring in Chemistry with a Chemical Engineering emphasis. “Being a Navajo” is the most salient aspect of Lucas’ identity in college. He mentioned that he sometimes “feel[s] out of place” because he does not “really see too many other Native people” in his “everyday encounters on campus.” He recognizes that there are campus clubs he could join to help surround him with other Native students, but due to his “heavy course load,” he does not

have “much spare time” to do “any kind of activities” like that. In his mathematics classes, he also does not “really see a whole lot of minorities” which makes him “feel like it’s [him] trying to represent.” Overall, he frames that in a “positive light” because he feels he is “showing that [Native Americans] can do it too” meaning “be successful in college” and “also the career.”

Lucas has successfully persisted through and “not been deterred” by several financial and academic barriers, including starting at a below-college-level mathematics course in college. His experience in that entry mathematics course was not the best and contributed to a “negative view” of mathematics. However, he was committed to continuing on with his educational goals of graduating with a “good,” i.e., STEM, degree which he knew would “require math,” because his “family isn’t very rich.” Thus, he “put in more effort,” practiced “doing [mathematics] problems, and ask[ed] questions when needed to get better at it.” And, “after putting in that effort and realizing” that he could succeed, his confidence “increased.” He noted the repeating nature of that confidence-effort cycle by saying that his confidence then contributed to him “put[ting] effort into” his future classes and “getting those courses completed.” His view toward mathematics at this point is much improved from two years ago, partly due to his success, confidence and more understanding instructors. Thus, he “feel[s] good about [his] choice” of major.

Currently, Lucas does not “see how calculus can really correlate to what [he’d] be doing in chemistry.” However, he holds hope that perhaps he just has not “reached” that point yet and will some day “see how it will eventually come together.” This showcases how he places importance on seeing the connections between the course content and the world outside the mathematics classroom, especially connections with his major field. He mentioned several times

how mathematics sometimes feels too “abstract” when it is not applied or connected to other aspects of his life or course work.

Lynne

Lynne self-identifies as a queer, white woman, using she/her pronouns. On the survey, when asked if she identifies “as transgender, agender, non-binary, gender fluid or something under the non-binary umbrella?” she checked maybe. When probed about this during the interview, Lynne did not want to sound “dismissive of anyone else’s experience” and went further to say that she’s “not entirely convinced gender” is really “a thing.” In her view, “there isn’t a consistent definition” and so it is frustrating to figure out how to respond to such questions.

She is a Mathematics major at CBSU, in her first year of college, with a planned graduation date of spring 2025. For her career, she stated that she is not interested in being a teacher, but would prefer a career where she can apply mathematics. She is enjoying being in college, with newfound freedoms and increased learning opportunities, compared to her high school experience. As part of an initiative that provides an opportunity for students to participate in research, Lynne took a class in the fall semester of her first year as part of that program and is doing research with a mathematics faculty member in the spring semester.

Lynne referred to herself as introverted and “really shy” which means she doesn’t “talk to people” much. Additionally, she self-identified as having ADHD and sometimes that causes her to make small mistakes even if she understands the material. Her introversion wins out over discussing things with peers or even wanting to feel a sense of belonging with them. During the interview, Lynne voiced her desire that educators do things that are not so centered on “people

stuff” and rather focused on mathematical content. In a follow-up email, however, she expanded on and further explained this sentiment. “If the course is just focused on the material and less on the social environment,” it makes it easier for her to handle her anxiety.

Her focus in a mathematics class is truly the learning and not on feeling a sense of belonging or community with others. She mentioned that in her schooling experience, she has always been ahead in mathematics. This meant she was frequently put in classes above her grade level where she did not know anyone and she would “be too scared to talk to” any other students. In those settings, she resorted to focusing on the learning aspect rather than the social aspect and “stopped expecting to feel like any sense of connection to people in [her] class,” which she feels probably influenced her current stance on mathematics classes. Also, she does not want an overriding focus to be placed on grades rather than learning, even though she has to keep certain high grades in order to keep her scholarship. Overall, she cherishes learning.

Naomi

Naomi is a sophomore at HSU, majoring in Computer Science. She self-identifies as an Asian, heterosexual woman, using she/her pronouns, and is an international student. Previously, she attended a community college in another state and then came to HSU for the opportunity to play for a women’s team at HSU, on an athletic scholarship. Naomi loves computer programming and has always wanted to be a software engineer for her career. She has a loving family who has consistently supported her athletic, academic and career goals. Due to travel for sports, she is forced to miss some classes and has felt supported academically by her instructors and peers. In her experience, all instructional staff have been helpful and flexible in keeping her up to date in her coursework, even while traveling for athletic competitions. This is impactful for

her college experience, especially given that the most salient aspect of her identity in college is her role as a student athlete since it “brought [her] so many experience[s] in college” in training her how to “manage [her] tasks in both athletics and also academics.”

Teamwork is really important to Naomi, including in her classes. This idea came up several times during the interview. She loves how teams “work together and achieve the same goal,” like being classmates all working toward “understand[ing] the [calculus] concepts” and earning successful grades. Additionally, teamwork helps expand perspectives and build connections when peers can “share [their] thinking with other people.” She is motivated to learn, especially when that knowledge can “have some kind of impact” to “change the world into a better place.” Further, I observed Naomi as a very bubbly and enthusiastic person, which came through during the entire interview, and this personality trait probably helps when seeking community and teamwork opportunities with classmates. Themes of creativity/play and utility came up throughout the interview. When I pressed her to decide if (a) creativity (or play) or (b) utility (or applications to her career) is more important, it seemed hard for her to make that decision. But she eventually said that utility would be more important because it “is useful for [her] career” and thus the “most important thing.”

Reegun

Reegun self-identifies as a white, heterosexual woman, using she/her pronouns. She has been a student at CBSU for four years and will graduate in 2024 with a degree in Biology, with an emphasis in Anatomy and Physiology, after which she is planning to go to medical school. She started out as a pre-Nursing major and “then took some classes” that “piqued [her] interest” which prompted her to switch her major and “go for medical school.” She is a second-generation

college student, and the first person in her family to have intentions to pursue a graduate degree. Reegun's "background and where [she] grew up" is the most salient aspect of her identity in college. The next aspects of her identity that are impactful for college are "being a woman" followed by "being super religious" as a Christian which "helps keep [her] centered" and "give[s] [her] purpose." Growing up in a small, rural town where poverty is common and then going out of state to university caused Reegun to see "how much more you can have with an education." Thus, education is a "big part of [her] identity" and she is driven to "do well" because she does not "want to end up stuck at home." Instead, she wants to "be able to provide a life for [her]self and [her] family" and to "help others." Self-sufficiency is crucial for Reegun and showcased when she said that she has a "hunger to prove" herself. In mathematics classes, more specifically, Reegun feels her "work ethic" along with her love for mathematics are the most relevant aspects of her identity.

Because she "loved Calc 2," she is also considering either taking more mathematics courses or switching her major to mathematics. Her enjoyment of the Calculus 2 course was in large part due to the instructor, the instructor's supportive demeanor and the course structure where she had opportunities for peer interaction. Students in that class were "really good at talking and asking questions" which was beneficial for Reegun because she "learned from other people's questions" and felt comfortable to "ask a lot [of questions]" herself. Whenever "class is more vocal, it definitely helps" her learn and speak up. Additionally, seeing mathematical applications for "real-world issues" allows Reegun to see the importance of the content, which in turn motivates her to "put more effort into" her mathematics class. She spoke about how "beneficial" it is to see different perspectives in mathematics courses "because people learn

differently.” Finally, she mentioned that her “best [mathematics] experiences” have been with “women instructors,” partly “because they’re examples [in STEM] that [she] can live up to.”

Sadie

Sadie self-identifies as an Asian and white, demisexual, biromantic woman, using she/her or they/them pronouns. To honor their preference, I will switch between the two sets of pronouns in this writing. They are a first-year student at HSU, majoring in Mechanical Engineering, with a planned graduation date of 2025. Her parents, and mom especially, have been “super encouraging” and “supportive” influences in her academic life. This was particularly important in their first semester of college due to a medical issue that created a temporary barrier to staying caught up with homework and class attendance. The support of their mom, instructors and peers helped them overcome that hurdle and succeed in their courses, including Calculus 2. The most salient aspect of Sadie’s identity in college is being “female, because [she’s] going into engineering and female engineers are not common.” They commented that the gender balance in high school seemed to be about “50/50,” but their college “math class is definitely not.” The fact that there are “not a whole lot of other women going” into engineering majors makes her feel like she is “in the minority.” Another way this gender imbalance shows up for them is in their campus job. She is a “student supervisor” at a “coffee stand” on campus where she “definitely know[s] what [she’s] doing,” but the “guys” second-guess her work, which “doesn’t feel great.” Additionally, this experience with having students who are men “second-guess” their work in classes frequently prompts them to work alone rather than in groups.

Partially because her mom is a teacher and partly because she has “a few different mental disorders” and does not “learn like the majority of students,” Sadie has a community-minded

view of teaching and learning strategies, or in her words, she takes “two eyes to it.” Many of their interview responses centered other students and/or the teacher, rather than only focusing on what was best for themselves. She wants mathematics classes to be structured in ways that support the learning and success for all students. For Sadie, mathematics classes are best when the instructor knows students’ names and “knows [students] exist,” which is one way to ensure the classroom culture is not a “cold environment.” Further, she feels empowered when she gets to see mathematics problems in class that she can “use in [her] future career.”

Tate

Tate is in his second year as a Computer Science major at CBSU, with a graduation date of 2024. He self-identifies as a white, bisexual man, using he/him pronouns. When asked what aspects of his identity are most salient for his college experience, he was not sure if “any specific part of [his] identity” impacted him “super significantly.” However, when asked if any aspect of his identity was impactful in his mathematics courses, his answer was an emphatic yes. His Calculus 2 instructor made it explicitly clear that “they were inclusive of people in LGBT communities” which made Tate feel “welcomed” and increased his “sense of belonging in [the] class” which “felt really nice.” His conclusion was that being “part of the LGBTQ community” is an important part of his identity as a college student.

Tate has “been really interested in mathematics since grade school” and it has been “overwhelmingly [his] favorite topic” in school. During his interview, he emphasized that any teaching moves that increase student interaction and engagement in class is beneficial, for him and others. He views mathematics as a “very collaborative topic.” One of the main benefits of collaboration for him is the ability to see “a solution that [he] maybe didn’t think of” which helps

to develop a deeper understanding and expand his perspectives of mathematics. When he sees only “one point of view” or one solution in a mathematics course, he feels “blocked off.” He wants a way to “connect” the mathematics in the classroom to parts of his life outside the classroom, including his other classes, rather than “just memorizing a formula,” partly because that increases his sense of belonging. When Tate feels he can apply the mathematics elsewhere it increases his learning and “definitely” improves his confidence. Overall, he wants mathematics to have systemic or structured ways to “welcome people,” especially those from “marginalized groups,” and get students involved during class because he thinks that people will learn “better” in such situations.

Theron

Theron self-identifies as “non-binary (gender fluid),” white, and demisexual, using they/them pronouns. They’re still questioning their gender, but the non-binary, gender fluid label is the best they have for now. They feel they are fluidly somewhere between trans and cis, so “what in particular feels right to [them] shifts over time, which is what the fluidness is, but it's all sort of under that non-binary umbrella.” They are in their first year of college at CBSU, planning to graduate in 2025. They took mostly general education classes “plus calc 2” in the fall semester “because [they were] undeclared when [they] got into college and [they were] taking that semester to sort of explore [their] options,” but Theron has now settled on a Computer Engineering major.

When probed more about their identity, Theron stated that they are “non-binary; [they are] a person,” indicating an importance they reflect on regarding the “existential” aspect of their identity. They went further to say that “being who I am is all [they’ve] got” and also that their

“experiences have shaped who [they are], and without that [they’ve] got nothing.” They are interested in presenting their authentic self in mathematics classes, but noted that “no one really knows the real you because code switching is such a big thing. We present ourselves in different ways to different people” based on what is “most appropriate for the scenario.” Thus, the authenticity and “freedom to express at least the parts of [themselves] that are reasonable to explore in an academic setting is important.” Along these lines, Theron wants educators to be “accepting” of them for who they are and “not trying to push” them into being someone the instructor “expected” them to be. In their opinion, one way instructors can work toward embracing students' authentic selves is by using each student's preferred name and pronouns because that shows the instructor cares about the student. They want to be respected both as a student and human being. If they are not given respect by the teacher, it is harder to return that respect to the teacher, which makes it harder to learn.

When asked about their mathematics class, Theron said it was “really awesome.” They formed a study group with some peers that they sat next to during class. The “social aspect” of their calculus course experience was helpful “in making sure [they] got everything done on time.” The study group supported their learning and performance in Calculus 2. Due to their positive experience with the study group, Theron stated that they “think everyone pretty much could use a study group for their math class, whether they realize they could use it or not” because it is then “easier to see how much it benefits” the students. They expanded this sentiment by noticing that they could “rely” on their study partners and the study group also relied on Theron “to help them as well” which resonated with Theron's goals for learning mixed with social support.

These biographies provide a short depiction of each interviewee as a human being, a mathematics student and STEM major. Given that the aim of this research is relational and intended to increase humanizing efforts, the biographies align with the framework and transformative design of the study, centering the voices of students. In the remainder of this chapter, I focus on the thematic qualitative findings from a group level, rather than an individual level as was done for the biographies.

Findings

This section is separated into several sub-sections to organize my findings into categories that help answer the research questions with additional nuance and depth, following the quantitative findings. The bulk of these findings are from my analysis of the interviews, with one section devoted to the open-ended essay question responses from the surveys across the focal and dominant groups. I first start with (1) findings from the interviews that center focal students' ideas about how they would define humanizing in the context of a mathematics class, as well as (2) what themes dominated their discussions about their perceptions of humanizing teaching moves, possibly outside the realm of the eight survey scenarios. Next I segue into the (3) findings from the interviews that center the scenarios, which serve as examples of the rehumanizing dimensions. Then, I discuss the (4) blending of the qualitative and quantitative findings by investigating scenario 2 and 5 further, followed by a short section regarding (5) students' reflections about the broader community when speaking about all scenarios. Lastly, I take up the (6) findings from the open-ended essay questions on the survey to highlight both differences and similarities between the focal and dominant group responses, along with which of feeling valued and a sense of belonging, having mathematical connections to their life outside

the classroom, and/or feeling supported in their learning emerged as most salient. Note that when I have provided direct quotes from the interviews, I have removed filler words (like, um, uh) for clarity and ease of reading²¹.

Humanizing Definition from Interviewees

Because “humanizing” is not a common word or lens that students would use to describe their mathematics learning experiences, the survey questions did not directly ask students to rank the humanizing-ness of each scenario directly. Instead, proxies of (a) feeling valued or having a sense of belonging, (b) feeling supported in their learning and (c) having connections of mathematics to their life outside the classroom were used, as discussed in Chapter 3. This section explores the themes that arose from interviewees’ free-form definition of humanizing, how that relates to the proxies used in the survey, and why these themes are foundational both for the qualitative findings in general and in answering the research questions.

During the interviews, students were asked the question: “Since ‘humanizing’ might not be a word we typically use to describe mathematics classrooms, I’d first like to ask you, thinking broadly, what would it mean to you, or what would it look like, for a mathematics learning experience to be humanizing?” This prompt was asked after the survey follow-up questions had been answered by the students, meaning that by this point in the interview, the students had already been reminded of the survey scenarios and how they responded to those questions.

The humanizing definitions supplied by the students fell into five categories with almost equal proportions (4-6 students mentioned something in each of these themes), namely respect,

²¹ For quick reference to a short description of each of the eight rehumanizing dimensions (Gutiérrez, 2018), please see [this document](#).

peer interaction, love or empathy, instructor relationship, and historical context. Indeed, the three proxies used in the surveys undergird these codes as students expressed ideas of interactions that improved their feelings of being valued and a sense of belonging (within the peer interaction and instructor relationship codes), their connections with humans and with mathematics (in the historical context code), and feeling supported in their learning (in the respect and love or empathy codes).

From these categories, two overarching themes of (1) relationality and (2) environment arose that provide an empirical backing for the theoretical ideas of what is experienced as humanizing for the focal students. Relationality refers to relationships and interactions with peers, TAs and instructors, as well as relating to folx outside the classroom, like past mathematicians, role models or community members. Environment refers to the culture built within the classroom, primarily driven by the instructor, that includes empathy, failure-tolerance²² and supportive caring. It is worth noting here that when students referred to caring, they sometimes spoke about the instructor caring for them as people. Other times, the students referred to the instructor caring about student learning or student grades. Some quotes used below indicate which type of caring the student was referring to, and others do not. For this context, I am using caring to encapsulate both types of caring mentioned by the students.

Relationships were at the heart of the relationality theme. Duncan said simply that humanizing would mean “more direct contact between the student and the professor” to illustrate the importance of relationships for meeting a humanizing goal. Andrew mentioned a specific example of having “to do labs every week” in groups as “the most beneficial parts” of class time,

²² A failure-tolerant environment is one where students feel free and encouraged to make mistakes and then correct that thinking by mathematical discussion, i.e., where students know their mistakes will lead to productive knowledge attainment.

and then went further to state that the “collaborative process” makes the “classroom more human.” Along these lines, Sadie added that “working with each other [and] working through problems in different ways” is what makes a mathematics class humanizing. Jayden also mentioned group work explicitly and explained that it “relate[s] [the mathematics] more to yourself” because “it’s not separated from you and other people,” and wanted more connection with “peers and TAs” to “definitely humanize the learning experience.” Tate succinctly said that humanizing to him meant that it “make[s] someone feel human” or as “part of the group” by “allowing people to be involved” through human interactions, because “interaction with others is just a good way to...boost a sense of belonging.” All of these sentiments align with the rehumanizing framework of feeling comfortable and welcome in the mathematics classroom and explicitly add a layer of relationality to others that helps students feel more human in their classroom experience.

In addition to relationships with others inside the classroom, the relationality theme also captures the idea of relating to those not inside the classroom as historical or current role models. Relating “back to scenario two,” Clarisa mentioned that “learn[ing] about different cultures and minorities and the way they do math [and] how their position as [a] mathematician or any other job may rely on math” felt like an “anthropol[ogical] approach to math” which was humanizing to her. Finley and Jack both mentioned applications of mathematics when asked about what would feel humanizing to them, but it was couched in the context of learning about people. For example, Finley said that “more applications of the math and more information about the history, the people,” by relating a name “to a [mathematics] concept” for example, would feel humanizing to them. Jack elaborated that “underst[anding] why the equations came about” and why people were “looking to do the things they did” would feel humanizing. Lucas’ comment

was more squarely about people in this vein. For Lucas, humanizing includes teaching moves that help him “understand how that [mathematical] method was developed, like who did it and when it happened and then see what kind of problems it solved” because this “little bit of historical significance” is impactful to him and his learning. Thus, for these students, the relational aspect of humanizing the mathematics classroom involves relating to historical or role model figures. This fits with Gutiérrez’s argument that rehumanizing mathematics includes framing mathematics as a process developed by people rather than some abstract system of rigid rules and fixed outcomes.

For the second theme, students’ responses to the interview prompt about “humanizing” also centered the classroom environment in terms of respect, empathy, failure-tolerance, and care. There is admittedly much overlap between relationality and a caring environment and this second theme is not intended to suggest that the two themes are mutually exclusive. Rather, it is to add more nuance to the sometimes-separate nature of the themes, how they arose for the students, and then to explicitly address the overlap. Lynne and Faith both expressed this theme in straightforward ways. Lynne said that she “want[s] the environment to be good...like a place where people can learn,” while Faith said simply that humanizing means a classroom is “more welcoming.”

There were several students who specifically elucidated the need for a failure-tolerant learning environment, purposefully created by the instructor. Alberto warns that if the environment is not failure-tolerant, then “questions don’t get asked because we’re worried that it’s going to sound dumb” and he wants instructors to “just acknowledg[e] that concepts are difficult that are being learned.” Similarly, Isabella also indicated that the instructor needs to “show the students that they understand that [students] don’t know everything and that’s okay,

they're going to learn." She added that "it's okay to mess up." Amanda wants to be "able to work through mistakes and learn from those mistakes instead of [instructors] just expecting perfection." Reegun focused on the need for an "environment where confidence is there [and students] don't feel scared to make mistakes." Her summary of such an atmosphere was that it is a "really comfortable, supportive environment." Further, she stated that "the most human [she] feel[s] in math class is whenever [she is] making mistakes and whenever those mistakes are handled in a really respectful, instructive, supportive way." All of these quotes illustrate the need for students to have a welcoming, failure-tolerant classroom environment as necessary to be considered humanizing.

A few other comments by interviewees that elaborate the environment theme highlighted ways instructors can create a classroom culture to help students feel whole and enthusiastic to learn. Theron pointed out that "for something to be humanizing, it needs to be accepting of [them] for who [they are]." They further state that instructors and peers should not try "to push [any student] into who [they're] expected to be" and "that respect is what makes it humanizing." Faith said that she feels "more welcome" in class when she "know[s] a teacher loves a subject" and "seem[s] to enjoy what they're teaching." Evan expanded this idea when he said that "being excited about what [the instructor is] teaching...and being excited that [students are] learning" is impactful and "helps the most." He categorized that enthusiasm and caring from the teacher as "empathy-that's the word there, empathy" which he seemed to equate with humanizing.

Finally, some comments by interviewees seem to sum up the intersection between the two overarching themes for a humanizing definition, namely in the overlapping space of relationality and environment. For example, Duncan said simply that he "like[s] when [instructors] get involved, like they care about students learning" which captures both the relationality with the

instructor and the caring environment created by that instructor as humanizing. Naomi captured the outcomes of attending to both themes when she said that humanizing means “people can feel that they belong [in the classroom]. People can feel love there...and how we appreciate one another.” This aligns with Gutiérrez’s (2021) foundational underpinning of the rehumanizing framework being about love and care. Indeed in several chapters of the *Rehumanizing Mathematics for Black, Indigenous and Latinx Students* (2018) book, there are references to the loving environment teachers create as being a crucial part of the rehumanizing framework (e.g. “Black girls in eMode thrive because they are in an environment of love and care,” p. 61).

Overall, the focal students who were interviewed highlighted the overlapping importance of relationality and environment in order for the mathematics class to feel humanizing. Relationality focuses on instructor-led efforts for building relationships with peers in class as well as between student and instructor which helps students feel a sense of belonging and supported in their learning. Additionally, relationality includes connecting to historical figures or mathematicians from diverse backgrounds, which in turn helps students feel connected to mathematics and potential role models. The students also need their mathematics classes to have an intentionally-created environment that is caring, respectful, supportive and failure-tolerant (and supports the relationality component). One important finding here is that the three stems used in the survey scenarios (sense of belonging, supported learning and connection) lined up well with the student-driven humanizing definition, suggesting that the surveys likely did a reasonable job of accurately gathering information about students’ perceptions of rehumanizing mathematics or that belonging, connections and support are outcomes of learning in a humanized environment. This can be seen by comments such as being “part of the group” (Tate; belonging) or “accepting” them for who they are (Theron; feeling valued), having a welcoming environment

that creates a “place where people can learn” (Lynne; supported learning) and understanding “why the equations came about” (Jack; connection).

This student-driven humanizing definition provides a guideline for rehumanizing mathematics. Although it does not specify exact teaching moves that students find humanizing, it does suggest that when teachers attend to relationality and environment in purposeful ways, students may be more likely to feel the mathematics class is a humanized space. Using this as the foundation, next I describe more specific ways educators can teach that will move toward a humanizing goal.

Humanizing: Experiences of and Advice from Interviewees

During each interview, right after asking for their definition of “humanizing,” I asked directly if the student had previously experienced anything in their mathematics classes that they would categorize as humanizing and if they had any advice to instructors to create a humanized class. A few other questions at the end of the interview also targeted this area of gathering ideas from students regarding teaching practices that would benefit the student. From this data, three main themes arose, specifically (1) real-world connections, (2) peer interactions, and (3) instructor relationships. These themes could really be summed up in one word—connections. Thus, building on the student-driven definition of humanizing, this section focuses more on actions teachers can take to help students feel their class is humanizing. Students want teachers to create pedagogies, structures and an environment that attend to connections to peers, the teacher and their lives outside the mathematics classroom.

Connections to Mathematics Beyond the Classroom

Having students work on mathematical applications that extend beyond the class curriculum or that have applications to students' lives outside the class feel humanizing to the students. Antonio explained that seeing "problems relevant to the real world...helps you to stay motivated" and helps students "see why [they're] learning what [they're] learning." He wants instructors to give students time to "work on math problems that will apply to [their] future career and interests [that] impact them." Jack provided further reasoning to explain why this connection feels humanizing to them. They think that "showing that you can solve things..to improve [your] own situation in [your] own community" feels humanizing, especially because it is "not purely theoretical." Lucas repeated this sentiment when he said that "it feel[s] more humanizing that somebody came up with this to solve a problem because if it's just introduced without much context...if feels just too abstract." The implication is that connecting the mathematics inside the classroom to situations outside the classroom, as well as connecting it with other folx who created these mathematical ideas to solve problems, feels humanizing.

Finley offered a particular example of a lab project they considered humanizing. It was a project that "deal[t] with heating a house while you're away on vacation, and whether you should turn the heat off and then turn it back on so it reaches the right temperature as soon as you get back, or if you should just leave it there." They stated it "was fairly humanizing because even though it...didn't have much application with [their] major...it was something [they] could imagine real people doing." This showcases that the heart of this connection-to-mathematics theme extends further to people and to students' lives outside the classroom. Lastly, Alex nicely summed up this theme by saying that doing mathematics that is connected to other classes is "like having an experience in math class that recognizes other parts of you as a human and your

interests” which feels “very humanizing.” Reegun expressed a similar idea, saying that “work[ing] on mathematics problems that you personally think will impact or apply to your future career...is pretty humanizing just because it applies directly to your life and to your career.”

Evan gave an example from his Calculus 1 course that bridges the connections to applications outside the class and peer interaction humanizing themes. He said they did “mini projects” in that calculus course and he enjoyed the group nature of working on those projects, because “there would be people...who know how to do this physics thing that other people might not know how to do and you can learn from that” and he knew “more about computer science stuff” which meant he could “help with graphing things and using programs that [they were] using.” His focus was on the truly collaborative way that students could share knowledge and perspectives to produce thoughtful answers and learn from each other which he equated with humanizing. Amanda also pointed out that “being able to just be with a group and mess with a problem before being told how to do it makes [her] feel more connected to the problem.” This connection to both the mathematics “problem” and her peers speaks directly to the connections that students crave, both to humans and to the mathematics, in order for their classroom experience to be humanizing. These sentiments are aligned with several overlapping rehumanizing dimensions, including Participation & Positioning, Living Practices & Futures and Ownership.

Connections to Peers

Several students noted how working with and discussing mathematics with their peers contributed to a better learning environment and a more humanized experience. Perhaps Alex

said it most succinctly when they said “nothing is more humanizing than interacting with other humans.” Andrew’s comment that “the best way [instructors] can humanize the experience is to...give more interaction” is in agreement with this notion. Tate said something similar during his interview, when discussing the scenarios from the survey, and commented that “the good thing about most of these scenarios is that it involves interacting with peers” which he felt was “very humanizing.”

A few students backed up such comments by providing examples of or references to classroom experiences. Clarisa mentioned that her first in-person college mathematics class was “the same thing over and over and over again every day of class until one time, [her] professor brought up a student to do the problem [and she] actually learned a lot more in those five minutes than [she] probably did in the whole entire week.” Alex voiced a similar experience, namely that the communication in their college mathematics classes “is always from the instructor to the students but very little from those students to each other” which they found problematic for learning. They further stated that they “feel like learning with [their] peers and working through a problem collaboratively is a good way to learn.” These comments indicate the power of collaboration between peers in the mathematics class for learning. It also suggests that students are leaning on the idea of supported learning as something that is an outcome of a humanizing mathematics experience.

Students need to feel connected to their peers for a variety of reasons, like creating a wider net of resources students can draw on for their learning. Antonio spoke about this when he said that “having the classmates as an extra resource is almost more beneficial than the teachers sometimes just because compared to having someone almost tell you what to do, you can have someone working with you [on] what to do” which is a better “dynamic” for his learning.

In that vein, however, six students (Antonio, Evan, Jayden, Lynne, Sadie and Theron) pointed out the importance of the instructor's role in proactively creating the classroom structure that supports and maintains peer interactions and relationships. They expressed genuine concern that this interaction should not be left up to the students to initiate on their own, in accidental or unpredictable ways. Evan was the student who coined the phrase "proactive interactions" in his interview. In his view, if the instructor enacts teaching moves that purposefully create opportunities for peers to interact, then "everyone [gets] the most out of it and [they're] feeling connected to the major or the class, the course, the material." Most of these students mentioned wanting a first-day, or first-week, introductory activity as a specific example of building the foundations for peer interactions. They want instructors to do this early in the semester in order to create a "comfortable environment" that can then "help the class dynamic throughout the rest of the semester" (Antonio). Lynne said explicitly that it "makes [her] life easier" when the structure is provided by the instructor for her to "actually talk to people" during class and it also "increases the sense of belonging because then [they're] all contributing." Going further, Antonio stated that if the initial peer connection is made in a structural way during class time by the teacher, then "[he] would be more willing to ask peers for help. [He'd] be more willing to go study with them, interact with them more in class [and they'd] probably work better together in groups." The implication is that the instructor's investment of time during the first week of the class to do an introductory activity has far-reaching and long-lasting benefits to students' learning. Antonio ended this interview response by saying that "being comfortable around [his] peers would essentially mean that [he] would...have more resources to learn because [he'd] be able to ask help from [his peers]." Again, this links back to the two foundational components of

the student-driven humanizing definition, namely relationality (with peers and instructor) and a welcoming environment.

In essence then, enacting intentional teaching moves to create and sustain peer interactions provides more teachers than the official instructor for students. It is also possible that positioning peers as extra learning resources disrupts some of the patriarchal power dynamics by distributing the power of teaching among many. Such a teaching move is squarely situated in both the Ownership and Participation & Positioning rehumanizing dimensions because it shifts power from one teaching authority in the class to “more resources” (Antonio) among peers and students then take on stewardship of knowledge creation. Theron pointed out that they would not have “done as well as [they] did in that [calculus] class without a group of people who [they] could rely on to study with and who were...relying on [them]...as well.” Their study partners from class “helped them in making sure [they] got everything done on time and performed as well as [they] could.” The idea of peer interaction being used as a tool to equalize the power in the classroom is summarized by Isabella when she said that when students work together, “they’re kind of on the same playing field.” Finally, Alex’s comment lends credence to the theoretical claims of the rehumanizing framework advocating for students bringing their authentic selves into the classroom. They said that “working in groups is very helpful” and “when you go into a calculus class, you should feel not like you’re just a calculus student but like you’re a student who’s taking calculus,” i.e., center the student, not the content.

Intentionally building connections between peers is a powerful tool for instructors to implement throughout the term of a mathematics course. Student comments here highlight the importance of building community with classmates as a mechanism to support their learning and create a more distributed set of teaching resources, including the teacher and classmates. These

sentiments are rooted in the student-driven humanizing definition, with relationality between peers and an intentionally-created collaborative and inclusive environment being the key aspects. The ideas discussed in this section are also aligned with the Participation & Positioning, Ownership and Windows & Mirrors rehumanizing dimensions because the peer interactions students discussed allows them to position themselves and others as both teachers and learners.

Connections to the Instructor

Just as peer interactions are crucial for a humanized classroom, instructor relationships were also highlighted by most of the interviewees. Andrew's comment showcases this intersectional need of connections to both peers and instructor nicely. He said "the best way [instructors] can humanize the experience is to...give more interaction...whether that's peer-to-peer or directly with the professor." Jayden brought up an instructor's office hours as productive time to connect with her instructor. She "like[s] office hours" because "it's humanizing to work on problems with the professor." Isabella provided some reasoning as to why interaction with the instructor is humanizing because it shows the instructor cares about the student's success in the class.

Instructor care was present in many interviews when discussing relationships or rapport with instructors as part of students' responses while discussing their views of humanizing moves that teachers can make. In such comments, students referred to two different ways instructors can show care, namely care about the students themselves and care about their learning and/or their grades. Duncan requested that instructors "just kind of pay attention and adjust based on [their] students...like care a little" in order to humanize the mathematical learning experience. Although Duncan's statement sounded a bit deficit-oriented, Antonio's comment was expressed through

more of an asset lens. He said he “believe[s] that almost every teacher does actually care about their students and wants them to succeed” but that many instructors are “sometimes reluctant to show that.” He went on to caution that it “always works better for the class when they do show that they care and actually want to help you.” Here, Antonio is merging the two aspects of caring together, commenting on how he needs the teacher to “care about their students” and also to care about their success.

Toward the goal of students feeling that instructors care about them and/or their success, three students (Amanda, Sadie, and Theron) explicitly mentioned that learning student names and calling them by name “feels good, like they care about [the student’s] success personally” (Theron). Sadie echoed this sentiment and then expanded it when she said that she wants instructors “to actually care about what [they’re] teaching” and to treat students like they are not just “another group of students that [they’re] teaching this material to for another year.” Calling students by name is a small way for an instructor to show that they “care enough to know who [the students] are” which “makes it easier for [them] to want to go to [the instructor] when [they] have problems” (Amanda). Thus, the act of using students’ preferred names while teaching contributes to a welcoming environment, providing an opening for students to build relationships with the instructor and communicate earnestly. Certainly, teaching moves that help build a relationship with the instructor and create a caring environment harken back to the two main elements that comprise the student-driven humanizing definition, namely relationality and environment.

Having an “open line of communication” with instructors “makes it more of a human experience” (Amanda) and is necessary for students to feel empowered and able to succeed in their mathematics classes. This is especially true during class time. Reegun gave an example of a

teacher who showed caring and exceptional communication when they would “take the time to go through [a mathematics problem], like really simple things,” meaning the teacher displayed patience during their explanation. Her teacher “was really good at...being really respectful” with the students, not “mak[ing] anyone feel inferior or slow” but instead “making it really human and making it a conversation, not necessarily just like a lecture.” Evan’s comment reflected this same sort of caring communication when he said that his teacher “would talk to [them] as...equals” showing that the teacher was “fighting for [them] to do well.” This comment also speaks to the way caring communication can help distribute power by treating students as respected adults in the classroom, which is aligned with the Participation & Positioning rehumanizing dimension.

Alberto went on to describe a situation in his Calculus 2 class that was “one of the most powerful moments of the class because it was at the beginning of the class and [he] was really doubting [him]self.” He felt “overwhelmed” and “stressed,” but because he had built good rapport with his instructor and was therefore comfortable communicating honestly with her, he asked for her advice. She validated that learning mathematics can be “difficult” but also that “it’s totally normal” and then reassured him that she would help him succeed in the class. “Those experiences really helped [Alberto] to push forward” because he had “a professor who believe[d] in [him]” and would help him through the course. “And those humanizing moments...were the turning points for [him]. Otherwise...[he would] have just broken under [his] anxiety” and given up. Alberto’s example sheds light on the potential positive impacts of a strong connection with the instructor that is built on caring and communication for establishing a humanizing mathematics space.

Wrapping up the interviewees’ thematic thoughts about actions teachers can take to humanize the mathematics class, Alberto pointed out a distinction that is noteworthy. He

reflected on the difference between mathematics being accessible versus humanized. For him, accessible means students “are able to do it,” whereas humanizing means “there is empathy involved and sympathy and understanding...not necessarily emotional connection, but...a sense of belonging.” When students feel that they are “all in the same boat,” like “it’s okay if you’re struggling,” that feels humanizing. Further, “if it is humanized, it is accessible,” meaning that humanizing is a superset of accessibility. When mathematics is accessible, for Alberto, it is “just available; [students] can understand it and...do it.” But when mathematics is humanized the student would “understand it better because [their] professor is meeting [them] where [they’re] at” and helping them succeed. This perspective captures the essence of connections being foundational for a humanized mathematics space that goes beyond accessibility and likely beyond equity, or at least beyond equity of access and achievement.

The findings here strongly suggest that to rehumanize undergraduate mathematics classes for STEM-intending majors, instructors need to attend to connections. Students need instructors to teach in ways that provide structured opportunities for students to have peer interactions during class repeatedly so students can build rapport and connection with one another. Instructor care and relationship is another type of connection that interviewees mentioned increases the feelings of a class being humanized, which means instructors must enact teaching moves that attend to this need. Finally, connections of mathematics learned inside class to other classes, careers or lived experiences outside the classroom need to be made in explicit and meaningful ways.

Building on the findings from the previous section, I next report the themes that emerged from the interviews regarding the eight rehumanizing dimensions specifically. The results reported on here are from the portion of the interviews that took place prior to discussing students' definitions of humanizing, i.e., no mention of the word "humanizing" had come up during students' participation in the research project. Recall that the coding process for the data producing the following results involved first bucketing comments interviewees made that were specifically associated with one of the rehumanizing dimensions. For example, when the interviewee would refer (prompted or unprompted) to a particular scenario from the survey, that comment would get bucketed into the corresponding rehumanizing dimension. From there, thematic sub-codes were created for each rehumanizing dimension theme. Here, I piece together all of those coding components to discuss overarching themes that arose across the dimensions.

When discussing the survey scenario questions during the interviews, the most salient themes that cut across several rehumanizing dimensions were (1) the ways those scenarios (or actions like those imagined in those scenarios) supported (or not) students' learning and (2) how critically important implementation is for those teaching moves to feel humanizing. Lastly in this section, I will discuss an additional, salient theme that appeared when students made references to all the scenarios on the survey, (3) community, which aligns well with the spirit of rehumanizing being relational. Worth noting here is that all quotes come from the interviews. With that said, there were no new themes that arose from the survey data analysis and thus, the themes presented here encompass those found in the survey data.

Supporting Students' Learning

Interviewees mentioned many ways in which the actions imagined in the proposed scenarios would better support their learning, especially when compared to traditional lecture. Sub-themes within the supported learning theme pertain to the reasons students gave to explain why the proposed scenario would help them learn. These sub-themes expand on how (a) group work and discussion help solidify understanding of mathematical concepts; (b) perspective-expanding moves promote deeper levels of comprehension; and (c) mathematical applications offer practical connections to a student's life outside the class and their future careers which boosts interest in and commitment to learning. Interviewees also noted challenges that some scenarios may pose to their in-class learning, which provides helpful information to instructors who wish to implement these teaching moves. It is potentially important to note that these sub-themes align well with the humanizing definition provided earlier, namely that the reasons given for how the scenarios support student learning lend more details about relationality and environment.

Group Work and Discussion Help Solidify Understanding. Several interviewees noted that communication between students, instead of always one-way communication from the teacher to the students at large, helps them learn. Alex said "a lot of my math classes in college" had communication "from the instructor to the students but very little from these students to each other." They further stated that "learning with your peers and working through a problem collaboratively is a good way to learn." Lynne also mentioned that "it's hard for [her] to learn from lectures sometimes," whereas she "learn[s] really well through discussion." She advocated for a classroom structure that builds in discussion between classmates because "reasoning

through things and then checking in with the teacher” feels like students are “grounded in the same learning process” and they are “actively learning” which she finds helpful.

Reegun stated directly, “I like group problem solving just because it helps me really get the material down and really solidify it in my mind.” She finds that “being able to explain [a mathematical problem] to someone else is super helpful because teaching is the best way to learn” and “whenever you’re working with someone else, you’re able to see how they’re teaching it too.” Jayden had similar comments, saying that discussion with peers “improves my learning as well just because I’m able to explain a concept to someone else” and after “I explain it to someone...I get it now.” Faith agreed, saying “if you don’t understand it then they could always help kind of clear it up, but if you understand it, you could always help them clear it up.” She then added to this sentiment by pointing out that “if you could teach it then you learn it way better and then you feel a little bit more confident.” This provides insight that group discussions can be helpful mechanisms for learning as well as for improving students’ confidence in their mathematical understanding, and is directly aligned with the relational characteristic that emerged when these students discussed what a humanizing mathematics classroom would entail. Finally, Amanda noticed that “getting to work with your neighbors, your peers a little bit more...gives you a little bit of time to struggle through problems which I think is very helpful.” This sheds a bit more light about why peer connections are humanizing, namely that it allows students the opportunity to struggle together.

Perspective-Expanding Moves Promote Deeper Comprehension. Students indicated their appreciation of seeing mathematical ideas presented in many different ways because it helps them learn. Reegun was perhaps most enthusiastic, saying “I love, love, love...the idea of being

able to see a problem solved in multiple different ways.” She noted that “people learn [in] different ways” which makes it challenging when teachers “only teach you one way.” She further lobbied for teachers to use “a lot of different tools” so students can “pick which one we want to use, which one is going to be the most helpful for us” because “it can be hard to try to force your mind to do something one way.” Similarly, Antonio said “when [the instructor] show[s] multiple ways, sometimes those other ways are actually easier for me to understand and easier for me to solve that problem. So when they give us more options of how to solve it, then I think it allows everyone to solve it in the way that makes [sense] to them the most.” Amanda further elaborated that “oftentimes if you see it one way and it doesn't click, seeing it over and over the same way isn't going to help it click,” pointing out that repetition from the instructor is not always helpful. She went on to say that “when you get to see it a few different ways...you might find the one way that works better for you or that you understand more,” again echoing the sentiment of the other students quoted here. Alberto brought in one extra component to this idea that varied explanations are helpful, namely that they can come from other students. He noticed that “different students in the class” had different explanations of how to do a certain problem and that “they came at it from a way where I was like, that makes way more sense to me...and then there were others where I'm like, I have no clue what you're doing. I'm not going to do that.” Thus, several students pointed out how knowing various ways to solve or do a mathematical problem helps them to find the way they would prefer to do or understand that type of problem. Further, these quotes highlight specific ways that relationships with peers and instructors and a caring environment, i.e., the two basis elements of the humanizing definition, support student learning.

Besides finding an approach to problem-solving that fits with a student's thinking, several students noted how the learning of various approaches to the same problem generally helps them have expanded perspectives, which they reported as beneficial for deeper understanding. Theron said that such a learning situation "is more focused on the community aspect because it's...all the different ways my classmates approached the problem." This makes them ponder "What can I learn from this? How can I expand my own knowledge by working with these other methods?" Tate was more direct, saying "when I only have one point of view or...one solution...I kind of feel blocked off." Further he said that having "other ways to solve it or other ways to apply it helps me understand it better" and then "I can apply that to just generally solving these problems...elsewhere." Lynne succinctly said that "seeing things from a lot of different perspectives...helps me understand what's going on and how things work." Lastly, Clarisa pointed out that "math allows for many approaches to be correct, so there is no one right way of getting to the answer, even though it might seem like that in our brains." She thinks that "in order to truly understand math...you'd have to understand multiple approaches." The implication from these students' quotes is that one foundation for deep mathematical comprehension is learning a variety of ways to approach the same problem. Once again, the humanizing element of relationality to others is key here.

Mathematical Applications Offer Practical Connections to a Student's Life. Students also felt supported in their learning by seeing mathematical applications that shed light on uses outside the classroom that then helped them feel more motivated or interested to learn. Reegun said that seeing "how [mathematics] applies to real-world things sometimes" allows her "to see why something we're learning can be important" and "when we think it's important, that's when

[we] make it a priority...[and] put more effort into it.” Duncan suggested that seeing “the professor do something that applies to my experience...would be a lot easier for me to learn,” and Naomi said simply that seeing a “real life scenario” is important because “it makes [her] thinking skills grow.” The implication here is that making mathematics content applicable to the students’ lives outside the classroom boosts their ability and/or motivation to learn. Evan’s comments are more direct in this regard,

When we're learning in college, we're preparing for a career...so we should be working on problems that we would see in the field in our career.... It would increase or does increase interest in the course material, which will most likely increase just overall performance. If you're interested in what you're learning you're more likely to spend time learning it and asking questions and just wanting to know more.

Some students explicated further reasoning of why connections to mathematics outside the classroom is beneficial for them. Finley said that “more applications of calculus related to chemical engineering or just other aspects of life” would be helpful for them because “in general [they] learn much better when [they] can see direct applications, when it's less abstract.” Jack concurred with this sentiment stating that “having examples that are actually applicable to my future and real world examples are a lot more helpful to me than just pure theoretical ones” because they “dislike math” and are “not very good at it.” Faith “feel[s] like when something from the class is taken out of the class and brought into the real world...I feel like I make a greater connection because...I learn a lot better.” Lastly, Alex brought up explicitly how connections between STEM college classes is important for improved learning, saying “math class usually feels kind of like an island where it's not directly connected to the other classes...and there are tons of scenarios where you could talk about a concept that you're learning in another class in math and it would increase your understanding in both of those

classes.” Here students are suggesting that connections of mathematics to their lives outside the classroom feel more “applicable,” “less abstract”, and “practical” which boosts their learning. Thus, they are providing reasons *why* relationality matters so much for a humanized mathematics space. Lynne added more nuanced reasoning for why this improves learning by noting that mathematics which “applies to my future career interests...would be really practical.... [It] shows that the teacher has an interest in us doing well in our interests, in our futures. I think that's like a really good definition of being supportive.” Here again, student quotes showcase the potential positive impacts that humanizing mathematics classrooms - through relationality to others and classroom environment - can have for their learning.

When discussing the possibility of having students provide their own mathematical application problems to be worked on in class or as assignments, some interviewees commented on the ways in which such a teaching move would support their learning. As a mathematics major, Isabella liked this idea because “it’s not really clear when [they’d] use [typical class examples] in going into a field of mathematics other than teaching it,” so she wants applications that feel more useful “and also just to help [her] decide maybe what [they’d] want to do as a career.” This teaching strategy would make Isabella “actually want to learn [the mathematics in the course] and it makes it more interesting for [her] to learn because it actually applies to [them] specifically.” This speaks to the notion that having students bring in mathematical problems to work on feels personalized, which in turn increases interest and helps them envision possible career options. Amanda focused instead on a different potential of feeling supported in her learning, saying that “it creates more excitement to go to class and learn and be more engaged in class” when students “find those real world problems and bring them to class.” Theron similarly said “I just like being involved in the course...I'm not just being given problems to solve; I can

take problems that I run into and have help in solving them and it just brings in this involvement that has always been really strong for my learning, personally.” The sentiment expressed here is one of ownership in their own learning and excitement at the prospect of contributing problems to be worked on as part of class and is squarely the intention of the Ownership dimension of the rehumanizing framework.

Challenges For Supporting Students’ Learning. Although many benefits were mentioned about how the scenarios on the survey would support student learning, there were also challenges noted that need mention here. Many students explained how they felt some scenarios may not be helpful for student learning. For example, Lynne stated that it “might be interesting to see how math works in other things,” like in scenario five (Broadening Mathematics), and that “relating [math] to other topics, depending on what they are...could actually be really helpful, maybe, but I don’t know.” Lynne’s wording here elucidates her thoughts that connecting mathematics to other areas might work to improve student learning and it might not. She also pointed out that activities for scenario seven (Body and Emotions) that get students “moving around as opposed to not moving around doesn’t really help” her. Along those lines, Jayden expressed that it “would just be cool to learn” extra things in her mathematics courses (like for scenario five-Broadening Math), but she was “not sure if everyone would want to.” Additionally, Jayden was concerned that “a lot of people in those classes...want to get through this calculus class just to have it over with” for their major. The implication here is that students might have a narrow, utilitarian view of mathematics courses and some of these teaching moves from the scenarios may feel counterproductive to students’ goals or at least misaligned with their sources of motivation.

Other concerns voiced by some of the interviewees centered around previous experiences or knowledge about their own learning that grounded their opinions. For example, Isabella said

that scenario three (Windows & Mirrors) “just gives me a bit too many options to figure out how I would do the problem. So I'm not really practicing any one more than the other, so I'm not really getting good at any of the different ways.” Antonio was more direct when talking about scenario five (Broadening Math), stating that “I personally do not like this type of teaching method just because I've had it taught to me like that in the past and it basically never worked.” He added that bringing “art or sometimes science” into the mathematics classroom does not feel directly correlated and “almost brings in a separate entity that kind of confuses me and distracts me from what I need to be learning and the actual math.” Duncan pointed out that group discussions can be experienced in helpful and unhelpful ways. In his experience working with groups in a calculus lab (i.e., a TA-led discussion session), “the first group that [he] was working with [was] really helpful [and] everything was moving smoothly...moving really fast, and [he] was actually understanding and every time [he'd] have questions, they would love to explain it to [him].” But, when his group changed, his experience with his second group was very different. “When [he] was working with the second group they were like, oh we don't really get it, so everything moved slowly...[the group] had to wait for the professor to help.” These examples showcase how teaching moves as presented in the survey scenarios can have unintended and negative impacts for individual student learning gains, particularly when students want to get through the course to satisfy major requirements. This suggests that attending to relationality and a caring environment is important, meaning instructors need to proactively create structures in the class and curriculum to support students. For example, humanizing mathematics includes opportunities for students to have mathematical connections to their lives outside the classroom or to their future careers, but meaningless connections may distract from their learning. One

potential way an instructor can counter this could be to explicitly consider the majors of their students and tailor the connections accordingly.

Finally, students pointed out some specific ways that things could go wrong with implementing the survey scenarios. For example, with regard to scenario seven (Body & Emotions), Reegun said “I really like the idea of moving around a little bit....I like the idea of getting up and stuff like that. I think I'd be a little bit afraid of taking away too much from the lecture.” Duncan reported a concern that any scenario where group discussion occurred “could lead to more of a negative” because “conversation could spin out to not even be about mathematics anymore” which would take up time in the class that could be more effectively used. Both of these students expressed worry about teaching moves that might take away needed class time for content coverage, which they see as a priority.

Interviewee quotes shed light on ways in which the survey scenarios, representing the eight rehumanizing dimensions, support student learning. The two key components of the student-driven humanizing definition of relationality and environment serve as the foundation for this finding. Interviewee quotes highlight the importance of interaction and discussion with peers and their instructors (relationality) to deepen understanding of mathematical concepts and expand their perspectives. Mathematical applications were also highlighted as providing connections to a student's life outside the class (relationality) and their future careers which boosts interest in and commitment to learning (environment). The takeaway here is that the survey scenarios offer potential teaching moves that students feel are humanizing and as a result students feel supported in their learning. However, the concerns listed in this section point out examples of possible challenges that need to be attended to while implementing teaching moves that align with the survey scenarios, in order to overcome the somewhat inconsistent perceptions

of students with regard to feeling supported in their learning. The next section takes up this idea more directly.

Implementation Matters

The second overriding theme that cut across most of the rehumanizing dimensions regarded implementation of the teaching moves proposed in the survey scenarios. In addition to providing a list of the above-indicated concerns, students suggested ways to overcome or address some of those challenges. Two major ideas came out of the interviewee comments in this theme, namely (a) the students need the teacher to be the leader with reliable structures in place to guide students and (b) instructors need to be mindful of the class time it takes to implement these teaching techniques. This section highlights student thinking that focuses on all the survey scenarios with little attention given to scenarios two and five. This is because those two exceptional scenarios have further results that need to be blended more specifically with the quantitative findings and will be discussed in more depth in the section following this one.

Recall (from Chapter 3) that the survey follow-up questions on each interview protocol were created based on the individual participant's survey responses. Thus, each interview did not necessarily cover every single scenario. Rather, each interviewee primarily discussed the most positively ranked and least positively ranked scenarios for them. This means that the scenarios highlighted here already had some level of importance to the student.

Students Need the Teacher to Lead. Interviewees gave their prompted or unprompted advice about how the survey scenarios could be carried out with fidelity or improved in some way by the instructor. Speaking about scenario three (Windows & Mirrors), Alberto said "I like when the professor says, this is how we approach the problem, so that I kind of have a map" of

how to approach that problem. “Then from there, I like to kind of branch out and see other ways to explore it.” Here he is pointing out that order matters in how ideas are presented, i.e., he first wants the teacher to lead with one approach and then later bring in other approaches, including other student perspectives, after students have had some practice time with the first approach. When discussing scenario four (Living Practice & Futures), Alberto further lobbied for “the professor to say, here's the connection. And then I'm able to go, oh, okay,” because “if that first connection isn't made, then for some reason my brain doesn't just go there.” This was in reference to the idea of students working on in-class problems or a project assignment that impacts their future career or interests. Alberto is essentially saying that he is most comfortable coming up with his own ideas only after the instructor leads. Clarisa was more pointed, saying “I like being assigned something specific and then doing that research on it” as opposed to coming up with her own projects or ways of solving things mathematically. Jack concurred, saying specifically “if you're relying on the students to supply the problems, I don't think the students know well enough to know what type of problems that they think will impact or apply to their future career interests.”

Scenario eight (Ownership) asks students to “Imagine that your instructor frequently invites all students to bring mathematical problems to them that come up in other classes or in your outside communities to work on both in class and for students to continue working on outside of class.” In regard to this scenario, Faith expressed concern that a student would bring up a “super duper hard problem” that would “take [students] forever to solve it.” Evan reiterated the same concern, saying that “problems that students bring in might not always be the best example of how to do [mathematics related to class content] or...[that] doesn't represent the course material the best.” To that end, Evan suggested concretely that “someone would have to

probably moderate those” mathematical ideas brought in from students. Here he is implying that the instructor should lead this activity in purposeful ways, pulling from their mathematical and pedagogical expertise to ensure the problems were an appropriate fit for the mathematical content of the course.

Scenario six (Creation) was another scenario that brought out a specific suggestion from some of the interviewees. This scenario asked students to “imagine that as a regular practice, your calculus instructor poses questions that allow you to play with the mathematics and algorithms you’re learning and provide a supportive space for you to create your own algorithms.” Several interviewees commented that this sounded overwhelming to them. However, both Antonio and Jayden mentioned that peer interaction would improve this scenario. Antonio said “solving the algorithm or creating your own helps you to...have that method of your own that you solved. But the downside was just that it can sometimes be extremely difficult to do so and kind of demotivating.” He followed that with the suggestion to have “time to work with your peers to create your own algorithm...because it can be very difficult...and demotivating.” Then, the “extra help or motivation from your peers or...the teacher can help you to create this algorithm in an easier manner that would support you better.” Jayden’s comments repeat this idea, saying “if we worked [with] peers while doing it, I think that would be better than doing it individually...I think I’d like that more.” Again, this emphasizes the importance of the relationality piece of the humanizing definition, specifically the connection to peers, in helping students learn.

Implementing Rehumanizing Teaching Strategies with Attention to Timing. Building on concerns presented earlier regarding challenges students voiced implementing the survey

scenarios in class, several students expressed ideas of appropriate timing and execution. With regard to scenario seven (Body & Emotions), Evan felt this teaching strategy was “not as efficient as just a lecture with notes and it would take up more time planning and implementing and doing...that could be put into other things more helpful.” This implies that instructors need to be mindful of the time new teaching moves take up and implement them in ways that feel helpful for the students.

For at least three scenarios, students specified that they would be best implemented if there was a clear boundary of time allotted to such teaching moves. For example, for scenario eight (Ownership), Jack suggested it would be best “if there were just five, ten minutes at the end of the class where [students]...come write up a problem...from a different class that you’re struggling with or something” and then “see what we can do real fast.” Jack did say this scenario seems “interesting” to them, but that the “execution...seems difficult.” Likewise, for scenario five (Broadening Math) Evan felt it “would be helpful” but did not “feel spending a certain amount of class time is necessary for that.” He offered the idea that making “those resources available online and just mention[ing] it instead of explaining things” would improve the implementation.

This same sentiment was noted by several students in regard to scenario two (Cultures & Theirstories) as well. Isabella commented that it was “already hard to get through a calculus curriculum in one semester” and that their “teacher always felt super rushed, like we were falling behind.” Although she thought this scenario “would be nice,” they were concerned whether or not “it would actually be able to fit into the curriculum with time.” Sadie echoed this sentiment, saying “it’s really hard as it is to get through all of the material...in a concise and timely manner, that adding in [the time it takes to implement the scenario]...would be really hard on the

students.” Sadie’s quote is a bit more forthright in explaining why the concern of timing exists; it is because it may have negative implications for student learning or in some way burden the students. Duncan’s comments went further as he made a tangible suggestion for improving scenario two’s implementation. He suggested that the instructor could take “the time to...post this on the class webpage” where students could “go check it out” if they wanted to, which he felt “would be really beneficial.” Faith agreed that if the instructor could take up only a few minutes of class time to have students keep mathematicians from historically marginalized groups “in mind while [they’re] learning,” it would improve the implementation of scenario two. Then she would know “that somebody had to work for this [mathematics], so now we’re benefiting from it,” but it would not take up time from class that is needed to focus on the course content. These quotes highlight the importance for instructors to build a classroom environment that respects students’ need for a manageable pacing of material. At the same time, it is the responsibility of the instructor to enact humanizing teaching moves with attention to timing and balance between content coverage and pedagogies that build connections.

Blending the Data: Scenarios Two and Five

Recall from Chapter 4 that there were statistically significant differences in distribution of answers for the survey scenario two (all questions) and scenario five (Connection question) responses between the dominant and focal groups, with the focal group responses more likely to be positive. In addition, the distributions for all three scenario two questions were more spread out and not left-skewed like all the other distributions. As stated in Chapter 3, I intentionally chose to interview only students from the focal group in order to align with the rehumanizing framework in elevating the voices of students at the margins. Therefore, the results reported here

are in line with the transformative mixed methods design of this research. Part of the mixing of qualitative and quantitative data occurred in the sequential collection of data, where the design of qualitative data collection was informed by quantitative data analysis. In addition, the results from the qualitative analysis presented here are further used to elaborate on the quantitative findings. Here, I provide rich descriptions of what the interviewees brought up with regard to scenarios two and five to explore possible explanations for the distribution differences found in the quantitative analysis.

Scenario Two: Cultures & Theirstories

Scenario two on the survey said:

Imagine that every week in your calculus course, the instructor spends a few minutes in class to discuss a current-day Indigenous, Black, Latinx, female or LGBTQ+ mathematician and showcase a bit of their work. A write-up and web links are also provided for each highlighted mathematician so you can read more about these people and their mathematical work on your own time.

Interviewees had much to say about this scenario. Three main themes arose from analyzing these data, including (a) the appropriateness of implementing this teaching move in an undergraduate mathematics class, (b) the role model impact it might have, and (c) the potential for this teaching strategy to be implemented in ways that feel dehumanizing to students (i.e., the previous theme of implementation matters is still relevant here). The interview comments for this scenario were also edgier than for other scenarios, meaning the responses were either highly positive or very hesitant with hardly any neutral answers, matching the quantitative findings.

Appropriateness. Although no interviewees said this scenario was all negative, many of them discussed how they felt this scenario was either great to have done in class or how they felt

it was an inappropriate use of class time. Alex's comments showcase the push and pull that this scenario can engender. Ze said that it "would be very interesting, but I feel like when I go to calculus class I want to learn calculus more than [other things like math history]...I just feel like it's a little bit off topic in that class." Evan had an unambiguous approach, saying that "it just doesn't seem like scenario two is appropriate for the math setting" and perhaps it would be better "to designate time out of a math class to talk about that." Amanda did not "really see a[n] issue with it," but she also "just do[es]n't see a benefit." She added, "I know that it can help feel more connected to your environment but I don't think it necessarily creates engagement and I feel like it would be kind of distracting and take away from the actual content of the class." Andrew did not "know just exactly how well it would relate to what [they were] learning and...if it would help [them] learn the material any better." They were quite blunt in saying that "it would just feel like more wasted time because of how it seems more disconnected" from the course content, i.e., implementation matters. Antonio wanted to have "the background of the mathematician" because it is a "neat fun fact...or just something that helps you to understand where they came from [or] what brought them to create" the mathematics they created, but he felt other scenarios would be better at supporting his learning, sense of belonging, and making connections outside of class than scenario two because they applied more directly to the mathematics he was learning. These concerns echo concerns reported in previous sections of this chapter that implementation matters and content coverage should not be sacrificed. Students seem committed to learning the mathematical content and worry about teaching techniques that will take time away from content coverage. Additionally, these quotes highlight the seesaw feelings of students, recognizing that this scenario could be "interesting" or "connected to your environment" while also being "inappropriate" or "distracting." This further shows students' commitment to a welcoming

environment as being humanizing as well as the implication that instructors must bear the burden of planning and leading for this teaching practice to feel helpful and caring.

Some students had a fully positive attitude about scenario two and its appropriateness in the classroom. Clarisa expressed her expectation of how a mathematics class is taught. In her experience, mathematics classes are “just a lecture, classwork and then homework, and you do it all over again.” In her opinion, this is “why people lose so much interest in math” because it is “the same thing over and over again. Even if it’s not the same material, [it’s] the same structure and format of a class.” Thus, in her view, “something like scenario two, where a professor were to talk about minorities and mathematicians and what they do, it would be a lot more appealing.” Lynne had similar thoughts, saying that scenario two, where instructors talk “about the math accomplishments of people from more marginalized demographics...would be really good.” She mentioned that this scenario would feel like “there is a human aspect to math that isn’t just like old German guys.” Reegun also “really like[d]” this scenario because “it’s important to bring attention to people who maybe aren’t usually brought attention to. It’s just really healthy, no matter what your opinion is; it’s good to have a really well-rounded view of people.” Specifically, she liked “the idea of mathematicians of all different backgrounds, cultures, ethnicities being brought up, because it’s really important to highlight that. It definitely brings more attention to maybe less-recognized groups.” These quotes accentuate the potential for scenario two to have positive impacts on students, with regard to being “human,” expanding perspectives of who can do mathematics and as a mechanism to disrupt traditional teaching norms. This ties back to the environment aspect of the student-driven humanizing definition, namely that students think scenario two can add to an “appealing” environment that promotes “interest” in learning.

Role Model Impact. Because scenario two focuses on presenting information about mathematicians from diverse backgrounds, it brought out comments regarding its potential to serve as a role model device. Several students shared insightful thoughts about this role model impact for them personally. One compelling comment came from Alberto,

Growing up and taking math classes in high school and even my experience in my first bachelor's degree, it felt like all of my teachers were...straight white males and it felt like this is the mentality to be a mathematician, that you need to kind of pull up your britches and be a man about it. And there's no room for emotion or thinking, it's logic... I never felt like it was someone similar to me if that makes sense. I felt kind of on the outside, like I was supposed to be doing something else because it didn't come as easily or as intuitively. And, so I think for me, it would make a big difference to know that you don't have to be that one thing... To be good at math or to be a professor or to learn difficult subject matter. I feel like, for me, it would inspire me to know that there are more people like me who do math and are good at it.

Clarisa explained her experience being mentored in mathematics by her grandma and how that influenced her to seek out other STEM role models,

My grandma actually taught me math. It was the only thing she could teach me because of the language barrier... So I had an interest since I was little and I always looked for people like minorities in math... I look[ed] up to Catherine Johnson who was [a] black woman in NASA, a mathematician. Or just like movies, even if they're fictional they show minorities in math and I feel like that's very empowering.

Thus, Clarisa is suggesting that this scenario would be “empowering” as well. Jayden had a similar experience to scenario two in her “intro [to] chemical engineering class,” where her “professor would also have different things like...different people that were important to the industry but not your classic people that you always hear about and it was really cool and fun to hear about.” This “inspired” her and because of that positive impact, she thought that “hearing

about mathematicians that aren't like conventional ones...would be very cool,” implying that she believed this experience in her mathematics course might have a similar inspiring impact on her.

In addition to the role model impact of this scenario, feeling inspired or empowered, Finley and Duncan pointed out ways in which their motivation or connection to the instructor would be improved by implementing the teaching practice of this scenario, highlighting again the importance of relationality for a humanizing experience. Finley stated an eagerness “to learn any new history” and because they did not “know any mathematicians” or “any history related to the groups” listed in the scenario, they would “love to learn more about mathematicians...and the history of these groups and how they come together.” This would “encourage [them] a bit more” and “be at least a little more motivation, specifically when learning about LGBT mathematicians.” Finley is indicating that learning about such mathematicians would benefit their motivation to learn mathematics. Duncan said that “a lot of students don't see themselves in a STEM field” because “all we hear about is just the generalized straight white men that did anything.... So having....some representation showing in the classroom would be very important for students to see themselves.” He conceded that “I am white so...I see a representation of myself in every field.” However, he “feel[s] like that would be beneficial for a lot of students to maintain their STEM journey...because they see that other people like them have done that.” Here he is suggesting a community-oriented view of the class, but additionally, he said “I think that I'd feel more connected to the instructor if they did that.” Thus, even if instructors show mathematicians who are not necessarily like Duncan, the fact that the instructor takes the time to highlight mathematicians from marginalized groups makes him feel “connected” to the instructor, and once again illustrates the relational characteristic of humanized mathematics classrooms that was described previously.

Potential to be Dehumanizing. Tying back to a previous section of this chapter focused on student concerns about implementation of the rehumanizing scenarios, I now address the findings from scenario two that shine a light on ways in which this scenario can be negatively experienced or implemented. Recall also that the quotes provided here are from the portion of the interview that preceded any use of the word “humanizing” by me. Several interviewees showed serious concerns about how this scenario could feel controversial, rejecting or dehumanizing if not implemented with caution, thoughtfulness and from an informed place. Evan was most succinct, saying “if not implemented correctly it could be very dehumanizing, depending on how it's presented and what discourse may occur within the class should there be any.” Faith was “kind of neutral” about this scenario because she “would really love to learn” about mathematicians from diverse backgrounds, but she also “know[s] that when that’s brought up then it also causes a lot of controversy” and “takes [the class] away from learning to everybody being a little sensitive about the subject.” Isabella went further to offer an example of how this scenario might end up feeling dehumanizing. They said,

While it's good to know [about mathematicians from diverse backgrounds], there's also going to be kids in the class who are going to be verbal about how they dislike it or very obvious that they dislike it and that would make me feel excluded from that. Like if [the instructor is] talking about a female doing something good [or] big in mathematics...a guy might giggle in the back and make a sexist joke and then I would not feel as safe being in that class.

This suggests that not only do instructors need to know how to implement this scenario with fidelity, but additionally, they need to have the skills to handle any classroom sensitivity or controversy, should it arise, so that no students are unintentionally harmed.

Jack voiced a similar concern that “there [might] be a bit of a negative reaction amongst some students over that [scenario] because they'd be like, why are we doing this?...this is just vague education trying to shove values on me again.” They contrasted this with another way to approach this scenario, suggesting that the instructor could showcase mathematicians doing work relevant to the course curriculum. So “if it's just like this person did this thing in their Indigenous community” then perhaps the identity of the mathematician is not “the focus but it's subtly the focus.” Then, “people from that [Indigenous] community,” for example, “would be like, oh yeah, that could be me someday, but people who aren't in the community and maybe reject the community don't necessarily catch on.” The implication here is that Jack is worried about what they view as the sensitive nature of bringing in mathematicians from marginalized groups and the potential for negative consequences. However, they believe that risk could be ameliorated by ensuring a fit of the mathematician with the course content.

Sadie said outright that scenario two “would be a slightly controversial one.” They based that opinion on similar experiences in a few high school classes where instructors would bring up scholars from diverse or minoritized backgrounds in the corresponding field, but the only class where it was a “positive experience” was in “chamber orchestra group.” Sadie mentioned that the reason it was positive was because “not only did [they] just take a day and learn about these composers,” but they also “actually did an entire performance of minority composers.” This meant that “it wasn't just a one day splash of, hey, here's all this information of minority composers in music.” Instead, “it was a couple month long dive into those composers.” She went on to opine, “personally I don't think mathematics is the right place for it, especially with how hard of

a topic and how condensed the material is already.” She feels it “would be really hard on the students.” However, they “definitely want to see it” implemented in the class. Given the one positive experience Sadie had in a different course, even though it was not mathematics, the implication here is that it could be done in mathematics, if done with thought, planning and attention to timing.

The quantitative findings showed that this scenario, specifically, had the most mixed perceptions and had significantly different distributions between the focal and dominant group responses, for all three Likert questions. The qualitative findings here suggest that the mixed perceptions were due to the concern regarding appropriateness of implementation. This includes student concern regarding how the instructor handles potential sensitivities or negative reactions from other students in the class, which could lead to the classroom feeling dehumanizing. Overall, scenario two has the potential to contribute positively to the classroom environment as well as relationships between instructor and students and connecting mathematics to students’ lives outside the mathematics classroom, i.e., to feel humanizing. However, this scenario must be implemented in appropriate ways that fit within the curriculum and do not take time away from necessary content coverage. Additionally, the instructor needs to handle sensitivities and classroom dynamics surrounding this scenario’s teaching move with care and awareness.

Scenario 5: Broadening Math

In the survey, scenario five focused on the instructor providing “opportunities for [the student] to practice doing mathematics outside of the traditional curriculum and to

pose mathematical questions [they] want to explore.” The example given in the scenario was that “they might spend a class day discussing and having students bring examples of how art is connected to mathematics.” Recall, the quantitative results for this scenario were left-skewed, meaning that responses were mostly positive. However, for the connections Likert question, there was a statistically significant difference between the focal and dominant group distributions of responses. Many of the interviewee comments focused primarily on the activity of extending the traditional curriculum and less on the students themselves posing questions to explore. Further, much of what the students had to say was either mixed or tinged with worry about appropriate and effective use of class time.

Andrew disagreed with all of the Likert questions for scenario five, meaning they had a negative perception of this scenario because “it seems like such a waste to be doing something that’s not related to what I’m studying.” They “might enjoy it” but think calculus class should focus on calculus. When I asked “what if the teacher was really adept at making sure that it was related directly to the content you were learning?” their opinion did not change. Instead, they shared a story of a time during their calculus course where the instructor brought up an example of “hanging from two ropes and he kept relating it to [the instructor’s] experiences [rock] climbing.” This was supposed to give context for an optimization problem, which is indeed part of the calculus content. However, Andrew and their “friends left that lecture being like, why did he talk about climbing so much?” It did not “resonate” with them because “it’s difficult material. None of us really know what we’re doing. We’re so desperate to just kind of figure it out.” Here Andrew is expressing frustration with the attempt of the instructor to broaden mathematics when the students did not first have a grasp of the underlying mathematical concepts, suggesting that

the order of these teaching moves matters. They are further suggesting that students first need to see and do enough examples to understand the core mathematics being presented and then see examples that broaden their understanding of that mathematical idea.

On the other hand, Evan had a “neutral” view of this scenario, thinking “it’s not going to hurt [and] it’s not going to help.” He followed that up by saying that he does “see the need to connect math to other subjects like art.” Lynne mentioned that “if it's relevant and if something is a really good example of something” they were learning in class, “then that makes sense. Like if there's something in another discipline that's really connected to what we're learning, then that could be cool.” With that said, she did follow up these comments with an example that would not be related directly to the course material, and she expressed a negative opinion of that situation. Clarisa was not enthusiastic about the scenario in the survey that suggested connecting art to mathematics class. However, when I probed further and offered a different idea of bringing in a connection about how another culture does calculus, she agreed that would be better and she would have ranked that scenario higher in that case²³. All of these quotes and ideas expressed by the students show students’ worry that the extension of content still be highly related to the class material, and that it resonates with student interests.

A couple students did focus more on the student-centered aspect of this scenario. Sadie “liked how it was about bringing students in and trying to get them to connect to the material,” but was concerned that “a lot of the time...it wouldn't be employed as it should.” This was because it would “require a really high level of interaction from [the instructor and] students and it's going to be really based upon the teacher themselves and making sure that they have that connection with their students” which showcases again the importance of relationships and a

²³ Keeping in mind the overlapping nature of the rehumanizing dimensions, this proposal would certainly fall in both Broadening Mathematics and Cultures/Theirstories dimensions.

positive environment for creating a humanizing experience. Lastly, Jayden was worried that it “felt like more work for the student...work that [isn’t] really important to learning math.” Jayden and Sadie point out hesitancy with the students initiating the connection of art to mathematics, as was indicated in the scenario. Jayden does not want to burden the students and Sadie connects back to the need for instructor-student rapport (relationality) and trust (environment) that is necessary to make this scenario beneficial.

The quantitative findings suggested that there was some discrepancy regarding how connections to students’ lives outside the mathematics classroom were perceived for the teaching move given in scenario five. Indeed, the interviewee comments focused on connections which provides nuanced information that cannot be uncovered with quantitative data. Interviewees highlighted the need for this scenario to be implemented in ways that preserves the content coverage, building on foundational understanding first (before broadening mathematics occurs), and aligns with students’ interests. They also noted the need for instructor relationship and trust for this scenario to create a helpful and caring environment, i.e., feel humanizing.

Reflection on Broader Community

In analyzing the comments interviewees made that referenced all of the rehumanizing survey scenarios, a noteworthy finding occurred. Several of the students took care to reflect on the broader community of students in the class and attended to what might benefit other students, which is certainly in line with the relational and human-being-ness spirit of the rehumanizing framework because it centers relationships and a caring environment. Although eight interviewees said something that suggested or implied they were thinking about the broader community within the classroom, only four students had direct quotes that elucidated this

thinking clearly. Additionally noteworthy is the fact that those four students all identify as women. However, there were other men or non-binary interviewees who brought up community-oriented views at various points of their interviews.

Amanda showed her care for others, saying “when I was going through each of these scenarios I felt like there was always one [that] I could see...helping someone that I knew.” She went further, saying that all scenarios intended “to introduce the content in new ways or to make the class feel important or involved with each other, and I think that all of those will have some form of positive impact.” Reegun had similar sentiments, saying “math is such a broad concept and people will learn in so many different ways. [I] recognize what works for me isn’t going to work for someone else and what works for someone else won’t necessarily work with me.” Here she recognized “how some of these different scenarios would be really beneficial for someone else.” Sadie focused on the “student engagement [and] student connection” in her comments. She did not see “a single [scenario] where [she] didn’t think it would lead to a better learning environment.” She felt that “all of them through their own different ways were really good and could have really positive experiences for everyone involved...and help you feel like you belong even more.” Faith commented that all scenarios were “on equal level” for her, saying further that “maybe some might not work for other people.” When probed specifically about why thinking about other students was important for her, Faith said “just because I’m not the only one in the class and everybody learns different[ly] and everybody has come from different places. So I just think everybody perceives things different[ly].” In all of these quotes, students are clearly thinking of their classmates and expressing interest in teaching strategies that benefit everyone, at least in some ways, which provides further evidence that the eight dimensions of the rehumanizing framework sit on a relational foundation. These quotes also suggest that indeed all

eight rehumanizing dimensions are necessary, i.e., they overlap and should be considered together rather than piece-meal.

Surveys: Additional Comparisons Across Groups

In this section, the similarities and differences between focal and dominant group qualitative responses about teaching moves that feel humanizing are considered. To address this, I analyzed the survey responses to the open-ended question: “Please list at least one thing that college mathematics instructors could do (or already do) that would contribute to your sense of belonging in mathematics class, build connections to your life outside of class, and support your success as a student.” One striking finding from analyzing the responses to this question was that the themes and codes developed from analyzing the interview transcripts were complete, meaning no new themes showed up in the survey essay responses that had not already been accounted for in the interviews. Most of the survey responses echoed sentiments already reported on earlier in this chapter, and thus will not be repeated here. The focus of this section will be on findings from the survey responses that add new results to what has already been described above.

With that said, one finding that showed up in the interviewee identities and short biographies is worth repeating here—the importance for students to have instructors who know and use their names. Many students explicitly stated that it is a positive experience for them to have an instructor call them by name, which was mentioned equally by students from both dominant and focal groups in their survey responses. Students want to be known and seen. In fact, it is enough for many students for instructors to “make an effort” to learn all their students’ names. Many of these comments were combined with reasons why this was helpful. For

example, one focal group student wrote, “My mathematics instructor does a good job of learning names and interacting with students during class rather than just going through the motions, which I really appreciate. This interaction keeps me engaged, making the class feel more personal.” This comment suggests that one consequence of the instructor learning student names is that students feel a sense of belonging in the class. A dominant group student wrote that taking the time to “learn every student[’s] name” makes them know that their instructor “genuinely cares for [their] students.” Here, you can see the result of properly using students’ names is that students feel cared for and engaged in class, which directly aligns with the previously established notions of relationality and caring environment that arose in the student-driven definition of humanizing.

Recall from Chapter 3 that the open-ended survey responses were coded in two distinct ways, namely for the three rehumanizing proxies and independently for the three humanizing themes mentioned earlier in this chapter. More specifically, each survey response was coded as attending to value and belonging (VB), connections (Cn) and/or supported learning (SL), since those were the triple-barreled ideas embedded in the essay question. This was done to see which, if any, of the three constructs was most important to students to get a broader sense of how students might be envisioning rehumanizing. Separately, each survey response was bucketed into one or more of the humanizing themes²⁴ of instructor relationship (IR), peer interaction (PI) and/or connections to mathematics outside the class (RW—colloquially for real-world connections) to see which theme, if any, was most frequently mentioned. Comparisons were made across groups and I found that there were no noticeable differences between groups. This

²⁴ These themes are from the Humanizing: Experiences of and Advice from Interviewees section earlier in this chapter.

conclusion was made based on the fact that the responses were similarly distributed by count, for both the dominant and focal groups, across the three proxies and across the three humanizing themes. In other words, I considered the counts for each of the nine regions, i.e., three rehumanizing proxies (from the survey) multiplied by three humanizing themes (from the findings). For example, there were 22 dominant-group and 24 focal-group survey responses that were coded as both connection (Cn) rehumanizing proxy and real-world (RW) humanizing theme, which are close in number. Although the counts for each of the nine entries in the table were different for the two groups, they were similarly distributed. This indicates that the humanizing thematic results of the interview data may also represent the thoughts of all the student participants, not only the focal students.

Next, the coded survey responses were analyzed in two distinct ways, namely prioritizing the three rehumanizing proxies or prioritizing the three humanizing themes. Tables 10 and 11 showcase the results of this analysis. Table 10 shows that each of the three humanizing themes aligned with one each of the survey proxies. This indicates that instructor relationship impacts a student's sense of belonging and feeling valued the most, out of the three proxies. Peer interaction most impacts a student's perceptions about being supported in their learning, which is a compelling piece of evidence for embedding student discussions within mathematics courses. Lastly, giving students the opportunity to do real-world problems in class most contributes to their connections of mathematics related to their lives outside the classroom, including connections to other STEM classes.

Humanizing Theme (prioritized)	Which proxy was most salient across groups?
Instructor Relationship (IR)	Value & Belonging (VB)
Peer Interaction (PI)	Supported Learning (SL)
Connections to Real-world Mathematics (RW)	Connections (Cn)

Table 10. Table that shows which proxy question was most salient, meaning most frequent, for each humanizing theme.

Table 11 shows that when the survey proxy is prioritized, peer interaction shows up as most compelling for both value and belonging and connections. And, unsurprisingly, the connections proxy properly captured students' feelings of mathematics being connected to their lives outside the classroom. What is perhaps surprising here is that instructor relationship, as one of the main humanizing themes, did not take precedence for any of the survey proxies. This could imply that instructor relationships are really secondary to peer interactions and real world connections, which could have implications for teaching practices and what should be emphasized by instructors. With that said, there is still work that needs to be led by the instructor in creating peer interactions and connections with mathematics outside the classroom.

Survey Proxy (prioritized)	Which humanizing theme was most salient across groups?
Value & Belonging (VB)	Peer Interaction (PI)
Supported Learning (SL)	Peer Interaction (PI)
Connections (Cn)	Connections to Real-world Mathematics (RW)

Table 11. Table that shows which humanizing theme was most salient, meaning most frequent, for each proxy question.

Summary of Qualitative Findings

It is necessary to point out that the words “pedagogies,” “practices,” and “structures” were not words that the student participants used when describing ways that instructors could support their learning, increase their sense of belonging or build connections. Frequently, in my analysis, I have referred to the collection of teaching pedagogies, practices and structures as teaching “moves,” i.e., using teaching moves as a sort of umbrella term. My use of pedagogies includes the attitudes, beliefs and philosophies that the instructor brings into their teaching that influences student learning experiences. Practices are then the actions taken during class, which are typically implemented in ways that are based on the instructor’s pedagogical stance. Structures refer to the expectations and communication of those expectations, as well as the rules or culture that is explicitly created inside the classroom, that allow the class to run smoothly (or not). As I discuss the conclusions from this chapter in the next paragraph, I have inserted the type of teaching move most relevant to each summarized point, to help the reader better connect these conclusions to the research questions.

In this chapter, I have reported on the findings from the qualitative data analysis. To address the main research question, focal students provided a nuanced and rich definition of humanizing that prioritizes relationality to peers, instructor, and past/present role models paired with attention to a caring and supportive class environment (teaching pedagogy). The interviewees further expressed ways instructors could humanize undergraduate mathematics classes, specifically by proactively implementing teaching moves that attend to real-world connections, peer interactions and instructor relationships (teaching practices and structures). When discussing the survey scenarios that represent the eight rehumanizing dimensions, analysis

of interviews with focal students shed further light on why and how these teaching strategies would feel humanizing to them and support their learning. The way certain scenarios are enacted in the class, especially scenario 2 (Cultures & Theirstories), matter deeply for students and have the potential to rehumanize as well as dehumanize which has implications for instructor professional development that will be discussed further in the next chapter (teaching pedagogy, practice and structure). To address the research question about differences between perceptions of the focal and dominant groups, the open-ended survey question responses, across both groups, provided the final key that indeed the findings from the interviews will do well to serve all students, and peer interactions are potentially the most important factor in supporting students' learning and creating a space for belonging to grow. Finally, the findings provide empirical evidence to support the overlapping and connected nature of the eight rehumanizing dimensions proposed by Gutiérrez (2018), which addresses the final research question.

CHAPTER SIX

DISCUSSION AND CONCLUSION

In this chapter, I discuss how the findings from Chapters 4 and 5 provide evidence to address the research questions:

What classroom structures, practices and pedagogies do undergraduate Calculus 2 students perceive as rehumanizing in their college mathematics classes?

- a. In particular, what are the perceptions of students from historically marginalized groups (in STEM) from various races, ethnicities, LGBTQ+ statuses, and/or genders? And how do these perceptions compare to overall perceptions?
- b. In what ways does examining student perceptions contribute to the existing rehumanizing framework?

Recall that this study used a transformative design with a theoretical framework that comes from a sociopolitical stance. As such, the goal was to recommend student-driven updates to our teaching that serve to further liberate and improve their mathematical learning and lived experiences in mathematics spaces.

I start by summarizing the findings, which address the overarching research question as well as part a. Then, I focus on addressing research question part b by considering the theoretical contributions that this work provides to the mathematics education research community. While summarizing, I discuss these results in the context of existing literature to situate this research within that body of knowledge. From there, I emphasize implications for teachers, as well as for

future research, arising from this research. This is followed by an acknowledgement of both limitations and significance.

Summary of Findings

To begin, it is imperative to first understand how focal students perceive, experience and define humanizing. The interviewed focal students described humanizing as attending to both relationality and environment. They feel that relationships and interactions with others, including teachers, TAs, and peers, are crucial. Relating to folx outside the classroom, like past mathematicians, role models or community members, is additionally meaningful as part of the relationality piece of a humanizing experience. The classroom environment is the other key element of a humanizing experience for students from the focal group. Instructors play an important and necessary role in establishing caring classroom environments where students can thrive, and build a sense of belonging (e.g. Lahdenperä & Nieminen, 2020). Students ask for the classroom culture to be built intentionally and thoughtfully in ways that feel welcoming, empathetic, respectful, failure-tolerant and caring. Relationality and environment are certainly not mutually exclusive; when instructors attend to one, it impacts both. Thus, characteristics of a rehumanized mathematics classroom, emerging from research informed by Gutiérrez's (2018) eight rehumanizing practices, include the foundational elements of relationality and a caring environment, suggesting that students will perceive teaching practices as humanizing if they meet these two overlapping criteria. These characteristics then inform pedagogies and structures of mathematics classrooms that instructors can implement to humanize their classes.

Keeping this definition of humanizing in mind, the advice received from the interviewed focal students regarding what teaching structures or practices feel humanizing centered

connections. The focal students want instructors to structure their mathematics classes in a way that provides multiple opportunities for structured peer interaction, so students can build rapport and connection to their peers. Essentially, they want their peers to be elevated to co-teachers in order to boost their learning, confidence, and sense of belonging. I found that peer interaction most impacts a student's perceptions about being supported in their learning, which is a compelling piece of evidence for embedding student-to-student interactions within mathematics courses. This finding echoes recommendations in the *MAA Instructional Practices Guide* (Abell et al., 2018) that learning and sense of belonging is “more likely to flourish” (p. 2) when instructors enact student-centered pedagogies and create and sustain caring classroom norms, starting on the first day of class. Additionally, the positive impacts are particularly felt by students from historically marginalized groups (e.g. Leyva, 2016).

Instructor care is another core need from students and aligned with a few of the seven recommended practices for calculus instruction emerging from the *Progress through Calculus project* (Bressoud et al., 2015). From the seven recommended practices, practice two focuses on supporting students in ways that foster academic growth, i.e., aligns with instructors caring about student learning. Practice four is a recommendation that instructors employ student-centered pedagogies and practice eight, which was outlined in a separate paper (Hagman, 2019), asks instructors to attend to equity, diversity and inclusion in their teaching. Both of these practices require instructors to care about the students themselves. One particular example of showing care, voiced by students from both groups in the survey as well as by many interviewees, is for teachers to know and use students' names and pronouns. This is a small investment of time on the instructor's part, i.e., attending to a very low bar, for a seemingly large win with the students who need relational connection with their teacher. Another way instructors can show care for

students is by creating a failure-tolerant classroom culture that embraces and encourages learning via mistakes (e.g. Abell et al., 2018; Battey & Stark, 2009).

Lastly, students ask for regular connections to be made between the mathematics they learn inside the class to their lives outside. Teaching moves that tend to this need will feel humanizing to students, including connecting the course content to students' other classes, their potential future careers, and/or their everyday lives. Instructors can work toward this goal by finding out what interests their students, as well as what their majors are or what other courses students are taking, and create relevant connections between the class curriculum and those interests/majors/courses (e.g. Gravemeijer & Doorman, 1999).

Finally, the results suggest that the curb-cut effect is indeed happening here, with perhaps a caveat regarding Scenarios 2 and 5 where attention to implementation needs to be carefully and thoughtfully addressed. This is evidenced by (1) the fact that the open-ended survey questions did not add any new or unfound results from what was found in analyzing the interview data. This indicates that the humanizing thematic results of the interview data, emerging from conversations with students from the focal group, fairly represents all the participants' perspectives, not only the focal students. In addition, (2) the quantitative data from the surveys showed that overall focal and dominant group students were mostly in agreement and had mostly positive regard for the scenarios. This suggests that the teaching moves outlined in the scenarios on the survey are considered rehumanizing—via supporting learning, promoting a sense of belonging, and making connections to students' lives outside the classroom—for students from both groups.

With that said, it is important to consider the challenges outlined by students in this study regarding the implementation of the teaching moves outlined in the scenarios that were

representing the eight rehumanizing dimensions. Students ask for instructors to center the student at the same time they are taking care to cover the content. In other words, focal students voiced their need for instructors to implement humanizing teaching moves, in ways that do not distract from the content coverage and instead take an appropriate amount of class time. For example, scenario 2 (cultures & their stories) could take up one minute of class time with further resources and information about mathematicians from historically marginalized groups provided outside of class for students to investigate on their own. Scenario 1 (participation & positioning) and scenario 3 (windows & mirrors) are practices and structures that could be implemented during class that do not take up any “extra” time.

Using the results of scenario two as an example, it is crucial that instructors are informed and aware of student sensitivities, especially those who have historically been marginalized in STEM spaces, and create and use a plan of action for noticing and handling any power and unwelcoming difficulties that might arise between students (Machen et al., 2021; Martinez et al., 2021). Also, based on the quantitative findings, students from the dominant group were more likely than focal group students to view scenario two negatively. This suggests that thoughtfully attending to the practice outlined in scenario two could be a way to push towards a rehumanized experience for students at the margins, which is precisely the transformative focus of this research.

Theoretical Contributions

This research provides empirical evidence that the teaching practices and instructor demeanor outlined by the rehumanizing framework does indeed align with students’ ideas of what is humanizing. There was nothing noted by the interviewees, nor in the surveys from all

participants, that was outside the scope of the dimensions and (implied) foundation of the framework. My study additionally provides evidence that the proxies of (a) “supports my learning,” (b) “I feel valued and/or that I belong,” and (c) “I feel a sense of connections to my life” are well-supported notions that students seem to understand. Also, these proxies, that are grounded in both Gutiérrez’s work (2018) and research by other scholars (e.g. Strayhorn, 2018), act as a reasonable set of ideas to capture “humanizing.” Thus, my research positioned the notion of “humanizing” established by the three proxies *and* as defined by the interviewees to see if the proposed practices from Gutiérrez’s framework (2018) seemed appropriate to create a rehumanized experience. The findings reported on in this dissertation indicate that those practices, when implemented carefully, seem to represent a reasonably comprehensive list of ways teachers could support students from the focal group to feel rehumanized in their mathematics classrooms (at PWIs), as nothing outside the scope of the rehumanizing framework was suggested by students. This ties back into the sociopolitical lens that is foundational for the rehumanizing framework, which specifically suggests that teaching and learning are both social and inherit political notions from the broader society. This research is squarely situated to promote equity in the undergraduate mathematics classroom by giving more people a voice that then influences teaching improvements based on those voices that have been historically underrepresented in STEM spaces.

This result regarding the rehumanizing theoretical framework is itself compelling because no previous study has provided empirical evidence guided by the framework. Further, analysis of the data elucidated how students define and perceive what is humanizing, i.e., relationality, environment and connections are key. Concerns were also voiced by STEM-intending focal students regarding possible challenges with the implementation of teaching moves aligned with

the rehumanizing dimensions. These findings suggest that the foundation of the rehumanizing framework needs to be more explicitly highlighted to be sure instructors are not implementing rehumanizing teaching moves in transactional ways that will then not be experienced as humanizing by the students. Although love and care is mentioned in some of the chapters of the *Rehumanizing Mathematics for Black, Indigenous, and Latinx Students* book (Gutiérrez, 2018), as examples, it is not explicitly emphasized enough as such in the brief description of the rehumanizing dimensions at the start of the book. The lack of direct attention to this crucial detail, especially in the graphic (see Figure 34), could lead some practitioners to misinterpret the necessity of relationality and love and care for authentic implementation. “Love and care” (Gutiérrez, 2021) is a concept mentioned or alluded to throughout the chapters of *Rehumanizing Mathematics for Black, Indigenous, and Latinx Students* (2018) (e.g., see the chapter by Joseph & Alston). I propose explicitly stating that the foundational circle (of the graphic) is indeed representing the relationality and caring environment that serves as the adhesive connecting all the dimensions of the framework together as a thorough framework.

Secondarily, it is clear from the description and provided warnings of the rehumanizing framework (Gutiérrez, 2018) that the dimensions are to be taken together, not as individual, independent units. The fact that the eight circles, one representing each dimension, surrounding the main circle in the rehumanizing graphic do not overlap is ill-aligned with the intention of the framework. Also, interviewees from this study highlighted how important connections were for teaching moves to feel humanizing, namely connections with people (instructors, TAs, peers, folx outside the classroom) as well as connections of mathematics to their lives outside the classroom. This result emerged from an analysis that considered the common components of each of the dimensions described by participants. Further, interviewees brought up the

overlapping nature of the scenarios, especially when discussing how implementation matters. For example, students suggested that the implementation of some scenarios could be improved if combined with elements of other scenarios, like the Broadening Mathematics scenario could be better implemented in a class if combined with elements from the Participation & Positioning scenario. Given the crucial nature of connections to humanizing teaching moves or experiences students described, having the circles representing the dimensions overlap with one another, as well as with the center, foundational circle, could serve as a visual reminder of those connections across dimensions.

My proposed graphic (see Figure 34) has the dimension circles overlapping with their direct neighbors and with the rehumanizing foundational circle to showcase that intention. One caveat to mention here is that ideally we could have a graphic such that each of the eight rehumanizing dimension circles overlap with each of the other rehumanizing dimension circles. Given the fact that the graphic is two-dimensional, this intent is not easily carried out without likely producing visual confusion for the reader. The overlapping nature of this proposed graphic is not intended to suggest that each circle can only overlap with its direct neighbors. Rather, the intent is to suggest visually that indeed overlapping of all sorts occurs here and the small amount of overlap that is visible lends imagination to the viewer to move in the direction of complete overlap.

Finally, based on information brought out in the literature review (see Chapter 2) rather than directly from analysis of the data, I propose renaming the Ownership dimension to Stewardship. This renaming is an earnest attempt to decolonialize the name of that dimension. Ownership, in this context, can easily be misinterpreted as hierarchical, ripe with power

dynamics that are not intended in this framework. Stewardship speaks more directly to the connectedness and relationality of that dimension's intent.

Thus, I propose an updated graphic for the rehumanizing framework, based on these results and for the reasons stated here. Figure 34 shows the latest version of the rehumanizing framework graphic from Gutiérrez (left) compared to the proposed updated version of the same graphic (right) based on results from this study.

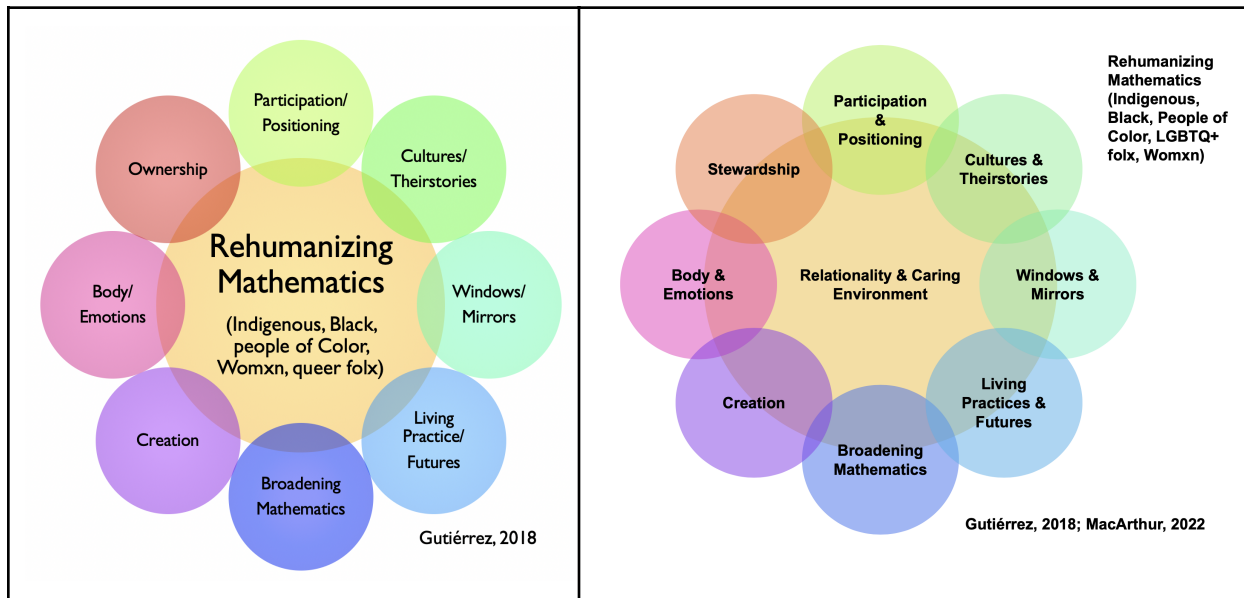


Figure 34. (Left) Most recent official graphic for Rehumanizing Mathematics framework (Gutiérrez, 2021). (Right) Proposed updated graphic for the Rehumanizing Mathematics framework based on this research.

One last acknowledgement should be made here. Both the quantitative and qualitative data showed some concerns surrounding scenario two especially and scenario five to a lesser degree. One might argue that those two circles (representing the Cultures & Theirstories and Broadening Mathematics rehumanizing dimensions) in the above figure could be drawn larger than the others to indicate the extra care that might need to be paid to those dimensions. I have

chosen not to do this because the scenarios were only one representative sample of ways instructors might enact pedagogies, practices or structures that fall in those two dimensions. There are other teaching moves that can be done within those dimensions that may alleviate the concerns found in this research. Thus, there is not enough evidence to suggest that any dimension is more or less important than the others, and the size of the dimension circles is not indicative of that dimension's importance. Rather the circles are visual indicators that all the dimensions matter and should be attended to.

Implications for Teachers

Answering my research questions squarely gives some information for teachers about how to work toward rehumanizing their undergraduate mathematics classes, particularly classes taken by STEM majors at PWIs, providing both concrete ideas of strategies to use in the classroom (e.g. implementing the scenarios from the survey) as well as a set of guiding principles (e.g. attend to relationality, environment and connections). Consequently, I will focus here on a few tangible teaching moves that instructors can implement immediately in their classes, since that might be most beneficial. Additionally, this research is focused on elevating the perceptions of students from historically marginalized groups within STEM; it is not, for example, highlighting results produced from teaching interventions that were observed inside classrooms. As such, the suggestions offered here are a revoicing of the participants' suggestions, based on the results of my analysis.

First, to work toward rehumanizing goals, students mentioned the importance of instructors knowing and using student names and pronouns (relationality and environment). Even if teachers are teaching a large enrollment mathematics course or if they struggle learning names

and it takes the entire semester to accomplish (or not) this goal, the interviewees noted that they appreciate the effort taken in this direction. Students participating in the survey and interviews suggested this as an initial step toward creating a welcoming environment. Additionally, instructors can implement teaching structures and practices that aim to purposefully create a failure-tolerant and caring culture within the classroom. It is important that students see and experience that mistakes are an example of rough draft thinking (Jansen, 2020) that can be leveraged for deeper understanding. Indeed, making mistakes is part of learning, as several interviewees mentioned, so a failure-tolerant environment can be felt as rehumanizing because it supports students' learning *and* does so in a caring and welcoming way. Nevertheless, creating an atmosphere that embraces student questions and mistakes does not guarantee equitable classroom participation, particularly for marginalized students; additional teaching mechanisms that seek to disrupt negative ability norms and treat students with care are needed (Leyva et al., 2022). Knowing student names is one step toward creating a space where students feel cared for and comfortable to make mistakes because it personalizes the learning experience and moves to center the human beings, rather than the content.

Second, echoing the importance of peer interactions and relationships from my results, many interviewees asked explicitly for regular and frequent peer interaction in class to be facilitated by the instructor, and for it to start early on in the term. Interviewees pointed out that peer interaction should not be left to chance from the instructor's viewpoint, meaning that merely recommending to students that they form study groups, for example, is insufficient to accomplish this goal of meaningful peer interaction. The interviewees want instructors to structure their classes in a way that regularly and frequently necessitates peer interaction, to satisfy the desire of students to have productive mathematical conversations during class. To achieve this goal,

instructors would likely need to provide support for students regarding how to engage in productive peer discussions by setting those expectations early in the semester and then facilitating repeated opportunities for peer discussion. Teachers can explain that structured peer interaction is grounded in research as beneficial for learning (e.g., Lotan, 2014; Rasmussen & Kwon, 2007) and adds to a welcoming environment for students (e.g., Abell et al., 2018). Interviewees wanted such repeated practice of mathematical conversations with peers, so their peers might then become additional teachers and resources for each other and to support their learning and potentially increase their sense of belonging. Although this research found evidence that students need plenty of peer interaction (e.g. group discussions) for a humanized mathematics learning experience, i.e., at a macro level, there is plenty of other research that showcases inequitable power dynamics and outcomes in group discussions (e.g. Ernest et al. 2019; Reinholz et al., 2022), i.e., at an individual or micro level. Thus, instructors need to be informed and attentive to the potential for negative group dynamics, and armed with pedagogical tools to counter those possible negative consequences, especially for students from marginalized groups. For example, instructors can gather frequent information and feedback from students in this regard and can reflect on their own biases. Then, they can make alterations to their course structures and norms, as necessary, to move in the direction of remedying the situation.

Third, if teachers are interested in implementing teaching practices rooted in the rehumanizing framework, they need to attend to the eight dimensions collectively, rather than individually. Gutiérrez (2018, 2021) mentions this explicitly in her description of the rehumanizing framework. Additionally, this study adds empirical evidence that indeed this generally feels humanizing from the students' perspective. This can be seen, for example, by the fact that many interviewees pointed out that all the survey scenarios, implemented thoughtfully,

would positively impact either them or other students. The scenarios presented on the survey as example teaching moves are a potential starting place toward rehumanization goals. With that said, instructors should be attentive to the concerns students voiced in the findings, namely that implementation matters. Enacting the scenarios without covering the mathematical content students need from the course could be counter-productive, for example. And, scenario two (highlighting mathematicians from historically marginalized groups) specifically needs to be carried out in sensitive ways by informed instructors, providing information about such mathematicians for further investigation outside of class time by students. Finding ways to incorporate all the scenarios with fidelity and also with attention to timeliness and connections to the curriculum is necessary for students to perceive and experience them as humanizing. Indeed the practices described by the rehumanizing framework, and further understood from students' perspectives here, align with practices described to promote student learning (like collaborative group work; e.g. Hayward & Laursen, 2014), sense of belonging (like being a caring instructor; e.g. Strayhorn, 2018), and making the course relevant to students beyond just the classroom (like problem-based learning, or projects, etc.; e.g. Gravemeijer & Doorman, 1999).

Limitations

One limitation of this study is that there were no Black students who participated in this research. In fact, there were very few students of color who participated. This is a definite weakness of the results reported here because the transformative design of the study relies on the need for learning from those students who are most affected by the status quo. Many students of color experience different forms of oppression and dehumanization than white minoritized students, and students with multiple minoritized identities experience an intersectionality of

oppression qualitatively different from their peers who may only experience one form. It is possible that some of the results with Black students would intersect with what was found here. However, that leap of logic might be too large a leap to take.

Another limitation is that the scenarios shown to students on the survey were intended to be representative examples of the corresponding rehumanizing dimensions, but that intention may not have been realized. There may be other examples for some of the dimensions that would produce different results. For example, for scenario five (Broadening Mathematics), I chose an example of connecting mathematics with art. Perhaps that particular example was unconvincing for the participants, and if I had replaced art with something more culturally based, it is possible that participants might have responded differently, especially on the survey where I did not have a chance to probe students' thinking. Likewise, for scenario two (Cultures & Their stories), perhaps having various guest speakers, who identify as mathematicians or engineers from marginalized groups in STEM, come to class for 10 minutes three times per semester would feel more welcoming to students. If that was the case, then the survey results and subsequent interviews might have revealed different results.

Lastly, the sample of Calculus 2 student participants in this research were from institutions that serve a lot of engineering majors. As such, it is likely that many of the participants have an affinity towards applications. This is perhaps less of a limitation and more of a boundary on the scope of transferability of the results reported here. It is possible that these results would be reproduced in a study with similar students, i.e., at another PWI with a prominent engineering program. However, it is also possible that different results would appear if the study were replicated with students taking Calculus 2 for the fun of taking a college course, for example. In that example, students might focus more on the virtues of joy, playfulness or

grace (e.g. Su, 2020) of doing mathematics rather than connections to their other classes or their future careers.

Implications for Future Research

It is incredibly important that future research gathers evidence from Black students regarding what they find humanizing in their undergraduate mathematics courses, especially at PWIs. It would likely be beneficial to repeat this study at a PWI (perhaps in a different region of the U.S.) with students of color, perhaps widening the scope to be students of any major rather than specifically STEM majors, especially because Black students are leaving STEM majors at higher rates than their white peers (Bressoud et al., 2015; Leyva et al., 2021). Further, the research findings presented here beg the question of whether or not students of color at minority-serving institutions (MSIs) would have the same attitudes and opinions of what they consider humanizing. Thus, doing research at a variety of institution types could shed more light or expand the views of what students from marginalized groups within STEM view as humanizing in their mathematics courses. These research agendas would certainly align with the transformative goals of the sociopolitical stance that the rehumanizing framework is built upon.

The survey instrument created for this study contained scenarios that were chosen as potential samples of the eight rehumanizing dimensions. The goal was to capture student perceptions about the rehumanizing dimensions via the scenarios, as well as to determine which prompts seemed to capture the underlying rehumanizing construct (or not). It is quite possible that the findings reported here are overly dependent on the particular scenarios chosen and not necessarily representative of student perceptions about the rehumanizing dimensions. Future research could change the scenarios to see if that changes the findings substantially and if so, in

what ways. Additionally, classroom observation research should be done to see if indeed teaching interventions in undergraduate mathematics courses at PWIs based on these findings produce a more humanized experience for students from historically marginalized groups.

A handful of interviewees voiced their desire that educators do things that are not so centered on humans or they wanted a mathematics class where they could leave their identity at the door and just focus on the course content. Similarly, a couple students suggested that they wanted mathematics classes to be a place where they could hide some aspects of their identity. A future study should look into this phenomenon to investigate why that is and whether or not different pedagogical experiences or time changes that attitude for students, and if so, why. Additionally, such a study could consider whether or not the visibility of a student's perceived identities impact students' views of bringing (or not) their full identities into the classroom. For example, do students of color (a visible-as-perceived-by-others identity) have differing opinions and experiences than LGBTQ+ (a possibly invisible-as-perceived-by-others identity marker) students in this regard?

Finally, this research provides empirical evidence that the rehumanizing framework is comprehensive and that the dimensions certainly overlap in their effectiveness for a humanizing student experience. Constructs of supported learning, feeling valued and a sense of belonging, and connections between the class and a student's life were used to get at a humanized experience. However, virtues of joy, grace, love, playfulness, for example, were not measured here. Future research could focus on combining a few different frameworks to produce findings that might be considered more complete – from a human-perspective – in providing students with a truly humane experience in their undergraduate mathematics courses. For example, Su's (2020) human flourishing virtues, Gutiérrez's (2018) rehumanizing framework and Gravemeijer

and Doorman's (1999) realistic mathematics education framework could be combined as a framework for a future study.

Significance

The results of this research have the potential to positively impact the teaching of undergraduate mathematics classes, in ways that students find humanizing. My research begins to answer the call from Gutiérrez (2018) to elevate the voices of students from groups that have historically been marginalized. When the rehumanizing framework was first introduced in writing, its focus was explicitly for "Black, Indigenous and Latinx" (2018) students. However, in future in-person work and in the updated rehumanizing framework graphic (2018), LGBTQ+ and women students, as well as all people of color, were added to the focal group of students for this theoretical framework (2021). My research results followed this intended expansion of the focal group and uses empirical evidence to explicate the rehumanizing theory, and to provide empirical evidence in support of the practical applications of this theory. The results here provide an experientially real definition of rehumanizing directly from the voices of students for whom the theory was created. With that said, there continues to be room for expansion of this framework, for example, to include students with visible and invisible disabilities.

The survey instrument created and used for this research did a reasonably accurate job of using proxies (the Likert questions) and scenarios (representing examples of the rehumanizing dimensions) that resonated with students and their views of humanizing teaching moves. The evidence for the previous statement is that the survey questions did a reasonable job of getting students to think about aspects of rehumanizing without having thought about that word before (at least in the context of mathematics classrooms). This means that rehumanizing, as a

construct, may be something tangible to students when discussed in terms of supported learning, relevant connections and value/belonging. The implication here, then, is that the theoretical establishment of the original rehumanizing framework aligns well with what students discussed and that my study provides more nuance about the foundational circle that connects the various rehumanizing teaching practices.

Conclusion

In addressing the research questions, the findings presented in this dissertation were not intended to be an exhaustive list of transactional moves that instructors can make in order to reach a goal of rehumanizing their class. Overall, the findings produced with this research provide guidelines that can be used to humanize a mathematics class by attending to connections, relationality and a caring environment. The evidence presented here suggests that all of the eight rehumanizing dimensions indeed focus on different aspects that, taken together along with the foundation of relationality and caring environment, move toward producing a humanizing learning experience for students. The specific instructional practices given in the survey scenarios served as examples of those eight dimensions. Additionally, instructors can use those survey scenarios and the results of this research to create and implement different teaching moves that are aligned with the findings provided here to rehumanize their classes. I will remind the reader that Gutiérrez (2018) cautions clearly, as do I, that rehumanization is not a destination; it is a continual process that needs repeated investigation, evaluation and updated implementation. The results reported here shed light on the direction to head in, i.e., a pathway to travel, not a final place to arrive to.

EPILOGUE

Recall from the Prologue, I discussed the need for this research to be wrapped in the human being-ness of myself, as both a researcher and a human being. In this short chapter, I conclude the dissertation with my earnest reflections.

Reflection: As a Scholar

Going into this research project, it was my hope that student voices from groups that have been historically marginalized in STEM spaces, including Indigenous, Black, Latin*, LGBTQ+ folx and women, be centered. They have too often been left out of the conversation and it is past time to elevate their concerns and wisdom in systemic ways. It is still my hope that this goal was accomplished with my research reported on here. With that said, there is always a nagging concern inside me that my work could be interpreted as performative or taken out of context²⁵. I have taken steps to be authentic and caring in this entire research process and hopefully it comes across as such. Although aspects of my personal identity do not overlap with those of all my interviewees, some aspects do align. I also have sincere care and empathy for the participants, especially the interviewees who voluntarily spent time with me earnestly answering my questions.

Perhaps my biggest worry with this research is that the voice of Black students was completely missing. This is not a small thing. Of course, I have done what is required of me as a researcher by reporting that and stating it as a serious limitation, and clearly there is no way to

²⁵ Indeed, if participants of this research told me it felt performative, I would be the most attentive listener and learner, gaining knowledge then on how to improve, reflect and interrogate my own positionality going forward.

force (with good reason) such students to participate in research. However, I am deeply worried that their voices are missing here. I can comfort myself slightly by acknowledging that other researchers are doing excellent work in elevating the voices of Black students at PWIs (e.g. Leyva, 2021), but this does not negate my worry. What is missing from my data? What results did I not find because a vital group of student voices were missing? How are the results I have reported here skewed? And what impact will that have on teaching that might inadvertently negatively affect Black students at PWIs? .These questions keep me up at night.

These worries serve as motivation driving me forward to continue my research and to find value in what I can contribute. My goal is to continue doing research that is transformative for people who are at the margins in mathematics. Completing a doctoral degree at a later age than most gives me a bit of liberation from earlier concerns in my adult life and allows me the freedom to focus on work I find most meaningful with a high likelihood of positive impact. I am unencumbered by attachments to and being compliant with the rigid expectations of the tenure system (although I will likely seek tenure) and thus, this type of research suits me well as a mechanism to disrupt long-held patriarchal and colonial power structures in academia, especially within mathematics.

In doing this work, I have definitely grown as a researcher. This has helped convince me that mixing quantitative and qualitative data is something I enjoy and am growing ever more competent at. I am now also further convinced that my role as practitioner, researcher and advocate is what suits me and my goals best.

Concluding Remarks: As a Person

I have a vivid memory from the Army while at the Defense Language Institute in Monterey, California, in the late 1980s. During a physical training time, i.e., required exercise sessions, a white, heterosexual, cis-man captain made a comment about a white, heterosexual cis-woman soldier's running style, telling her that she "runs like a girl." I remember that I was personally offended by that comment, but not at all in the same way that comment would impact me today, after 30 years of personal growth, reflection and experience. I took the comment the way I believe he intended it, namely as a criticism of her running style which implied that running like a man was more desirable and normative. I internalized that comment to mean that we women should change the way we run to be more like men and indeed that is what I myself desired because I did not want to be the target of such criticism and I wanted to prove that I was not "lesser than" men (a common theme as a woman soldier then). What surprised me the most in that moment of time, and impacts me even now, is that the woman soldier to whom the comment was directed replied immediately and confidently with the retort "I AM a girl" meaning of course it makes sense that she runs like a girl because she is cis-woman and thus she should be proud of her running style, even if it did not fit the norm that this captain wanted. I was struck by my envy of her confidence and presence of mind to speak back so quickly and decisively, even to a man of higher rank than she was. I also notice (now) the captain's use of "girl" here when "woman" would have been more appropriate and accurate. This is another layer of gendered language that is rife with political undertones and discriminatory usage, adding to the main point of this particular anecdote.

I have thought about that moment many, many times over the last three decades. Why did my internal reaction not match my female colleague-soldier's external dialogue? Was her outward comment additionally internalized as truth to her and as such, the comment sprang from that deeply held knowledge naturally? And, if so, how was she enculturated so differently than I was regarding gendered comments? Or was her retort made to sound confident, but did not match her internal dialogue? I will never know the answers to these questions, but the questions themselves are worth pondering. Furthermore, the ideas presented in this personal anecdote are worth exploring in the context of the mathematics classroom, which has also been historically extremely white, heterosexual, cis-man dominated and thus subject to the same level of explicit and implicit enculturation portrayed in my example. What changes must be made in the mathematics classroom, by educators, to create a culture where students truly feel comfortable bringing their whole selves and honoring their different ways of understanding or approaching mathematics?

My research contributes knowledge regarding this exploration, as does the work by many other scholars, and seeks to find ways to reframe the conversation away from a deficit view to an asset view of students, disrupting heteronormative, patriarchal norms along the way. I have sought to honor and elevate the voices of students who have historically been at the margins in order to improve the teaching of undergraduate mathematics in meaningful ways for students. With that said, we still have much to learn, research and ponder in this realm.

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APPENDIX A

SAMPLE INTERVIEW PROTOCOL

Lorenzo (he/him) Interview Protocol

[Get another signed consent form.]

[Verify that it's okay to record the interview. (Then actually hit record and also have backup audio recording on my phone going.)]

Thanks so much for taking the time to do this interview. I really appreciate it! As you know, I'm interested in interviewing you based on your survey responses regarding how we can make undergraduate mathematics courses supportive for students' learning and to help them feel valued and empowered. Do you have any questions before we begin?

There are a few different parts of interview questions. First, I'll ask some basic information about your general experiences in college. Then I'll ask you questions that relate directly to your survey responses. I'll segue next into more specific questions about my research goals with regard to your college math classes. Lastly, we'll wrap up the interview with any questions or further comments you have.

Basic information/General experiences

First I'd like to begin with some general questions about your college experiences thus far.

1. For how many years have you been a college student?
2. What is your anticipated graduation date?
3. What is your major?
4. How would you describe your experiences overall in your major thus far?
Then, ask specific follow-up questions if not addressed:
 - How has your experience with your instructors been?
 - How would you describe the quality of courses in your major?
 - How has your interaction with peers in your major been?
5. *If major is NOT mathematics:* Now I'd like you to think about your experiences in mathematics courses. How have those experiences been overall?
Follow-up questions:
 - How have your instructors been?
 - How has your interaction with your peers been?

6. I want to confirm the demographic data that you gave on the survey. You identify as Mexican, straight man, using he/him pronouns.

I'll first give you this list of some of the interview questions I'll be asking [hand them or give them a link to the document of questions, which does not include the basic information questions]. Please read through the questions and jot down any quick notes that come up for you.

Their Notes

Based on what you noted after reading the interview questions, I wonder if there is a question or set of questions you feel compelled to start with or that really stand out to you as most important? (Then, start with that section of questions and come back to the other questions after addressing those important-to-them questions first.)

Survey Responses

Now I would like to transition to discussing your survey responses. I have those responses here and would love to ask you a few questions about them. And, if you aren't sure why you said something or responded in a particular way and don't feel you can elaborate on the previous response, just say so; that's no problem at all.

7. In your survey, I noticed that you marked scenario #3 as the most positive. I'm curious if you can explain why this scenario feels so compelling for you?
-Follow-up questions:
 -How would that increase your learning in the classroom?
 -How would this help you feel more connected to your peers and/or your instructor?
 -Would this help you feel empowered and if so, why?
 -In what way would this experience impact your feelings of persistence in your chosen STEM major?
 -In what way would this experience impact your confidence?
8. The next most positive scenarios for you were scenarios #2 and 8. I wonder what feels helpful for you in those scenarios, compared to the other scenario that you ranked more positively?
9. You marked scenario #5 as the least positive, with all disagree answers. Can you describe how you would feel as a student experiencing this scenario in a classroom?
Follow-up questions:
 -How would this impact your learning in the classroom?
 -What could make it better for you?

10. I also notice that you were not so positive about scenario #4, with two somewhat disagree and one neutral answer. I wonder what's a bit better in this scenario compared to scenario #5 that you ranked lower?

Possible probes: Can you describe a negative learning experience in a math classroom that would have impacted your answers differently for this survey?

11. You marked all neutral responses for scenario #6. Can you describe how that scenario could be changed to have a more positive impact on your learning?

12. In your open-ended response, when asked about what positively impacts your learning you said that "I think they could use the first week of class to allow everyone to get to know each other and feel comfortable in the work place." Can you expand on this sentiment?

Possible probes- Can you recall a specific example when you experienced something like this in a mathematics class?

13. When asked about what would adversely impact your learning or sense of belonging, you said: "They will get angry with you or be impatient making you feel like you don't belong." Can you expand on this?

Possible probes- Can you recall a specific example when you experienced something similar to this in a mathematics class? How would this or did it impact your persistence or confidence? Can you recall a specific example of a class that was structured better for you? And if so, what did that look like?

Role of Identity

Now I'd like to ask you a couple questions about your identity in relation to your college experience.

14. When you think about your college experience, what aspects of your identity are most salient, or have been important for you as a college student?

15. How, if at all, have aspects of your identity influenced, or been relevant in, your college mathematics experience? Can you explain?

Probe with follow-up questions: e.g. Tell me more. What do you mean by X? Can you recall a specific example when you noticed that, or when you felt that way?

Humanizing

At this point, I'd like to ask you some general questions about how we instructors or the university can make your mathematical learning experiences humanized.

16. Since “humanizing” might not be a word we typically use to describe mathematics classrooms, I'd first like to ask you, thinking broadly, what would it mean to you, or what would it look like, for a mathematics learning experience to be humanizing or to feel humane?
17. Can you think of any specific mathematics experiences you've had thus far in college that you would describe as humanizing? If yes, can you tell me about that experience?
18. Now, can you think of any specific mathematics experiences you've had thus far in college that you would describe as dehumanizing? If yes, can you tell me about that experience?
19. I'm curious how important relationships with your instructor and peers are for you in your college mathematics courses? And, how might your learning be impacted by the love and care you feel from your instructor? How have your instructors demonstrated their caring for you in the past? How would you like them to show you care?
20. Based on your own experiences, do you have any recommendations for instructors, for the university, or for other students regarding practices that would make mathematics learning experiences more humane or humanizing?
21. Are there any of the eight scenarios from the survey that feel more or less humanizing to you? If so, which scenarios and why?

Wrap-up

Okay, just a couple final questions!

22. Is there anything else you would like to share with me before we finish up?
23. Do you have any questions for me?

Thank you so much again for your time!

- [1. *Figure out how to pay them, either in cash via venmo or paper check or amazon gift card. If mailing something, I'll need their address. If I give them a gift card, I'll need their email address.*
2. *Ask if they'd like to choose their pseudonym.*]

Scenarios from the Survey:

Each scenario asked these questions.

- A. I would likely feel valued and an increased sense of belonging.
- B. I would likely feel a sense of connection between mathematics and my life.
- C. I would likely feel supported in my learning.

1. Scenario: Imagine that your calculus instructor invites you to work on calculus problems with your neighbors at least a few times per class for rough draft thinking, i.e., to begin producing solutions that you would be able to revise throughout the lesson. The instructor also recognizes and builds on ideas and strategies used by students, allowing their questions and knowledge to guide some of the class time. Class time always includes discussion between students and teacher.
2. Scenario: Imagine that every week in your calculus course, the instructor spends a few minutes in class to discuss a current-day Indigenous, Black, Latinx, female or LGBTQ+ mathematician and showcase a bit of their work. A write-up and web links are also provided for each highlighted mathematician so you can read more about these people and their mathematical work on your own time.
3. Scenario: Imagine that your calculus course is structured in a way that allows you to see a variety of ways to solve the same problem by sometimes seeing how other students in the class think through the problem and sometimes having your own work highlighted.
4. Scenario: Imagine that several times throughout the semester, through both (a) in-class activities or problems and (b) a project assignment, you get to see and work on mathematics problems that you personally think will impact or apply to your future career or interests.
5. Scenario: Imagine that several times throughout the semester your instructor provides opportunities for you to practice doing mathematics outside of the traditional curriculum and to pose mathematical questions you want to explore. For example, they might spend a class day discussing and having students bring examples of how art is connected to mathematics.

6. Scenario: Imagine that as a regular practice, your calculus instructor poses questions that allow you to play with the mathematics and algorithms you're learning and provide a supportive space for you to create your own algorithms. For example, you might be asked to use examples and patterns to find a formula for the n th derivative of a given function and compare your answers with your peers for similarities and differences.
7. Scenario: Imagine that a few times during the semester, your instructor invites the students to participate in an improvisational mathematics activity or some other activity that involves you moving around. For example, you might work in small groups of students, getting up from your seats to do a card-matching activity, matching printed graphs of functions to their derivative graphs.
8. Scenario: Imagine that your instructor frequently invites all students to bring mathematical problems to them that come up in other classes or in your outside communities to work on both in class and for students to continue working on outside of class. Additionally, with the consent of you and the other students, the instructor updates the course structure and curriculum of the course to include such mathematical problems as they come up.