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An Equity Centered Analysis of Course Coordination's Effect on Undergraduate Calculus 1 Students' Mathematics Identity

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AN EQUITY CENTERED ANALYSIS OF COURSE COORDINATION'S EFFECT ON UNDERGRADUATE CALCULUS 1 STUDENTS' MATHEMATICS IDENTITY

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ABSTRACT

For institutions offering multiple sections of Calculus 1, course coordination allows for consistency among the sections through the reduction of variation of material and/or instructional approaches. Studies on course coordination have shown that a coordinated system can bring benefits to instructors and promote equality for students across multi-section course so they can expect the same instructional treatment as their peers. The benefits to students are often left implicit in current research and usually measured through academic success while the benefits to instructors are well documented. Past studies have also stressed the importance of consistency and fairness across sections brought by course coordination, linking equal treatment with coordination.

This study aims to address gaps in the current literature by explicitly examining the benefit of course coordination on student experiences through equitable classroom practices in multi-section math courses and viewings its impact through the lens of mathematical identities. Furthermore, given the underrepresentation and attrition of women and gender fluid students in mathematics, we choose to center these identities in the research. As such, this study answers what aspects of course coordination influenced students' experiences in their math course and how did those experiences impact their math identity, specifically for women and gender fluid students.

The research design for this study draws on a qualitative multiple exploratory case study with a phenomenological lens rooted in positioning theory. It was conducted at a

southeastern research-intensive university that included two calculus courses, business calculus and long calculus.

Data were collected from ten student participants through periodic video journals, math identity surveys, and individual interviews with students. Individual interviews with course coordinators and instructors as well as artifacts and classroom observations were also done to contextualize the student data. Thematic analysis was performed to analyze the data.

When it came to uniform elements, participants reported that coordinated policies around timing provided structure and engagement but instructor agency to adjust these policies, such as flexibility with due dates, accommodated their needs and promoted their content understanding. Furthermore, participants reported that their instructors' ability to facilitate interactive lessons supported developing relationships and that their instructors' encouragement of resources assisted in the utilization of resources which contributed to positive views of mathematical ability. We found that participants reported that instructor pedagogy was more salient in their described experiences than their awareness of uniform elements.

Of the ten participants involved, three of them described a change in their math identity from their experiences in the course. Two of them, both identified as cisgender women, had their math relationship strengthen due to their ability to be positioned as mathematical explainers and mathematical inquires over the semester through their instructors' utilization of embedded resources, facilitating interactive lessons, and student-centered pedagogy. One participant, who identified as a transgender woman, had

her math relationship weaken due to the absence of being positioned as a mathematical explainer throughout the semester. She expressed feeling uncomfortable with peers around her due to her social identity, experiencing the class differently than her peers and necessitating research that examines these difference and coordination that aims for equity and equality.

Course coordination promotes instructor support of students' mathematical identities in two major ways: providing necessary resources and support for instructors to facilitate interactive lessons and student-centered pedagogy and agency to accommodate student needs.

DEDICATION

This work is dedicated to the students who feel that they are not a “math person.” And to my future students, I hope that my utilization of this research will help in strengthening your math identity.

ACKNOWLEDGMENTS

I am a huge Survivor fan. In this competition show, contestants are marooned on a tropical island where they compete in challenges for reward and immunity. After every challenge, the losing tribe is sent to tribal where one contestant is voted off losing their shot at the million. In this setting, contestants are starving, losing energy, fighting paranoia, and wanting nothing more to become the sole survivor.

Although I can't personally attest to what contestants go through on the show, I would venture that the PhD process is far more exacerbating. This journey has been filled with doubt but also pride, sorrow but also joy, and long stretches of fatigue but also short spurts of energy. There have been times when all I wanted was to give up, the prize of the PhD not worth the amount of time and strenuous effort. But through perseverance and support I get to say that I have accomplished what I sought out to do.

I can honestly say without the support of my advisor I would have left the program a long time ago. Matt, we started the Engineering and Science Education Department (ESED) together with me as your first advisee and I am so fortunate that you came to Clemson and that we got paired together. Your approach, your compassion, your expertise, and your presence have all contributed to helping me throughout this process. I looked forward to anytime I was going to get feedback from you because I knew the feedback that I was going to get was going to be thoughtful and detailed. I looked forward to meeting with you because I knew that I could be honest with you and talk about anything. If life was just kicking me down, we could reorient the meeting to best meet my needs. If I had something unconventional, I wanted to try, we could discuss

these ideas. Having your support and encouragement helped give me the opportunity to complete this journey.

Another big thank you would have to go to my friend Abby who I have leaned on heavily during this process. She has lent an ear, offered her expertise, shared her time, and lifted me up over and over again. Without her support, this road would have been a lonelier one and a bumpier one as well.

I would like to also give a big shout out to my research group TIDES for all of their support over the years offering me feedback and input. A special thanks to Sarah Otterbeck for the help that she provided with coding. Although it won't be a party I would like to attend again anytime soon the Coding Parties I had with Abby and Sarah were instrumental in getting my research to where it is today.

Finally, I would like to thank my participants to without which this research could not have been possible. Thank you for agreeing to participate in the study and for offering your amazing insights. And to my family and friends, thank you for your words of encouragement and emotional support during this time. Unlike survivor where contestants can't call home, I was able to get doses of love when I needed it the most.

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CHAPTER ONE[1]

INTRODUCTION AND MOTIVATION

So, my roommate, she's also taking a calculus class. But in her calculus class, they don't do the learning activity like in the classroom. They have just like an online one. I kind of wish we just had to do the online instead of having to do the paper in class, because I feel like it's just busy work. (Olivia Interview)

Storyline Illustration

Picture this. You are starting your undergraduate degree at the university and sitting in on your first day of Calculus 1. Your teacher walks in with a one-page syllabus. On it, it's listed that homework will be 20% of your grade and exams will be the remaining 80%. There will be no quizzes, no review sheets, and no other assignments. Your teacher then goes immediately into lecturing, filling the board with mathematics material for you to take notes.

Your hand is cramping after every lecture. And your notebook starts to fill up quickly. You know your roommate is also taking Calculus 1 and you ask how it's going for them. They inform you that they watch short lecture videos outside of class and work in groups on activities inside class. Not only that, but exams are also worth 70% of their grade and they have practice exams to study with. But that's not all. Your roommate heard from a peer down the hall that their Calculus 1 class doesn't even have exams. Instead, their class has projects and excessive assignments to complete for their grade.

[1] Author's note: Each chapter we open with a quote from one of our student participants to emphasize their voices in this study. We then follow each excerpt with a storyline illustration to provide the reader a narrative for motivation and context. This storyline illustration of a calculus journey will continue throughout the dissertation.

You contemplate if it's too late to change classes thinking how better your experience might be if you were in another section, one like your roommate or even the peer without exams. You complain how unfair your setup is compared to everyone else's.

Reflective Summary

For courses with multiple sections, it can often be a "wild wild west" situation. If unchecked, instructors can teach the course how they see fit entirely independent from what other sections may be doing, leading students to complain about unfairness. Course coordination is a way to bring stability to these multi-section courses.

In this chapter, we[2] briefly introduce the concept of course coordination and the motivation behind its enactment in undergraduate mathematics courses. We also dive into the motivation of this study which focuses on the student experiences within coordinated mathematics courses. We draw on student math identity as a lens to view student experience and affective success outcomes. In this chapter, we share our prior relevant experience and positionality and conclude with the research questions that will be addressed as part of this dissertation study.

1.1 Calculus 1 Across the United States

There has been a global decline in the number of people pursuing mathematics degrees (Boaler & Greeno, 2000) as well as high failure rates and attrition in Calculus 1 courses (Cavalheiro & Grebot, 2021; Hagman et al., 2017). As such, there have been

[2] While writing I use the plural form "we" to reflect commonly held practices in mathematics; however, this dissertation study and writing is my own work.

concerted efforts to examine introductory mathematics programs to increase the number and success of students in undergraduate mathematics courses. Two of the most prominent national studies examining introductory mathematics courses include Characteristics of Successful Programs in College Calculus (CSPCC) and Progress through Calculus (PtC). From 2009 to 2015, CSPCC conducted a national study of college Calculus 1 courses by the Mathematical Association of America (MAA) and supported by the National Science Foundation (NSF). The CSPCC study was then followed up, from 2015 to 2019, by a second series of national studies of college calculus, Project through Calculus (PtC), also overseen by the MAA and supported by the NSF.

The CSPCC and PtC studies examined ways and efforts of improving student success within the context of introductory math courses. The aims of the CSPCC study were to measure what characteristics of Calculus 1 courses influenced student success in efforts to help improve retention rates for students in Science, Technology, Engineering, and Mathematics (STEM) majors (Bressoud & Rasmussen, 2015). CSPCC identified seven characteristics of successful calculus programs which included:

1. Regular use of local data to guide curricular and structural modifications.
2. Attention to 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.

7. Proactive student support services, including the fostering of student academic and social integration.

The subsequent PtC study set about cataloging departmental efforts in improving student success and documenting the effectiveness of implementation efforts (Rasmussen et al., 2019).

The first phase of the CSPCC study launched a national survey (n=212) to students, instructors, and coordinators in the Fall of 2010. It revealed that Calculus 1 is "extremely efficient at lowering student confidence, enjoyment of mathematics, and desire to continue in a field" in which mathematics is needed (Bressoud & Rasmussen, 2015, p. 144). With Calculus 1 a requirement for many STEM intending students to continue in their program, this is not the sentiment any university wants to hear from their student population. As reported by students, Calculus 1 is successful in lowering their affective beliefs towards mathematics in terms of their confidence, enjoyment, and desire to continue.

The PtC study found similar results in its national survey of mathematics departments (n=223), launched five years after CSPCC. Across the country Calculus 1 is averaging a 22 percent DFW (Drop, Fail, or Withdrawal) rate, ranging from 0-61% across institutions (Rasmussen et al., 2019). Students within these courses are not identifying themselves with mathematics and as such are likely to leave STEM for another field (Calleros & Zahner, 2021; Cobb et al., 2009; Patrick & Borrego, 2016). This exodus is prompting increasing efforts towards recruitment and retention of students (Calleros & Zahner, 2021; Patrick & Borrego, 2016) through the improvement of

introductory math courses (Apkarian et al., 2021; Hagman et al., 2017). With the disparity of DFW rates across institutions it is critical to discover ways to enhance student experiences with mathematics.

For institutions in which multiple sections of the course are offered, course coordination is one such way for institutions to improve their introductory math courses, as identified in CSPCC as one of the characteristics of successful calculus programs.

1.2 Course Coordination and Calculus 1

In the second phase of the CSPCC study with its case studies, particular institutions were chosen due to their student success compared to other universities, reporting improved retention rates and a lower DFW rate than what was seen nationally (Bressoud & Rasmussen, 2015). *Success* in the CSPCC study was based on three outcomes: affect, persistence, and achievement. It should be noted that out of the three notions of success, persistence, in terms of retention, and achievement, in terms of pass rates and final grades, are the most discussed outcomes from this phase (See *1.3 Student Experiences*).

From these case study sites, seven characteristics of successful calculus programs were identified (Bressoud & Rasmussen, 2015). One characteristic of a successful calculus program is coordination of instruction. For institutions in which multiple sections of the course are offered, coordination is a way for departments to introduce and maintain consistency among sections of a course through the reduction of variation of material. This form of consistency can range from common elements such as requiring sections to use the same textbook to requiring students to take the same tests (see Section

2.1.2 A Coordinated System and its Course Coordinator for more information on coordination). Through the establishment of a standardized curriculum, universities can better equip their instructors with resources (Faudree, 2021; Martinez et al., 2022; Rasmussen et al., 2021; Williams et al., 2021).

Coordination also promotes high quality instruction through instructors communicating with each other (Faudree, 2021; Rasmussen & Ellis, 2015). For universities utilizing Graduate Teaching Assistants, coordination can ease their transition into instruction through the accessibility of resources and communities of practice with other seasoned instructors to share pedagogical approaches.

With the characteristics identified from the CSPCC study, the PtC study asked participating institutions to answer how **important** the characteristics identified from the CSPCC study were to having a successful program and how **successful** their programs were with implementing those characteristics on a scale from 'Not', 'Somewhat', and 'Very'. The coordination characteristic was broken into its two features: uniform course components (e.g., common schedule, common grading) and regular meetings of instructors (e.g. weekly, biweekly).

For the whole Precalculus to Calculus 2 sequence of the institutions who answered the question (n=223), 94% of the institutions reported that uniform components were important to a successful program (55% very important; 38% somewhat important) while 79% of the institutions reported that instructor meetings were important to a successful program (27% very; 51% somewhat) (Rasmussen et al., 2019). For Calculus 1, in particular, when asked who coordinates the uniform aspects across sections, 87% of

the courses are coordinated by either an individual person or a team held responsibility for coordinating uniform aspects across sections (Rasmussen et al., 2019). From the PtC data, we can see a trend of universities moving towards coordination nationally as a step towards improving their introductory math courses.

Along with universities adopting and implementing course coordination, they are also employing another characteristic found from the CSPCC study, active learning (Bressoud & Rasmussen, 2015). When asked about their priority of active learning, 91% of the institutions who answered the question reported that active learning was important to a successful program (44% very; 47% somewhat) (Rasmussen et al., 2019). Nationally, institutions are reporting the importance of coordination and active learning for their programs.

When asked how successful their programs were with uniform components, 98% of the institutions who responded to the question reported their program was successful with uniform components (62% very; 35% somewhat) (Rasmussen et al., 2019). The same level of success was not reported for instructor meetings and active learning. When asked how successful their programs were with instructor meetings and active learning, 72% of the institutions who responded to the question reported their program was successful with instructor meetings (22% very; 50% somewhat) and 82% of the institutions who responded to the question reported their program was successful with active learning (15% very; 67% somewhat) (Rasmussen et al., 2019). Out of the reported characteristics, uniform components, instructor meetings, and active learning, uniform components were the only characteristic for which institutions reported similar levels of

importance and success for their programs, leaving room for improvement for both an increase in instructor communication and the implementation of active learning in the classroom.

Through uniform components, coordination establishes *equal* opportunities for students in muti-section courses. Students in a coordinated section of their calculus course can expect to have the same treatment as their peers in any other section. However, not every student is identical and often it is students from nondominant racial, cultural, linguistic, or gender groups who are marginalized from learning opportunities as mathematical spaces are dominated by whiteness and the male superiority myth (Battey & Leyva, 2016; Goffney et al., 2018; Kurth et al., 2002; Leyva, 2017; Martin, 2013).

Calculus 1 attrition is not uniform across demographic groups. Compared to men, women are 50% more likely to leave the calculus sequence (Hagman et al., 2017). "There are longstanding and persistent inequities in STEM related to gender…as women have been positioned as not mathematically capable or fit for doing mathematics due to their gender," (Calleros & Zahner, 2021, p. 106). When it comes to persistence in STEM majors, students are more likely to stay in the Calculus sequence when they are actively engaged and challenged (Apkarian et al., 2021; Williams et al., 2021), active learning activities creating positive impacts for all students, especially for women (Rasmussen et al., 2021).

Coordination can be a mechanism for encouraging and supporting instructors to utilize active learning pedagogy in their classrooms (Rasmussen et al., 2021; Williams et al., 2021). These strategies can also be used towards establishing *equitable* opportunities

by providing necessary support for traditionally marginalized individuals (Apkarian et al., 2021; Murphy et al., 2019). Thus, coordination can facilitate the employment of student-centered pedagogies to bolster student success not just through persistence and achievement but also through their confidence, interest, and enjoyment of mathematics.

1.3 Student Experiences

From the CSPCC study, coordination has been revealed to be a successful characteristic of a calculus program. However, in introductory calculus courses there is little research in mathematics education literature on how a coordinated system affects student experiences (Apkarian et al., 2019) with the first paper formally defining and discussing course coordination appearing in 2015 (Rasmussen & Ellis, 2015).

Subsequent papers have continued to discuss course coordination, such as highlighting common examples of uniform components (Apkarian et al., 2019). Other research has examined the ways and reasons why universities implement coordination (Rasmussen et al., 2021; Williams et al., 2021) and showcase how it can be used to encourage active learning in the classroom (Williams et al., 2021) and provide a justification for initiating regular instructor meetings (Apkarian et al., 2018). In subsequent studies, institutions have shared their experiences with implementing course coordination for their own departments (Apkarian et al., 2018; Bode, 2018; Cavalheiro & Grebot, 2021; Faudree, 2021), explaining the benefits their instructors had from it and the results they saw with their student pass and retention rates.

A common trend among these current studies when discussing course coordination in terms of student experiences within the classroom is the implicit benefits

students receive. Similar to the CSPCC case studies, the focus in these studies is on the success of students' achievement and persistence in STEM. However, attendance to only these success outcomes are insufficient as coordination is not yet achieving equal success among its students from the equal opportunities it creates. As concluded in a study of an undergraduate coordinated inquiry-based linear algebra course, what may be more important to student experiences is how they engage with the material in day-to-day interactions (Mesa et al., 2020). Finding and determining ways to increase students' interest in mathematics and their desire to continue to study math is essential in creating classrooms where all students have opportunities to be successful. Attending to the support of all students and a willingness to adjust programs when necessary is what was common among all the successful calculus programs (Hsu et al., 2014). Student success can't be viewed solely on achievement and persistence, as passing rates alone are not sufficient in determining the problems students are facing in the classroom (Apkarian et al., 2018). To support all students, the experiences they have in the classrooms need to be explored to help in increasing their affective success too.

Understanding student experiences and affective success can be facilitated by examining their mathematical identity. Positive identity formation has been linked to increased STEM participation as well as retention rates (Calleros & Zahner, 2021; Cobb et al., 2009; Patrick & Borrego, 2016) and "interventions designed to support students' identity in math is likely to be beneficial" (Godwin et al., 2016, p. 327).

Identity is how people come to understand who they are and in mathematical learning spaces, claims of belonging and achievement position students as learners and

doers of mathematics, contributing to their overall mathematical identity. Women tend to have lower estimates than men for seeing themselves as a 'math person' (Godwin et al., 2016). When experiencing an incompatibility between their gendered identity and STEM identity, women have heightened stress, negative achievement expectations, doubts towards their ability to perform, and report lower performance even when they tend to perform better than men (Ancis & Phillips, 1996; Rosenthal et al., 2011).

By distinguishing certain classroom structures that aid in the formation of positive STEM identity (Calleros & Zahner, 2021), identity theories can be drawn upon to attend to the missing gaps in the existing research on coordinated systems.

There has been an increase in research on mathematics identity in recent years as positive identity formation has been correlated with pursuing STEM majors and careers (Bieri Buschor et al., 2014; Calleros & Zahner, 2021; J. Cribbs et al., 2021). With the influence of a positive mathematical identity on students' persistence and engagement in mathematics, identity can be an important tool for making sense and understanding ways a coordinated system can best position students. Together, through the analysis of identity, a coordinated approach can help to promote equity in the classroom (Cobb et al., 2009; J. Cribbs et al., 2021; Darragh, 2016).

1.4 Prior Relevant Experience and Positionality

I've always gravitated towards mathematics, it being my favorite subject in school and the major I pursued for both my bachelor's and master's. I described to people that my reasoning was because math came easy to me. Where other people may have struggled, the topics introduced made sense. I excelled in my classes and my

mathematical ability was consistently recognized and affirmed by others—even when I began to doubt myself in graduate school. I felt like I belonged in math and this sentiment was often reaffirmed by everyone else. By being a white, cis-gender man, I was positioned more than my peers to be naturally gifted and inclined towards understanding mathematics.

In high school, when the teacher announced there would not be a curve on the exam because someone scored a hundred, the class assumed I was the one to do so. I confessed I scored a B and that actually it was my friend, a cisgender woman, who was the one to ace the test. Similarly, in undergrad calculus, my friend, a cisgender woman, and I were working together in class when the teacher, a white cisgender man, accused her of getting too much help from me, implying I was the driving force behind our work.

I provide these two examples to illustrate how people, students, and instructors alike, can position others during everyday interactions. As a student, and later, as an instructor, I had always been frustrated with the phrase "I'm not a math person" as I thought it was often used as a justification for not understanding a topic and/or a lack of desire in pursuing mathematics further. Upon reflection, I realize and understand that not everyone has had the privileges I have had to be positively positioned with respect to mathematics.

As I mentioned previously, I am a white, cisgendered man. I come from a middle-class family with both parents having a master's degree and the schools I attended were well funded and staffed. I attended the local college down the street and stayed home for undergrad, saving money and stress. When it came to school, I had the luxury of time and

energy for my studies. I did not require anything to be flexible or accommodating and many of my courses, if not all, were set to be this way. As a student in my position, this wasn't an issue for me.

When I first started teaching as a Graduate Teacher of Record (GTR), I began to understand how equity in students' access to mathematical ideas could be an issue for some students. I have taught coordinated systems which included common homework, common exam nights for tests and final, common grading, and common syllabus and schedule. If the coordinated course was a neighborhood, the welcome sign would be "Welcome to Calculus Where Everything is Fair."

As a first-time instructor, I appreciated the number of resources I had available and the lesson plans that were already made. However, I started to notice that the students were not always getting the support they needed and that the system to provide consistency and fairness across the multiple sections seemed to present an unfair advantage for the students strongly identified in math. Instead of helping students be successful by providing access to the same resources, the coordinated system I taught seemed to be rewarding students who were already strongly associated with mathematics as they were the ones who did well on tests—a whopping 80% worth of their grade. Students were graded the same but had no other opportunity to demonstrate their learning nor to improve their grade, conflating "I'm not a good test taker" to "I'm not a math person," and I had no agency to intervene.

I have now taught for five years now procuring a job as a Lecturer for the School of Mathematical and Statistical Sciences in 2022. I was hired to teach the math education

classes and am essentially a coordinator of these sections. As a Lecturer for these courses, I have the agency that I was lacking as a GTR, an exciting, but also intimidating position to be in. The students I teach, mostly cisgender women, will be future elementary teachers. Many of them come into the class having a strong hatred of mathematics. Their relationship with math is something I want to change and strengthen.

A driving force behind this study is to learn what aspects of course coordination influence students' experience and how these experiences impact their math identity. As my advisor has said, “you are a math person, just not yet.”

Through my prior experiences, this study will aid in determining how a coordinated system can be used to cultivate and strengthen students’ mathematics identity by encouraging equitable practices.

1.5 Research Questions

With the history of mathematical spaces and curriculum being dominated by white cisgender men and excluding other voices, such as women (Burton, 1990; Heybach & Pickup, 2017; Joseph, 1987; Leyva, 2017; Martin, 2013), the focus of this study will be women and gender fluid students to understand how course coordination can better support them and to understand how issues of equity and equality are interwoven in course coordinated systems. As such, this qualitative dissertation study aims to answer the following research questions:

Research Question 1: What coordinated and uncoordinated course aspects influence student experiences?

Research Question 2: How do the experiences within a coordinated math course impact women and gender fluid students' math identity?

1.6 Roadmap to the Manuscript

CHAPTER TWO LITERATURE REVIEW AND THEORETICAL FRAMEWORK dives into further details about the research on course coordination introduced in this chapter. In chapter two, we provide additional description of when course coordination was first studied and how it has been researched in subsequent studies. Presenting the literature review we also identify gaps in the existing literature. Along with literature review on course coordination, we also cover synopsis of mathematics identity and the theoretical framework situating the study, positioning theory.

CHAPTER THREE RESEARCH METHODS AND STUDY DESIGN describes the research methods for the dissertation study. In this chapter, we share our reasoning behind conducting qualitive research and why we choose to make use of a multiple case study approach with a phenomenological lens for our methods. We further discuss details about our pilot project, our data sources and data collection, and the analysis of the data.

CHAPTER FOUR RESULTS shares the major findings from the data. We share out the six themes for what aspects of course coordination influence student experiences. After we present the themes, we then discuss how the experiences within a coordinated math course impact women and gender fluid students' math identity by sharing three case studies for participants whose mathematical macro-identities changed from the start of the semester.

CHAPTER FIVE DISCUSSION AND IMPLICATIONS we discuss the need to rehumanize mathematics especially in coordinated systems in which issues of equity are not addressed. For this process, we provide recommendations for course coordinators to consider implementing in their design of a coordinated system.

CHAPTER SIX CONCLUSIONS we discuss the limitations of the study and then follow it with future directions that can be taken with this research.

CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Not, really. It's been very neutral in terms of that. Everyone's treated the same. Everyone has the same opportunities, you know. (Aves Interview, responding to the question, "Do you feel there was anything unfair at all?")

Storyline Illustration

Picture this. You have dropped your Calculus 1 course and are now taking it the following semester. This time around, your university has implemented a coordinated system to establish consistency across all sections of Calculus 1. Now all instructors must adhere to the same course calendar and syllabus. You have been informed that all students taking Calculus 1 will work on the same assignments, take the same exams, and be subjugated to the same grading policy.

Better yet, you're told that there is a collection of resources, old exams and practice quizzes, that you will be able to use to study, just like your roommate had for their section. You are happy to hear that everyone will be on the same playing field. You believe this semester will be your semester.

A few weeks pass by, and it is getting close to exam time. You end up in a car accident the day of the exam. Because of your injuries you must spend a few days in the hospital. You email your instructor about making up your exam. However, by the time you are released the make-up window for the exam has closed. You are told not to worry. The final exam can replace your lowest test score.

Because of the accident you must wear a cast on your writing hand for the next few weeks which makes it difficult for you to complete your assignments. You start to miss submitting the assignments on time because of how long it's taking you to complete them. You ask for an extension and are told that the three lowest assignments will be dropped and that these will have to be the ones that get dropped according to course policies.

You express your frustration of this decision, and your instructor informs you that if they made an exception for you, they would have to do it for everyone else to keep things "fair". Once again, you find yourself complaining about how unfair the setup is for you as not everyone has been in a car accident like yourself.

Reflective Summary

Course coordination has tamed the "wild wild west" bringing in pillars of stability and equality. But how fair is a system that may not meet the needs of individual students?

In this chapter, we dive into further details about research on course coordination providing a description of when it has been first studied, how it has been researched in subsequent studies, and we identify gaps in the existing literature. We also cover a synopsis of mathematics identity and the theoretical framework, positioning theory, that will be used to situate the study.

2.1 Course Coordination Literature and Research Studies

2.1.1 Course Coordination First Studied

Course coordination was first studied by Rasmussen & Ellis (2015) when examining it in the context of calculus coordination at PhD granting universities across the United States. Part of a larger study, referred to as the Characteristics of Successful Programs in College Calculus (CSPCC), this study was a national study that identified five universities as having successful calculus programs and a well-established system of course coordination. The five PhD granting universities examined within the study contained varying characteristics, such as private or public university, class size, class schedule, and the number of common exams and quizzes. The research utilized case study methodology with interviews being conducted among instructors, administrators, and students.

As identified by the original CSPCC study, universities shared a goal in wanting to reduce variation across sections of courses by providing consistent material for students in the way members of the university deemed fit (Rasmussen & Ellis, 2015), prompting them in moving towards course coordination.

Rasmussen & Ellis (2015) identified two shared features of a coordinated calculus system, *uniform course elements* and *regular instructor communication*. Uniform course elements are elements of a course that are the same for every student across all sections of a coordinated course (e.g., textbook, topics, pacing, homework, tests, grading). Regular instructor communication is an opportunity for instructors to frequently contact

each other to discuss aspects of the course and to offer support to one another as a community of instructors.

2.1.2 A Coordinated System and its Course Coordinator

When both features are present, uniform course elements and regular instructor communication, then we have a coordinated system (Rasmussen & Ellis, 2015). Moving forward in this study, we draw on Rasmussen and Ellis's definition of course coordination as defined below.

Definition: Course Coordination
A system arranged around multi-section courses consisting of uniform course elements and regular instructor communication. Both must be present in promoting uniformity in a coordinated system.

A key stakeholder facilitating a coordinated system, is the *course coordinator* (Apkarian et al., 2021; Rasmussen & Ellis, 2015; Williams et al., 2021) whose main responsibilities may include structuring uniform elements of a course as well as interacting and communicating with instructors. Course coordinators typically plan, design, and oversee the aspects of a multi-section course. In many ways, the course coordinator functions similarly to an architect planning the construction of a building to provide a blueprint and communicating with the builders on the project, who are the instructors of the course. Through their decisions, coordinators can influence instructors to make a desired choice by nudging "faculty in certain directions regarding what content gets emphasized and assessed" (Rasmussen & Ellis, 2015, p. 113). Nudging could be

done by setting default options in their designs and/or providing information about what others are doing (Rasmussen & Ellis, 2015). Because of this power, Rasmussen and Ellis also refer to course coordinators as *choice architects* (Rasmussen & Ellis, 2015).

Definition: Course Coordinator
Facilitating a coordinated system is the course coordinator. Also, referred to as the choice architect, a course coordinator plans, designs, and oversees the aspects of a multi-section course through potentially structuring uniform elements of a course and interacting with a community of instructors.

A choice architect may approach coordination from two different orientations, Humanistic-Growth and a Resource-Managerial (Martinez et al., 2022). In a Humanistic-Growth Orientation, personal and professional growth of instructors teaching is attended to while for a Resource-Managerial Orientation, knowledge, and skills, as well as their delivery, is leveraged (Martinez et al., 2022). These orientations are not permanent and not mutually exclusive but highlight how a coordinator's orientation may influence their actions, such as nudging instructors.

2.1.3 Course Coordination, Choice Architect's Orientation, and Active Learning

Given the role of course coordination to influence the design and implementation of high-quality instruction for students, researchers have studied the role of course coordination in promoting active learning (Milbourne, 2018; Williams et al., 2021). In a study examining course coordinators as agents of change in instructional practices, which drew on 12 interviews with key stakeholders (e.g., course instructors, coordinators,

department chairs, administrators, students, etc.) and three classroom observations for each site, qualitative analysis was done to focus on "identifying strategies for successfully implementing and sustaining active learning" (Williams et al., 2021, p. 11). Data were drawn from a larger study, Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL)[3], choosing five public universities in the United States with high research activity and well-established systems of course coordination. The authors determined that coordinators could nudge instructors towards adopting active learning in their pedagogical approaches "by creating course materials that lend themselves to active learning" (Williams et al., 2021, p. 4) and by initiating and promoting conversations during instructor meetings (Williams et al., 2021).

One of the reasons to examine the link between course coordination and active learning in the active learning study is based on past research that has demonstrated the potential benefits of active learning for the development of students' math identity (Calleros & Zahner, 2021) (see *Section 2.2 Mathematics Identity Research Motivation and Contexts*) and more equitable assessment outcomes (Williams et al., 2021). The study demonstrated how coordination can be a vehicle of change towards active learning. However, what has not been studied explicitly is how coordination can be a vehicle of change toward equitable practices.

[3] During the same period as PtC, from 2016 to 2019, the Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL) project wanted to understand and foster systematic change in mathematics departments and promote active learning in introductory mathematics courses. Universities for this project (n=9) were selected from the PtC data.

2.1.4 Course Coordination in Other Studies

This initial conceptualization of course coordination has been taken up in subsequent studies as the emergence of research on course coordination has grown (Apkarian et al., 2021; Bode, 2018; Hagman et al., 2017; Mesa et al., 2020; Williams et al., 2021).

Building off the CSPCC study, a subsequent mixed-methods study was conducted investigating Precalculus to Calculus 2 programs across the country, referred to as Progress through Calculus (PtC). The first phase of the PtC study drew on survey responses of 889 courses from 223 of the 330 university departments offering a master's or Ph.D. degree in mathematics in the United States. The survey asked details about calculus programs, specific course details, and what elements were uniform across sections for each introductory math course. Hierarchical cluster analysis was then used to identify eleven homogenous clusters based on the intended use of uniform elements across sections (Apkarian et al., 2019). These clusters were then nested within five larger groups of the reported courses (See Table 2.1), being characterized further with respect to department type, PhD or MA/MS, and by course level, Precalculus, Calculus, or Calculus 2 (Apkarian et al., 2019).

Table 2.1 Hierarchical Cluster Analysis Groupings: Groups Formed from the Hierarchical Cluster Analysis Along with the Uniform Elements Common Within Each Group and the Percentage of Courses from the Study that Fall in those Groups.

Group	Highlighted Uniform Elements	%
A	None	11
B	Textbook	1.5
C	Textbook, Topics, Final Exam, Grading (Course)	30
D	Textbook, Topics, Pacing	16.5
E	Textbook, Topics	41

Note: N=889

Based on the cluster analysis performed in this study, 11% of courses surveyed had no uniform elements (Group A), while 89% had at least one element coordinated (Apkarian et al., 2019). The most common cluster of uniform elements (Group E), 41% of the reported courses, utilized a common textbook and topics. Regular instructor meetings were rare in Group E. Given the amount and complexity of uniform elements, instructor communication may not need to be utilized as much to ensure uniformity within these types of coordinated systems. The group that reported having the most instructor meetings was Group C, 30% of the reported courses. Group C saw the most uniform elements of any group besides Group D. Regular instructor meetings ensured uniformity in instruction and implementation of these elements across the sections. The hierarchical cluster analysis study demonstrated the extent to how course elements varied between universities and how there is no distinct set of uniform elements that universities are currently implementing.

Providing consistency across course sections has been studied elsewhere in undergraduate mathematics education, although sometimes referred to as “course unification” (Cavalheiro & Grebot, 2021). In one particular study at a Brazilian federal

university, pass rates before and after course unification were compared. For course unification, multi-section courses were coordinated by having the same weekly schedule, operating under the same syllabus, and utilizing common assessments (Cavalheiro & Grebot, 2021). There was no statistically significant difference in pass rates between the two periods, prior to the unification and after the unification. However, there was greater homogeneity in the pass rates for each of the sections (Cavalheiro & Grebot, 2021). From the course unification, the study saw that the distribution of students who passed the course was more evenly—and equally—spread among the sections instead of pass rates being concentrated to only a few sections. Along with pass rates among the sections of Calculus 1 being distributed more evenly, unification also provided information moving forward in determining what calculus concepts needed to be targeted to support and benefit students with their learning and development.

As part of the course unification, high-quality instruction was also professionally developed through scheduled interactions among instructors to discuss content of the course and adequate actions such as implementing student centered teaching practices (Cavalheiro & Grebot, 2021). The original CSPCC research study also identified the promotion of high-quality instruction as a characteristic of successful calculus programs. Providing materials for instructors wasn't enough to generate change in instructional practices (Henderson et al., 2011). With students leaving STEM fields due to ineffective teaching methods (Apkarian et al., 2021; Boaler & Greeno, 2000; Hagman et al., 2017), effective instructor regular communication can help ensure a positive community of

instructors (Apkarian et al., 2018; Williams et al., 2021) in order to serve students (Cavalheiro & Grebot, 2021).

2.1.5 Gaps in the Course Coordination Literature

Past studies have stressed the importance of consistency across sections brought by course coordination (Apkarian et al., 2019; Cavalheiro & Grebot, 2021; Faudree, 2021; Rasmussen et al., 2021; Rasmussen & Ellis, 2015). Uniform elements are implemented to give students similar opportunities to their peers, allow for consistent assessment, and address concern over fairness (Apkarian et al., 2019), **all related to equality and not equity** which they have been improperly referred to in the past (Faudree, 2021; Rasmussen et al., 2021). To be uniform is mostly defined as being the same, meaning students are experiencing equal treatment. **Often this equal treatment does not mutually support all students** (Apkarian et al., 2021) as Calculus 1 attrition is not uniform across demographic groups. For instance, women are 50% more likely than men to leave the calculus sequence (Hagman et al., 2017). Regardless of a student's needs, a system based on equality treats that student the same as everyone else.

In contrast, with an equitable lens, students are provided with what they need to be successful. As a vehicle of change, course coordination can take action to make a difference to marginalized groups (Apkarian et al., 2021). By incorporating professional development through regular instructor communications, course coordinators can integrate these support systems into their courses and/or educate instructors "about topics such as stereotype threat or inclusive teaching" (Apkarian et al., 2021, p. 23). Stereotype threat presents issues of inequities such as for achievement on standardized tests (Langer-

Osuna & Esmonde, 2017; McGee, 2016; Nosek et al., 2002). Course coordinators can contribute further by providing multiple opportunities to revise and submit work for evaluation, creating specialized differences in curricular experiences, and/or creating multiple options for knowledge acquisition (Hagman et al., 2017), to use their power to promote equitable practices in coordination.

Another missing aspect in this research of course coordination is the student perspective. Prior research has identified what course coordination is (Rasmussen et al., 2021; Rasmussen & Ellis, 2015) and what course coordinators do (Rasmussen et al., 2021; Rasmussen & Ellis, 2015; Williams et al., 2021), especially with relation to instructors. Yet, none of the prior studies have centrally drawn on data from students related to course coordination. For instance, in Rasmussen and Ellis (2015), 92 interviews from instructors, administrators, and students were collected but no material from students was reported. Similarly, Williams and colleagues (2021) study of course coordination reported 12 interviews with key stakeholders (e.g., course instructors, coordinators, department chairs, administrators, students, etc.) were conducted but only excerpts from coordinators were included in the paper. Students were also left out in the narrative within the theoretical framework section when referring to *people* as only instructors and coordinators (Williams et al., 2021).

Williams and colleagues (2021) also created a diagram of focal interactions, mapping the participants, course coordinator(s), instructors, and students, in a coordinated system and their interactions (see **Error! Reference source not found.**.1). T he diagram of interactions consists of multiple embedded instructional triangles. In the

inner triangle, are the instructors, the course coordinator(s), and the course content. It is this inner triangle that is the focus of the study. The outer triangles, connecting the course content and instructors to the students, are not discussed fully as this part of the diagram represents how the "core work permeates to the coordinated classes" (Williams et al., 2021, p. 5).

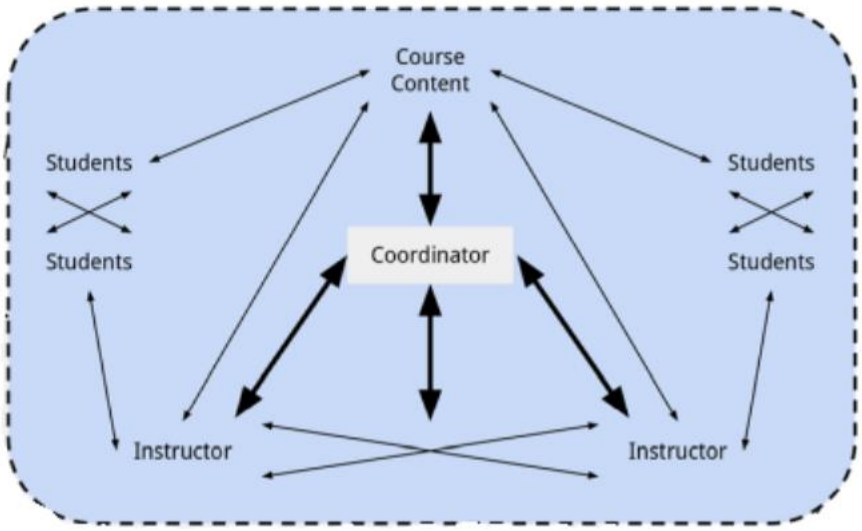

Figure 2.1 Diagram of interactions related to instruction between stakeholders of coordinators, instructors, and students.

How coordination relates to content and instructors is a recurring focus in current studies. We see in detail how coordination benefits instructors (Faudree, 2021; Martinez et al., 2022; Rasmussen et al., 2021; Rasmussen & Ellis, 2015; Williams et al., 2021) as well as how authors have discussed the benefits to students, but this benefit is often left implicit, typically examined in the terms of DFW rates, and not directly measured and explored (Mesa et al., 2020). DFW rates are often the lens chosen to view student success and test the effectiveness of course coordination (Bode, 2018; Cavalheiro & Grebot, 2021; Faudree, 2021). However, passing rates do not identify the root causes of the

problems students are facing (Apkarian et al., 2018) which is why it is important to attend to the motivating factors behind students' beliefs and experiences in these undergraduate mathematics courses.

We have seen how a coordinated system can build support for a community of instructors. In this current study, we examine how it can do the same for its students.

2.2 Mathematics Identity Research Motivation and Contexts

Researchers are utilizing identity theories to understand students' participation in mathematics lessons (Wood, 2013) as identity has been connected to students' persistence and engagement (Boaler & Greeno, 2000; Cobb et al., 2009; Cribbs et al., 2021; Langer-Osuna & Esmonde, 2017). In a national study surveying approximately 11,000 students across 336 college calculus classes in the United States, to determine the extent to which mathematics identity predicts students' career intentions in mathematics-related fields, results indicated that a stronger mathematics identity predicts higher student interest in pursuing certain STEM careers (Cribbs et al., 2021). Results also indicated that mathematics identity is a positive predictor for other STEM fields that are commonly perceived as being math intensive (Cribbs et al., 2021). In particular, women students are more likely to choose STEM careers when they develop an identity in STEM early in academia (Bieri Buschor et al., 2014).

Due to mathematics identity being positively correlated to students' persistence, engagement, and motivation, there has been an "explosion of research" in recent years (Darragh, 2016, p. 1). In a review of 188 mathematics identity articles (Darragh, 2016) and engineering identity articles (Patrick & Borrego, 2016), most studies opted to utilize

qualitative methods. In alignment with these studies, this dissertation study will do the same.

In the review of past studies, a similar consistency for the definition of mathematics identity was not seen (Cobb et al., 2009; Darragh, 2016; Patrick & Borrego, 2016). In another review of mathematics identity literature, Langer-Osuna and Esmonde (2017) expressed difficulty in being able to synthesize their findings of research on identity due to literature either not defining identity or defining identity vaguely. Since these scholars have pointed out that there is a gap in the literature when it comes to defining mathematics identity, we take the time to define it for this study here inspired by Langer-Osuna & Esmonde (2017) and Urrieta (2007).

Definition: Mathematics Identity
Identity is how people understand who they are. Identity is constructed through interactions with others whether through associated claims made by others and/or the individual themselves. In a mathematical learning space, claims of belonging and achievement position individuals as learners and doers of mathematics, contributing to what we refer to as their mathematical identity.

Mathematics identity in education research has been primarily drawn from four theoretical perspectives which include poststructural, positioning, narrative, or psychoanalytic (Darragh, 2016; Langer-Osuna & Esmonde, 2017). In North American math education literature, sociocultural approaches to identity are by far the most common (Langer-Osuna & Esmonde, 2017). For this study, we will be examining

identity through the lens of the positioning theoretical approach which is detailed in Section 2.3 Theoretical Framework.

2.3 Theoretical Framework

2.3.1 Synopsis of Positioning Theory

The concept of positioning emerges from feminist works developed as a tool for research into "gendered differentiated positions in discourses" (Hollway, 1984, p. 67). *Positioning* is the process in which an individual is assigned positions by others, such as their peers or instructors, or by assigning positions personally to themselves (Kayı-Aydar, 2019). In Holloway's study, the conception of power for women in social relations of a heterosexual relationship was examined through feminist lens, such as how women may be positioned as objects or subjects, and how these meanings, such as femininity and weakness, are the product of dominant sexist discourses in a patriarchal culture (Hollway, 1984).

Branching out from poststructuralism, Davies and Harré made a proposal to transition from the use of role to position to study people capitalizing on the concept of positioning (Davies & Harre, 1990). *Roles* are a function that people carry out, such as being a teacher or a student. Roles are more stable and long lasting and can affect the ways individuals position themselves and others. Unlike roles, *positions* are fluid, situation specific, and ephemeral, emerging out of social contexts and conversations. A student can be positioned as a *mathematical explainer* during a group activity or even as a *menial worker* in the same activity but at a different point in time (Wood, 2013). Roles

are the mechanism for which positions may be ascribed and assigned and consequently challenged, negotiated, accepted, and disputed.

From their earlier work, positioning theory has emerged (Harré & Valsiner, 2012; Kayı-Aydar, 2019; Rochette et al., 2020), being used commonly to analyze political activity (Harre et al., 2009). Positioning theory investigates what positions are ascribed to individuals and then how these individuals react to the positions allotted to them. It is only recently, positioning identity is being discussed in depth and grown by mathematics education researchers (Anderson, 2009; Esmonde & Langer-Osuna, 2013; Herbel-Eisenmann et al., 2015). In the mathematics classroom, positioning theory can be used to examine what people are doing and saying in exchanges with each other (Kayı-Aydar, 2019). Within these interactions, individuals construct meaning through their actions or speech (Anderson, 2009; Mcvee, 2011; Rochette et al., 2020) as they claim, take up, or deny the rights, duties, and obligations distributed among them.

For an individual, *rights* are what people must do for that individual; *duties* are what they must do for others. Storylines refer to a narrative of moments knitted together. For example, in the storyline involving an instructor and student, we are looking at the broad overview of the classroom relationship between them. For a mathematics lesson, instructors can position students as having a *duty* to complete their assignments. Instructors may also position students as having a *right* to ask for help and work together. However, instructors may also position students as not having a right to copy each other's work. For this storyline, and others that may emerge, positioning is how these rights, duties, and obligations are distributed in social interactions.

2.3.2 Mathematics Identity and the Positioning Perspective

Through interacting with others, an individual can position themselves as "displaying certain qualities or as having a particular role" (Langer-Osuna & Esmonde, 2017, p. 639).

For example, here is an illustrative example of how this may play out in a classroom. Whenever there is a group activity, Luisa, takes on the role of a mathematical explainer. She prescribes this position onto herself as she is the first one to help her classmates work through the problems. However, if Camillo says something along the lines of "I don't want you to tell me the answers," then he is contesting the position of Luisa as a mathematical explainer. Instead, positioning her as something else. If Camillo says something along the lines of "you're really good at explaining this Luisa," then he would be reaffirming her position as a mathematical explainer.

Positioning theory considers two types of identities: micro- and macro-identities. *Micro-identities* are the positions of a person in a moment of time (Langer-Osuna & Esmonde, 2017; Wood, 2013) as seen in the group activity example with Luisa. These differ from *macro-identities* which are more stable, established identities such as "being a math person is a persistent part of how someone sees" themselves (Wood, 2013, p. 776). A limitation of macro-identities is the assumption that identity is constant over time. In a mathematics learning space, identities can shift in a single lesson with a student feeling capable one moment and incapable the next. Macro-identities miss the intricacies of exploring these differences in identities that can arise within these smaller moments of time.

2.3.3 Mathematics Identity Studies with Positioning Theory

By also considering micro-identities, positioning theory can be used to examine issues of equity in cooperative mathematics learning (Esmonde, 2009) and to advocate for equitable teaching practices as well (Gutiérrez, 2009). Positional perspectives provide a lens to conduct research into equitable and productive mathematics learning spaces.

For an example of this, consider the study by Boaler & Greeno (2000) in which they interviewed 48 high school students and asked them to describe their AP calculus courses from six Northern Californian high schools. Interviews were semi-structured, and students were asked to describe mathematics lessons and their mathematical confidence (Boaler & Greeno, 2000). For four of the six schools the mathematical learning spaces were described as highly ritualized and procedural. In these schools, students would attend class where the teacher would demonstrate procedures for the students to then practice and reproduce, offering very limited positions for students to accept. In contrast, students from the remaining two schools described their math lessons as being more discussion based, spending time discussing questions as a class and as groups. The differences between learning spaces, and the opportunities provided, had a significant impact on how students positioned themselves as learners (Boaler & Greeno, 2000).

In the discussion-oriented classes of the Boaler and Greeno study (2000), students were active agents, working with each other when constructing understanding (Talbert & McLaughlin, 1999). Students reported the opportunity to discuss their work, gaining deeper insights into the mathematics (Boaler & Greeno, 2000). These affordances allowed students to position themselves or others as creative, verbal, and resourceful,

learners and doers of mathematics. For students in ritualized classes, they did not prioritize ability or effort; success was based solely on catering to a particular form of knowing (Boaler & Greeno, 2000). Students were positioned by their instructors as doers of mathematics, however, in the sense of being able to execute what had been presented—and not all students were able to reaffirm this position. If students could not do so, then they would reposition themselves as incapable of doing mathematics successfully.

The procedural classroom is popular within many higher-level math classes as the dominate mathematical learning space (Boaler & Greeno, 2000). Studies have found that these environments tend to lead to an underrepresentation of women at high levels as women are particularly likely to reject subjects that styme opportunity for deep understanding (Becker, 1995; Burton, 1995). This can be seen in Boaler and Greeno (2000), as nine girls rejected mathematics (compared to five boys) in the four didactic classrooms, slightly over 50% of the girls and 30% of the boys interviewed from those schools. When rejecting mathematics, students did not talk about their inability to do the math but their desire to pursue subjects offering "expression, interpretation, and agency" (Boaler & Greeno, 2000, p. 187). Their rejection of mathematics supports the findings of identity being connected to students' persistence and engagement in mathematics. To prevent this rejection, attendance of both students' macro- and micro- identities are critical.

Boaler and Greeno's study (2000) focused overall on students' macro-identities, as students described their experiences in their classes as a whole. In doing so,

"participants may have dismissed moments that contradicted their macro-identities" (Wood, 2013, p. 777). For example, a creative student in a ritualized classroom may have ignored a time when there was a question asked to the class asking for personal definitions of a concept. By focusing on macro-identities, variations in students' identities are missed and left out through participation in mathematical activities as well as the teaching practices and/or activities that may have contributed to those micro-identities.

In a similar vein, examining two different mathematical classrooms, Cobb & Hodge (2009) analyzed the identities students developed by eleven eighth-grade students enrolled in both a statistical design analysis course with a design experiment form of instruction, and an algebra class with a more traditional approach. Forty-one group interviews were conducted to capture their interpretations of each mathematical learning space. The study determined two ways in which learning was valued; either extrinsically (such as DFW rates) or intrinsically (relationships, experiences of mastery) (Cobb et al., 2009).

Students based their success in the algebra class on the merit of grades they received from the teacher with only four describing themselves as being successful. In particular, of these four students who viewed themselves as successful, all three Caucasian students of the participants were included (Cobb et al., 2009). As we saw in the Boaler and Greeno (2000) study, the students who are positioned as mathematically competent in these types of courses are the students who typically dominate these fields, white men. We see that the positions available to students in these types of courses

exclude positioning opportunities for all students. Compared to the design experiment class, all eleven students viewed themselves as successful, success based on students' ability to contribute to class discussions in relatively substantial ways, with one student even expressing feeling equal among their classmates (Cobb et al., 2009). Through the classroom activities, students were able to develop their mathematical identities by accepting and reaffirming positions provided to them as learners and doers of mathematics. However, this study doesn't explore how the differences in classroom activities connect to these differences in identities (Wood, 2013).

2.3.4 The Positioning Triangle

Guiding the analysis of positioning theory is the positioning triangle (Baker & Green, 2011; Harré & Valsiner, 2012; Kayı-Aydar, 2019; Mcvee, 2011; Rochette et al., 2020) a new addition to Davies and Harré's original proposal. The three vertices mutually influence and shape one another as a social episode unfolds. The three vertices are: positions (rights and duties), storylines, and communication acts (see Figure 2.2).

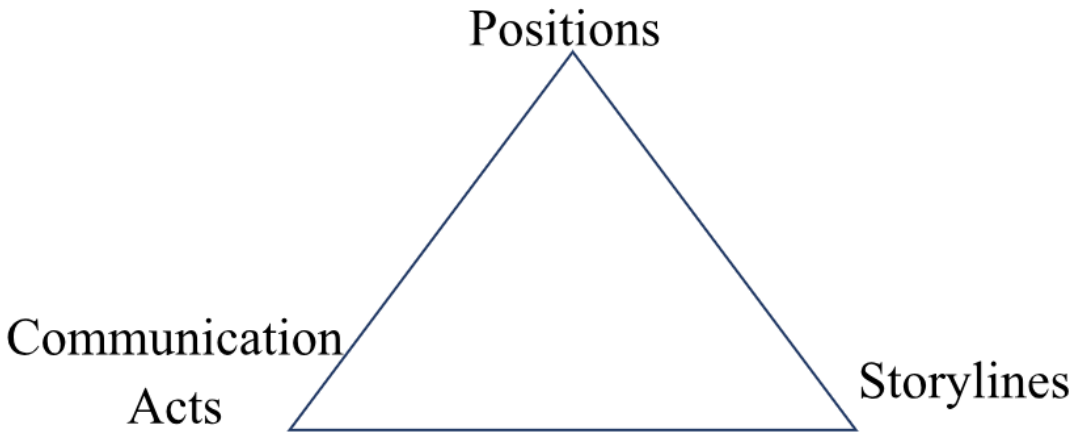

Figure 2.2 The Positioning Triangle consists of three vertices that together guide the analysis of positioning theory.

A critique of positioning theory has been that one component of the theory is used to represent the whole theory (Herbel-Eisenmann et al., 2015). Positions are typically the focus of studies, leaving out important considerations (Baker & Green, 2011). Communication acts refer to speech, both verbal and non-verbal, and paralinguistic aspects, such as gestures and stances. In the past, this vertex used to be referred to as speech acts, with positioning being viewed as only a conversational phenomenon (Davies & Harre, 1990), but has been updated to reflect nonverbal components (Kayı-Aydar, 2019). One means of "revealing" the position within an interaction is by attending to communication acts (Mcvee, 2011, p. 6). Storylines are the episodes created through communication acts and positions and it's through storylines that themes, such as implications for equitable practices, can emerge. Positioning theory will be leveraged to a greater extent during the study design and data collection portion but leveraged less directly for the analysis part.

2.3.5 Storylines

Researchers who are familiar with figured worlds will see similarities to storylines in the sense that both are socially and culturally constructed realms of interpretation (Holland et al. 1998). Researchers employing figured worlds, have leveraged positioning theory in understanding positioning and students' mathematics identity (Esmonde & Langer-Osuna, 2013; Herbel-Eisenmann et al., 2015; Holland et al. 1998; Urrieta, 2007; Voigt et al., 2021; Wood, 2013). Similar to the framework of figured worlds, researchers can use storylines to interpret how students' mathematical identity

can be repositioned through different classroom activities and practices (Voigt et al., 2021; Wood, 2013).

The intricacies of classroom interaction are what distinguish storylines from narrative identities (Langer-Osuna & Esmonde, 2017) as well as its definition for identity. For the narrative theoretical perspective, identities are explicitly defined as stories which do not align with the definition of mathematics identity posed for this study. Moreover, these reported stories are told broadly by narrators and are only "meaningful to the person telling the story" (Langer-Osuna & Esmonde, 2017, p. 641). In positional approaches, storylines better capture the detail of local interactions allowing researchers to examine the construction of identity during these moments as well as how these interactions are organized through means of power allotted through features of a coordinated system.

2.3.6 Positioning Theory Illustration

To help illustrate some of the concepts being introduced in this section, examples from Wood (2013) will be employed. Wood (2013) used positioning theory to examine the identities of one fourth-grade student during lessons in a mathematics classroom. They wanted to capture the identities within a lesson as mathematical identities can shift and vary from moment to moment (Wood, 2013). The qualitative study explored the interactions between one group of students during a single mathematics lesson. This group was selected because it contained clear evidence of learning and it provided a wide range of micro-identities (Wood, 2013). Micro-identities are the positions of a person in a

moment of time (Langer-Osuna & Esmonde, 2017; Wood, 2013) and macro-identities are more stable, established identities.

The focal student, Jakeel, was specifically chosen due to the stark difference in his self-reported macro-identity and the teachers' described macro-identity. Jakeel described himself as smart in mathematics whereas the teaching staff reported that he struggled. In the following examples, we can see the level of detail positioning theory affords as we see three storylines develop: a storyline of inquiry, a lesson storyline, and a storyline of subservience.

In the storyline of inquiry, Jakeel's teacher produced this storyline by asking him to explain his solution, positioning Jakeel as a mathematical explainer through their verbal request. With positions, students have the agency to challenge or accept their positioning and we see that Jakeel takes on and embraces the position given to him, contributing to an identity of mathematical capability, as he discusses his process and explains his solution to the teacher and his group, communicating his affirmation of the storyline.

In the lesson storyline, a member of Jakeel's group, Daren, took on the role of a teacher to give Jakeel a lesson, positioning Jakeel as a mathematical student. As in the previous storyline, Jakeel accepted this positioning, indicated by the fact that he watched and listened to Daren, even asking Daren to explain, and inserting his own mathematical interpretations. In these two storylines, we see Jakeel with micro-identities of being mathematically capable.

In the storyline of subservience, however, we see Jakeel being identified as mathematically incapable. Another member of his group, Rebecca, took on the role of a supervisor with Jakeel as the menial worker. In this storyline, Jakeel needed to follow her directions, producing the steps she dictated to reach her ideal final product. This storyline involved minimal engagement with mathematics as Rebecca positioned him as mathematically incompetent.

Initially and consistently, Jakeel rejected her storyline and positioning, framing himself as mathematically capable. However, Rebecca persisted and in an unprecedented move used a derogatory statement towards Jakeel to assert her dominant position. Given Rebecca's white skin color and Jakeel's darker skin tone her tone and statement suggests a potential racial microaggression and emphasizes "her desire to be in charge of Jakeel" (Wood, 2013, p. 795). After her statement, Rebecca succeeded in shifting Jakeel's identification as he acquiesced to her positioning and storyline and this storyline of subservience continued for the next seven minutes until the teacher returned.

When his teacher returned and asked Jakeel to explain his work again, he easily shifted back to the identity of mathematical explainer, embracing the storyline of inquiry, due to the teacher's positioning. When it comes to students' learning in the mathematics classroom, it has been found that teachers' positioning of their students can be more influential than classroom resources (Tait & Loveridge, 2016). Thus, it is important to consider all participants within a storyline and how they influence the micro-identities of a focal student.

2.4 Affordance to Research

The findings in Wood's study demonstrate the importance of attending to micro-identities. From one moment, Jakeel was positioned as mathematically capable. In another moment, he was positioned as mathematically incapable for a solid seven minutes until being repositioned as mathematically capable again the next moment. With macro-identities being a thickening of micro-identities (Langer-Osuna & Esmonde, 2017), it is critical to create the kind of moments in mathematical learning spaces that can position students towards being mathematically capable. This is especially critical for women and gender fluid students for which mathematical spaces are typically associated with equity issues (Burton, 1990; Heybach & Pickup, 2017; Joseph, 1987; Leyva, 2017; Murphy et al., 2019; Nosek et al., 2002).

Within the scope of a coordinated system, researchers can use positioning theory to examine the ways in which and how mathematics lessons, whether through uniform elements and/or instructional autonomy approaches, can encourage and promote moments of positive micro-identities (Voigt et al., 2021). In turn, these positive micro-identities may then influence and result in students' developing an overall positive macro-identity (Wood, 2013). By knowing more about micro-identities and how they're enacted and shifted during lessons, this information can be used to help course coordinators "be more purposeful in encouraging productive sequences of identities" (Wood, 2013, p. 805).

As seen in the examples with Jakeel, participants in a conversation jointly contribute to the construction of the positioning triangle. All three vertices help deepen

our understanding of inequities within a classroom as not everyone has the same access to the rights and duties to perform meaningful actions (Anderson, 2009; Esmonde & Langer-Osuna, 2013; Harré & Valsiner, 2012). For a heterogenous classroom, positioning theory allows researchers and educators to examine and understand power dynamics within a classroom to gain the necessary tools for "managing issues of equity that emerge" (Esmonde & Langer-Osuna, 2013, p. 289). And by observing what storylines are unfolding, we can note what positions are available to students and to which students (Harré & Valsiner, 2012) which can then inform implications for equitable practices (Herbel-Eisenmann et al., 2015).

The possible positions afforded to students within mathematical learning spaces can impact their identity formation. Through identity research, mathematics educators can "investigate students' experiences of marginalization in schooling" (Darragh, 2016, p. 23). From these results, course coordination can be used as a vehicle of change for equitable practices in encouraging participation and engagement for *all* students as a coordinated system greatly impacts the positions students can take in a classroom, with respect to the uniform elements selected and the quality of the instructor communication and the pedagogical approaches that may be encouraged and/or nudged.

When it comes to student interest and engagement with mathematics, teachers play an instrumental role (Köller et al., 2001). Instructional practices have been found to predict higher levels of students' mathematics identity, particularly, high amount of interaction and activities involving conceptual learning (Boaler & Greeno, 2000; J. Cribbs et al., 2021). Teachers have the power to make positive acts more likely to occur

for more students (Cobb et al., 2009), a skill that can be developed and nurtured through regular instructor communication set up by the choice architect.

Aligning with studies on course coordination promoting active learning, students need to be actively engaged in conversation with their classmates as well as their teacher (Boaler & Greeno, 2000; Godwin et al., 2016; Langer-Osuna, 2017). A coordinated system can supply teachers with the necessary activities to best position students within the classroom, offering multiple ways for students to engage in mathematics and make sense of their own ideas (Langer-Osuna & Esmonde, 2017; N. I. Nasir, 2011; Wilson & Kittleson, 2013). In providing students with opportunities to work collaboratively, students can position themselves as a mathematical explainer, expert, or facilitator (Langer-Osuna & Esmonde, 2017), allowing all students to meaningfully contribute and promoting equity in the classroom as a result (Cribbs et al., 2021).

In turn, students' development of their micro-identities as productive doers of mathematics (Boaler & Greeno, 2000; Cobb et al., 2009; Langer-Osuna & Esmonde, 2017) could consequently influence who they are and who they want to become (Gee, 2000). With "different assumptions about who can learn, what they can learn, and how they learn it" (Nasir, 2005, p. 31), schooling institutions, particularly course coordinators, can structure mathematical learning spaces to best support students' micro-identities for their mathematics lessons to then, hopefully, support their macro-identity at the end of the course.

For this dissertation study, we will attend to more than just students' macro-identities by also focusing on their micro-identities, exploring the different kinds of

mathematical learning spaces and opportunities they provide, and how these classroom elements may then impact students' mathematics identity. In particular, we will focus on women and gender fluid students' mathematics identity.

CHAPTER THREE

RESEARCH METHODS AND STUDY DESIGN

Yeah, I feel like I actually did enjoy the study. I remember my friend was like, 'Are you doing it for the money?' And I was like, I feel like it helps. I don't think that teachers, especially in college, have too many students who just like to participate in things. And obviously, if we're not coming up to you guys in person. how would you know what's going on in our minds? How would you know how we really feel about it? (Dylan Interview)

Storyline Illustration

Picture this. You have graduated from college and are ready to start your career. Through trials and tribulations, you have earned your degree and have answered the all-consuming question: what do you want to do with your life?

You have decided to become a professor and you are excited to teach Calculus 1, determined to leverage your experiences to support your students. You are fresh and eager with ideas for how to run a fair but also equitable classroom. You have plans to offer leniency and flexibility towards due dates for assignments, remembering how you were denied accommodations for your situation.

Days leading up to the start of the semester you have your first instructor meeting. Just as in your undergraduate program, at the university you work at Calculus 1 is coordinated. Now on the other end of the desk you are informed of even more details about how the coordinated system works and how much control you have over your class. You learn that anything that is given to all students in the course must be kept the same across all sections of the course, including yours, to keep things fair, which include rigid due dates of assignments.

As an instructor, you bring up some of your ideas to your team of coordinators, to which they respond that the coordinated policies in place are equitable because everyone has the same opportunities. You decide not to correct them on their misconception of equity. Instead, you decide it would be best to educate them through research and evidence-based claims–specifically your research.

Reflective Summary

Knowing how your experiences have been and wishing you had your voice heard, you set on conducting a research study to reflect on the need to document and understand the student perspective through research-based practices within course coordination.

In this chapter, we describe the research methods for the dissertation study. We conducted qualitative research because we wanted to understand women and gender fluid student experiences within a coordinated calculus course. Qualitative research tends to be better suited than quantitative methods for capturing interactions among people and the intricate details of individual differences such as gender (Creswell & Poth, 2016).

With qualitative research, there are typically five approaches to a study design. We decided to primarily make use of a case study approach to explore the experiences of these individual students within the bounded system of course coordination. To focus even more on students' lived experiences with the phenomenon of course coordination, we also made use of a phenomenological lens to describe the meaning for these individuals (Creswell & Poth, 2016). Thusly, this qualitative research study is a multiple exploratory case study with a phenomenological lens.

For the case study process, there are six stages: plan, design, prepare, collect, analyze, and share (Saša Baškarada, 2014). In this chapter, we discuss further details of a multiple exploratory case study with a phenomenological lens, share information about the pilot project, and describe the collection and analysis of the data. The next few sections align with the six stages of the case study process as outlined by Saša Baškarada.

3.1 Multiple Exploratory Case Study with a Phenomenological Lens

The **planning and design** stages of a case study involve identifying the research questions (see *Section 1.5 Research Questions*), rationale for using case study method, defining unit of analysis, identifying the case study design, and developing procedures to maintain case study quality (see *Appendix H Quality Considerations*). In this section, we will explain the rationale, define the unit of analysis, and identify the case study design.

A case study allows researchers to explore a study of an issue through a single or multiple units within a bounded system (Creswell & Poth, 2016; Saša Baškarada, 2014). An exploratory case study aims at describing "different characteristics of a phenomenon in its context" and, after the investigation, to generate theories (Saša Baškarada, 2014, p. 4). For this study, the unit of analysis is a women or gender fluid single student within a coordinated calculus course. We drew on a multiple case study as multiple students were explored.

Case studies allow for a rich account of a particular phenomenon, leading to the inclusion of phenomenology as a lens in the research design, as the phenomenological approach allows the researcher to make sense of the essence and underlying structure of a phenomenon (Crawford, 2016; Creswell et al., 2003; Creswell & Poth, 2016; Moustakas,

1994; van Manen, 1990). For the phenomenological lens, transcendental phenomenology will be utilized because it focuses "more on a description of the experiences of participants" (Creswell & Poth, 2016, p. 59) as we believe it is important to understand women and gender fluid students' experiences in a coordinated calculus course to develop the best policies of course coordination that will strengthen their math identity and encourage equitable instructional practices.

For a phenomenological research design, the recommended sample size for data collection is for about 5-25 individuals (Creswell & Poth, 2016; Onwuegbuzie & Collins, 2007). For qualitative research, sample sizes should be an adequate size to achieve data and theoretical saturation but not too large to make analysis difficult (Onwuegbuzie & Collins, 2007). Considering these recommendations in sample size, including 10 women and gender fluid student participants is an appropriate size for both the analysis and data and theoretical saturation.

Through this fusion of qualitative methodologies, this multiple exploratory case study with a phenomenological lens will allow us to "narrow [our] focus in a previously explored broad field" (Crawford, 2016, p. 53). As mathematics identity and course coordination have been studied separately this unique approach will add to the literature by looking at them both in a single study.

This multiple exploratory case study with a phenomenological lens was done in two parts. The first was a pilot project (see *Section 3.2 Pilot Project* for more details) which was used to test protocol and develop the research design. The project was conducted at two different universities and included multiple courses. Data was collected

from three course coordinators and one instructor through semi-structured interviews. Data was collected from two students through video journal entries, surveys, and semi-structured interviews. The pilot project helped inform directions and necessary changes for the overall dissertation study, the second part.

The overall study was conducted at one university and involved two different entry level calculus courses and approved exempt from review by the University's Institutional Review Board (IRB 2023-0060) (see *Section 3.3 Data Collection* for more details). Data was still collected from coordinators and instructors with additional data sources than was included in the pilot project. A brief overview of the study design and data collection can be seen in Figure 3.1 below. Two course coordinators were individually interviewed and asked to provide artifacts. Five instructors were individually interviewed and had their classroom observed once. Data collected from these two stakeholders were used to contextualize the data from students and were not overtly analyzed. From the students, data was collected from the Pre- and Post-Math Identity surveys, video journal entries, and semi-structured individual interviews. The Pre-Math Identity survey was sent to all students enrolled in both courses. Ten participants were then selected. The data collected from the video journals and the interviews from these participants were analyzed using thematic analysis.

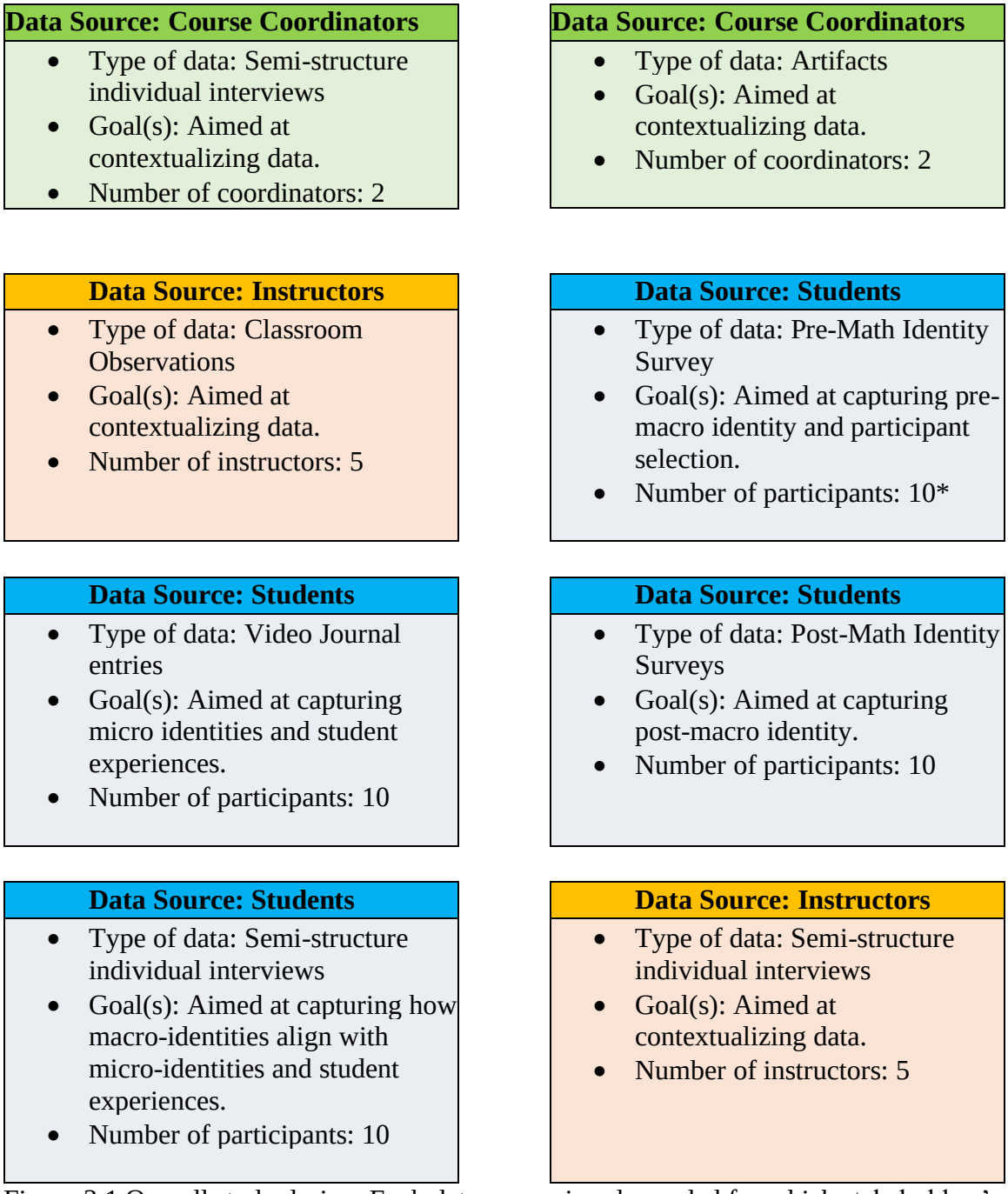

Figure 3.1 Overall study design. Each data source is color coded for which stakeholders' data are collected from with green for coordinators, orange for instructors, and blue for students.

3.2 Pilot Project

In the **prepare** stage we focus on developing a case study protocol, conducting a pilot project, and developing the appropriate skills needed to investigate case studies. Interview protocols can be found in the Appendices (*Appendix D Course Coordinator Interview Questions, Appendix F Student Interview Questions, Appendix G Instructor Interview Questions*). In this section we will discuss the pilot project. The necessary skills to prepare before data collection, such as bracketing, can be found in *Appendix I Bracketing Journal.*

3.2.1 Pilot Project Data Collection and Participation

The pilot project was conducted in the spring semester of 2023 at a southeastern R1 institution and a western R2 institution in the United States, which we will refer to as East University and West University respectively. Two courses were selected from East University, a long calculus course[4] and a short calculus course. One course was selected from West University, a short calculus course. Both courses at East University had one course coordinator who also taught at least one section of the course they coordinated. The course at West University was overseen by a team of two coordinators, neither of whom were teaching a section that semester.

We refer to pilot project instead of pilot study as the project did not meet the full criteria and scale of a study. An institutional review board (IRB) application was not submitted as the aim of the pilot project was to test protocols and develop the research design and was not intended to produce human subject's research. For the pilot project,

[4] A long calculus course is Calculus 1 split across two semesters.

we intentionally aimed for variability in courses, instructors, and institutions, to inform the direction to take for the full study. The project was also used to aid in evaluating the feasibility of data collection, such as video journal prompts, and the general alignment of the data in answering my research questions.

At the beginning of the spring semester 2023, course coordinators were contacted to schedule an interview and to share a Qualtrics Pre-Math Identity survey with students that was primarily used to select participants. With the survey sent, 62 students responded from East University and 46 responded from West University. From the responses, the guidelines for selecting participants were created using purposeful sampling.

The inclusion criteria used for participants were if they were over the age of 18, planning to take another math class, willing to participate in additional interviews, and identified as a woman or gender fluid individual. Fifteen students met the inclusion criteria from East University and seven students met the inclusion criteria from West University. After potential participants were narrowed down by those criteria, we then needed to determine how to select participants further. This was done by organizing them by class section and grouping them into categories of math identity based on their responses to the survey.

Identity categories were made by averaging interest and recognition items from the Qualtrics Pre-Math Identity survey to organize students in the math identity categories: High Interest and High Recognition, High Interest and Low Recognition, Low Interest and High Recognition, Low Interest and Low Recognition (see Figure 3.2). Average interest over 67% was labeled as high and under 67% as low. Average

recognition over 70% was labeled as high and under 70% as low. The reason the intersection of interest and recognition items were used in determining student math identity is based on Cribbs research highlighting the role of interest and recognition having a direct effect on students' mathematics identity (Cribbs et al., 2015). Students determined to be in the High Interest and High Recognition category were not considered as we wanted to investigate into the other intersections of interest and recognition more as we believed students with lower mathematics identities would provide richer experiences.

<table>
<tr><td>Interest →
Recognition ↓</td><td>100%</td><td>67%</td><td>33%</td><td>0%</td></tr>
<tr><td>100%</td><td colspan="2" rowspan="2">High Interest and High Recognition</td><td colspan="2" rowspan="2">Low Interest and High Recognition</td></tr>
<tr><td>75%</td></tr>
<tr><td>50%</td><td colspan="2" rowspan="2">High Interest and Low Recognition</td><td colspan="2" rowspan="2">Low Interest and Low Recognition</td></tr>
<tr><td>25%</td></tr>
</table>

Figure 3.2 Students mathematics identity category determined by interest and recognition items.

Once the additional criteria were applied, there were only seven students to consider contacting from East University and only four to consider contacting from West University. Because of these low numbers, we wanted to improve recruitment for participation for the full dissertation study. From there, participants were then contacted to be invited to the pilot project with four from West University and four from East University (two for the long calculus course and two for the short calculus course).

Participants were emailed with the first video journal prompt after accepting the invitation and given a week to submit their response via Zoom. One student from East University had to drop out so another student was contacted to participate. All three

students from West University did not submit a video journal prompt. Follow-up emails were sent, and an extension period offered. One student responded needing to withdraw. The other two students made no contact and did not submit a video journal prompt. With the semester already halfway done and the limited number of alternate students to invite for participation, it was decided to continue with the video journal prompts for East University and only complete the course coordinator interview at West given the dual nature of the position.

Video journal prompts continued for the rest of the semester for a total of four prompts. There was a steady decline in the number of participants for each prompt at East University with only one student submitting all four. The average response time was approximately 5-7 minutes per prompt. Only two participants from East University were asked to be interviewed at the end of the semester due to their participation of three or more video journal prompts. The struggle with retaining students was a demoralizing one. This attrition informed us the importance of providing a higher incentive for the dissertation study to improve participation.

During the semester, interviews with coordinators were also being conducted to test the protocol. The coordinators at West University were interviewed together. The coordinator for long calculus at East University was interviewed. However, a common time for the coordinator for short calculus at East University could not be found.

Only one instructor was interviewed at the end of the semester. Interviews for the instructors of the two student participants were planned. However, one of the instructors

was also the coordinator for short calculus and a common interview time could not be found.

3.2.2 Pilot Project Results

From the course coordinator interviews, coordinators initially expressed a Resource-Managerial Orientation. They viewed their responsibility as one of communication and organization. By creating materials and curating resources, coordinators laid down a "ground floor" for instructors and students alike. "Ground floor" was used as an analogy by coordinators for providing a foundation for instructors to work from. With resources and materials provided, instructors could then spend their time and energy on other tasks, like designing lessons and building activities for students. Coordinators expected instructors to utilize the provided resources and to grade consistently.

From this "ground floor," coordinators took on a Humanistic-Growth Orientation, desiring instructors to do what was best for their classroom and expressed that they hoped teaching the course would make them a better instructor.

From the pilot project, we were able to see similar results found in previous research on course coordination with this relationship between the coordinator and instructor. We were also able to hear about the student experiences within these coordinated systems. We saw the following observations from the video journals and interviews:

1. **Classroom structure.** It was unexpected to hear students discuss the physical structure of the class, such as seating arrangement (rows vs. tables), having an

impact on their experiences in the classroom, especially with how they could connect with peers during active learning activities. Class size and time also played a part in their relationship with their peers. Prior research in course coordination did not refer to the effect of classroom design. The classroom setting and the use of the environment is something to further examine in the full study.

2. **Instructors.** In the pilot, students didn't report much discussion with peers within their section, but they did know peers in other sections and described the variations in teaching style across instructors contributing to different experiences. Students also reported the importance of their instructor showing they care. When a teacher showed they care and put effort into wanting to help, students felt more motivated and willing to learn. Students also felt that this work from the instructor made their life easier.
3. **Uniform elements.** Students reported finding the organization of the course extremely helpful and made use of the resources available to them. They also reported the class as fair and equal with access to resources and similar assignments.
4. **Math Identity.** A common sentiment reported by students was not being great at math and not finding calculus enjoyable. They also expressed test anxiety and wanting to avoid making mistakes and losing "careless" points.

Aligned with these themes were the storylines of relationship with instructor, math as intimidating, making mistakes (not good at math), and expressed excitement to

learning math. The pilot was used to test the modality of video journal prompts and their alignment to the theoretical framework of positioning theory. We were able to see storylines emerge as well as communication acts both verbal and nonverbal due to this medium. What was lacking were salient positions. For the dissertation study, we added the additional phrase "share a story or an experience" to the prompts to elicit better positions as well as more detailed storylines. In accordance with this goal, we plan to utilize the individual interviews and introduce classroom observations to further align with the theoretical framework.

3.2.3 Changes Informed by the Pilot

From the pilot, it was decided that due to the difficulties of recruiting and retaining students, we would implement the following changes: limit the full study to one institution, increase the incentive to participate from $25 to $50, lower commitment time to participate in the study.

Limiting the full study to one institution aided in the in-person recruitment through the utilization of placing fliers advertising the study. In the pilot project, the video journal prompts were also advertised to take an hour of students' time. We learned from the pilot that involvement in the study actually resulted in lower commitment time, approximately half an hour less. Advertising lower commitment time and higher incentive to participate also helped with recruitment and retention.

Collecting data from the same location also helped with reducing variability. For the full study, it was decided to collect data from East University alone. However, we still wanted to have more than one course from East University. These courses being the long

calculus course again and a business calculus course. The reason for this selection is that the designs of these coordinated systems are similar, but they each have different student populations in terms of the majors of students enrolled.

For the full study, multiple sections for each course were selected. Although including multiple sections and instructors doesn't necessarily reduce variability, it was seen in the pilot from both survey responses and video journal prompts that students' relationship with math appeared to be dependent on their instructor. And with course coordination aiming to establish similar experiences for students across all sections of a course, this variability in data collection is something we wanted to maintain to see if students report any variability in experiences.

For the full study, course coordinators were contacted prior to the start of the semester to schedule interviews when their schedules were more flexible. Instructors were also contacted earlier to schedule interviews in their calendars. Classroom observations were also added to data collection to help provide context for classroom setting as described in the video journal prompts.

3.3 Data Collection

The **data collection** stage involves following the case study protocol and using multiple sources of evidence. Data were collected from course coordinators, instructors, and students through semi-structured individual interviews, surveys, artifacts, classroom observations, and video journals. Logistical questions to aid in inviting student participants, such as adding an entry for their names and contact information, were added to the Pre-Math Identity survey. Data collection such as artifacts and classroom

observations were implemented in the full study. In this section, we discuss participant recruitment and selection and data collection (see Figure 3.1). Interview protocols can be found in *Appendix D Course Coordinator Interview Questions*, *Appendix F Student Interview Questions,* and *Appendix G Instructor Interview Questions*.

3.3.1 Timeline of Data Collection

The completion of our research took approximately 18 months (see Figure 3.3) A pilot project was conducted in Spring 2023 to develop and test the survey for participant selection and recruitment, test and refine interview protocols, and to test the alignment of data collection with the study's theoretical framework in answering the research questions. These details were discussed in *3.2 Pilot Project*. Summer 2023 was used to prepare for the full study by finalizing protocol and participant selection. The full study was conducted in Fall 2023 with recruitment and data collection, discussed below. Analysis of the full study was done throughout the fall semester and Spring 2024 as seen in Figure 3.3

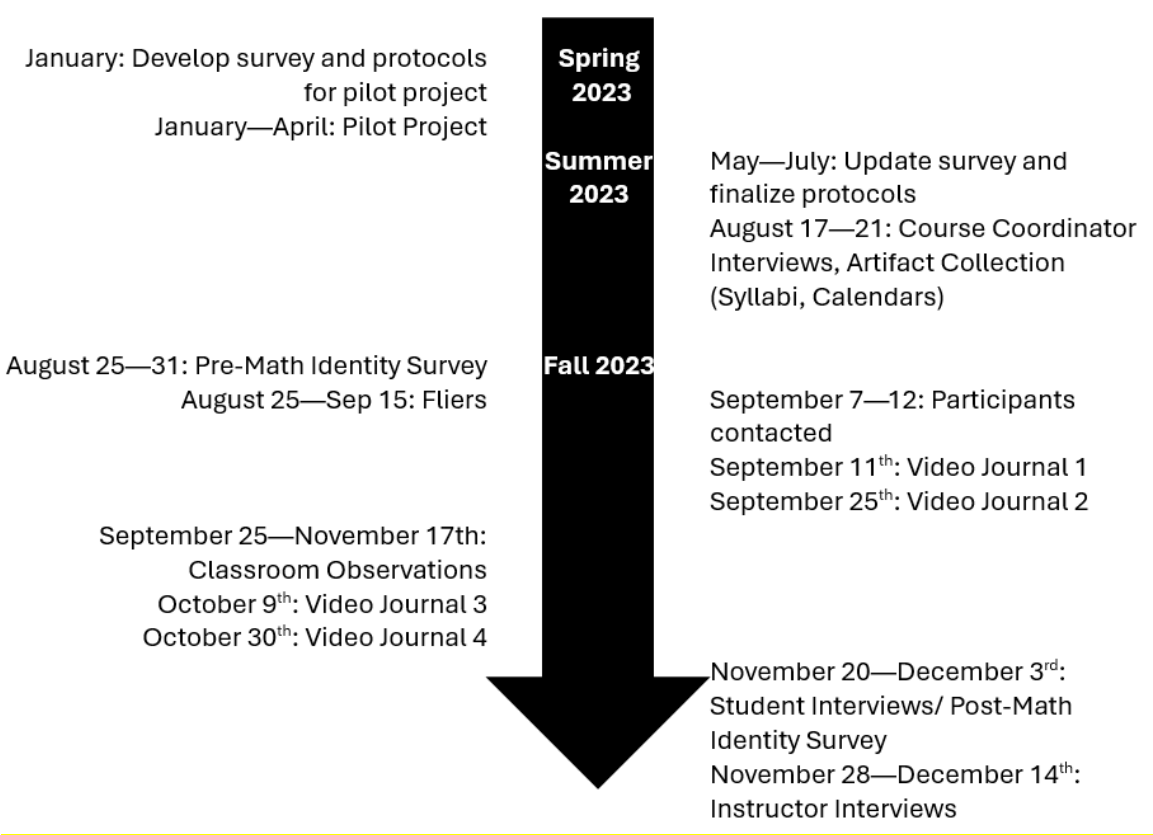

Figure 3.3 Timeline of data collection

3.3.2 Semi-Structured Coordinator Interviews

Before the fall semester started, course coordinators for a business calculus course and a long calculus course from an R1 southeastern university were contacted to discuss their involvement in the study. These two calculus courses were selected due to having a different course coordinator and different majors of enrolled students.

Semi-structured interviews with coordinators were conducted through Zoom before classes started to establish the motivations and objectives of course coordination from the choice architects themselves. These interviews were used to establish context of the coordinated system the choice architects designed, how coordinators are approaching

their role, whether their approach was more aligned with a Humanistic-Growth or Resource-Managerial coordinator, as well as what they expect instructors, and possibly students, to get out of the course (see *Appendix D Course Coordinator Interview Questions*). It's a long chain from the course coordinator to the instructor to the students themselves (Williams et al., 2021). By collecting information from the choice architect on selected uniform elements, the intention around that selection, instructor autonomy approaches, and instructor communication, the context helped with drawing conjectures of any findings later and contributed to the discussion portion of the study.

3.3.3 Artifacts

Before their interviews, artifacts such as course syllabi and calendars were also requested. These artifacts were used to aid in establishing context of the coordinated system.

3.3.4 Pre-Math Identity Survey

After the coordinator interviews, we requested course coordinators to send the Pre-Math Identity survey to all students enrolled in their courses during the first few weeks of classes. During this time, fliers were also placed inside the classrooms to encourage students to fill out the Pre-Math Identity survey through Qualtrics. From the survey, there were overall 71 responses, 40 students from business calculus and 31 students from long calculus.

The purpose of the Pre-Math Identity survey was two-fold. Questions from the Pre-Math Identity survey captured business calculus and long calculus students' mathematical macro-identity before taking a coordinated course. The Pre-Math Identity

survey also served for participant selection. As we wanted to get at identity and equitable components in mathematical learning spaces for women and gender fluid students, purposeful sampling was done.

As done in the pilot project, participants were first filtered with the inclusion criteria of being over the age of 18, planning to take another math class, willing to participate, and identified as a woman or gender fluid individual. Sixteen students met the inclusion criteria for business calculus and only five students met the inclusion criteria for long calculus. After potential participants were narrowed down by those criteria, we then selected participants further by considering their math identity (High Interest and High Recognition, High Interest and Low Recognition, Low Interest and High Recognition, Low Interest and Low Recognition, see Figure 3.2), race, gender, and course section.

During the third week of the semester, ten students were selected and contacted from the information provided from the Pre-Math Identity survey. After a few days of contact, there were only five interested in participating. With five being the minimum needed for a phenomenological research design and unbalanced representation between the two courses, the Pre-Math Identity survey was sent out again the following week.

With the survey sent again there were now a total of 179 responses. However, out of those survey responses only 79 students answered the survey completely, 45 students from business calculus and 34 students from long calculus. Completed survey responses for average interest and recognition with mathematics are presented in Table 3.1.

Table 3.1
Survey Responses Pre-Mathematics Identity Average Interest and Recognition in Mathematics.

Course	Gender	Average Interest (Percent)	Standard deviation	Average Recognition (Percent)	Standard Deviation
1020	Cisgender men (n=16)	71.43	38.41	65.65	21.40
1040	Cisgender men (n=15)	71.26	40.68	65.34	21.19
1020	Women and gender fluid (n=29)	70.78	39.26	65.75	21.57
1040	Women and gender fluid (n=19)	70.94	39.24	64.81	21.64

An additional ten students met the inclusion criteria for business calculus and an additional six students met the inclusion criteria for long calculus. Ten students were selected and contacted. During this time, four additional students replied and were interested in participating from the original invitation. With the second invitation, there were six interested in participating. Pseudonyms were requested and the first video journal prompt was sent to interested participants. After the first video journal prompt, there was attrition, leaving us with ten participants for the study, six for business calculus and four for long calculus. We include a table summarizing our participants in *3.3.8 Post-Math Identity Survey*.

3.3.5 Video Journals

During weeks 4 and 12 of the semester, video journals were collected every two to three weeks from participants for exactly four entries each. Prompts were sent to

participants through their school email provided from the Pre-Math Identity survey. The emails included a differentiated Zoom link for participants to record their video responses. These prompts were crafted to get at women and gender fluid students' positioning and thusly their micro-identities during mathematical lessons.

Journals provide an opportunity for individuals to narrate their experience, establishing the characters and articulating the relationship of their interaction. This articulation of "both the narrator's and characters' voices" (Aryaja, 2016, p. 394), through a process of reflection, follows with the communication acts vertex of the positioning triangle. The interactional relationship between the narrator and characters (students, instructors, TAs) is explicitly or implicitly constructed through positioning (Hermans, 2003; Wortham, 2001). Through the developing storyline of their video journals, the narrator evaluates their positioning though this interaction (Aryaja, 2016). With this form of data, storylines are rooted in the day-to-day interactions of mathematics lessons getting at student participants micro-identities (Pavlenko, 2001). Furthermore, "analysis of [participants'] discursive reflective positions" allow for the identification of recurrent themes (Andrew, 2011, p. 64).

Participants must be asked two general questions according to Moustakas (1994) procedures to ensure data is gathered that will elicit descriptions of the experiences of the student participants; these being: "What have you experienced in terms of the phenomenon?" and "What contexts or situations have typically influenced or affected your experiences of the phenomenon?" (Creswell & Poth, 2016, p. 61) which were

exhibited in the video journal prompts and included in the interview protocol for the individual interviews.

Participants' video journal responses were coded immediately afterwards to help inform and construct additional questions and follow-ups for the individual interviews at the end of the semester.

3.3.6 Classroom Observations

During the same time frame of the semester, classroom observations were done for the class sections that had student participants. Classroom observations were done only once and scheduled in advance with the instructor to get a greater sense of the classroom environment. A class session was recorded and observed by taking field notes.

3.3.7 Semi-Structured Individual Student Interviews

After the video journals were completed, semi-structured individual student interviews were conducted with participants through Zoom during the fourteenth and sixteenth weeks of the semester. Semi-structured individual interviews with student participants were used to triangulate claims made in their video journal entries and to further inquire how certain motivations and objectives of course coordination may influence their identities. An outline of questions was constructed from the findings of themes reported in the video journals (*Appendix F Student Interview Questions*). The order of the questions was predetermined; however, the interview was semi-structured to allow for additional prompts that may generate themselves naturally in the interview process.

3.3.8 Post-Math Identity Survey

After the interview, participants filled out the Post-Math Identity survey through Qualtrics. The Post-Math Identity survey was used to capture participants' mathematical macro-identity and to denote any changes in mathematical macro-identities after taking a coordinated calculus course if any changes occurred. The Post-Math Identity survey was sent to participants immediately after the individual interview was completed to contextualize any shifts that were presented from the participants. The participants in the study along with their Pre- and Post-Math Identities can be seen in Tables 3.2 and 3.3 below. We provide more details about the participants average interest and recognition in mathematics in Table 3.4. In the

CHAPTER FOUR, we also compare this reported macro-identity from the Post-Math Identity survey with the self-reported macro-identities provided by the participants in their video journal entries.

Table 3.2
Business Calculus Participants

Participant	Pronouns	Gender	Race	Pre-Math Identity Interest	Pre-Math Identity Recognition	Post-Math Identity Interest	Post-Math Identity Recognition
Mabel Wyler	She/her	Woman	White	High	High	High	High
M	They/he	Transgender /Gender Fluid	White	High	High	High	High
Sappho	She/her	Transgender Woman	White	High	High	High	Low
Ally Jackson	She/her	Woman	White	High	High	High	High

Elizabeth	She/her	Woman	White	High	Low	High	High
Olivia	She/her	Woman	Black or African American	Low	Low	Low	Low

Table 3.3
Long calculus participants

Participant	Pronouns	Gender	Race	Pre-Math Identity Interest	Pre-Math Identity Recognition	Post-Math Identity Interest	Post-Math Identity Recognition
Joselyn	She/her	Woman	Hispanic or Latinx	High	High	High	High
Nadia	She/her	Woman	Hispanic or Latinx	Low	High	Low	High
Aves	She/her	Woman	White	Low	Low	High	Low
Dylan	She/her	Woman	Black or African American	Low	Low	Low	Low

Table 3.4

Participants Responses Pre-Mathematics Identity Average Interest and Recognition in Mathematics.

	Average Interest (Percent)	Standard deviation	Average Recognition (Percent)	Standard Deviation
Pre	63.33	42.89	61.5	24.73
Post	70	29.31	74	18.53

3.3.9 Semi-Structured Individual Instructor Interviews

Interviews with instructors for sections that had participants were done during this time as well. Semi-structured individual interviews with instructors were aimed to

capture how coordination and instructors' positioning influenced how they teach. Although the student perspective is one of the gaps in course coordination literature and the primary focus of this study, it is important to also include instructors as they are the facilitators of the coordinated system and the direct influencers on students. Instructors are the common vertex between the inner and outer triangles of a coordinated system. These individual interviews were semi-structured to allow for additional prompts that may generate naturally in the conversation.

3.4 Data Analysis

The **analysis** stage utilizes analytic techniques and displays data separate from interpretations. Data analysis strategies for case studies involve analyzing data through description of the case and themes and cross-case themes (Creswell & Poth, 2016). While analyzing the data, our research questions were regularly referenced. As such, we reiterate our research questions from *Section 1.5 Research Questions*.

Research Question 1: What coordinated and uncoordinated course aspects influence student experiences?

Research Question 2: How do the experiences within a coordinated math course impact women and gender fluid students' math identity?

3.4.1 Thematic analysis

Thematic analysis is a method of identifying and analyzing themes that emerge from within the data (Castleberry & Nolen, 2018). With the analysis process, there are five stages: compiling, disassembling, reassembling, interpreting, and concluding (Castleberry & Nolen, 2018).

The first stage, **compiling** the data, consists of the researcher transcribing and familiarizing themselves with the data. As mentioned in *Section 3.3 Data Collection*, data collected from student participants included Pre-Math, and Post-Math Identity surveys, video journals, and semi-structured individual interviews. Classroom observations, artifacts, and interviews with coordinators and instructors were used to contextualize and make sense of the student data. Also, due to the gaps in course coordination literature on the student perspective the stakeholders of coordinators and instructors were not the focus of the analysis.

To answer the first research question, thematic analysis was primarily done from the data collected from video journals and interviews. Zoom was used for participants to submit their responses to the video journal prompts and conduct interviews due their familiarity with the software and for Zoom being able to record and transcribe their entries. After participants submitted their video journals and the interviews were completed through Zoom, the files consisting of the transcript and video were downloaded and transferred to MAXQDA, a software used for qualitative data analysis. The videos were then watched as many times as needed to clean the data. Compiling the data was done September through December 2023.

This is when compiling the data then transitions to the researcher **disassembling** the data which involves coding. Data coding involves summarizing and reporting data into meaningful categories either using words or phrases. There were multiple cycles of coding. The first cycle involved initial summarizing of the data to further familiarize with the data as a whole especially as data was being collected throughout the semester. The

descriptors were mostly words or small phrases such as “overwhelmed,” “teaching style,” and “class size.”

Once all the video journals were collected and most of the interviews conducted, a second cycle was done to summarize the data into even more meaningful categories. Examples of these initial codes are “Student feels overwhelmed,” “Instructor connects lessons to real world,” and, “Small class size helps engage with peers.” Throughout this stage approximately 444 codes were made and took about five months to complete (September 2023 through January 2024).

The **reassembling** stage sifted through these codes for any patterns. The disassembling stage can be thought of as establishing what codes are present and the reassembling stage sorts these codes and condenses them into buckets. Aiding in this endeavor, a team of researchers met to discuss the condensing of codes. Agreement between researchers is necessary for data coding to establish inter-coder reliability and is done to ensure that the same conclusions are being met by the researchers involved (Castleberry & Nolen, 2018). The team of researchers validated the consistency in the reassembling of the data reaching mutual agreement and refinement of codes.

In this stage, the 444 codes were organized into 77 subcodes. For example, the disassembled codes from above were reassembled to fall under the respective subcodes of “Outright negative feelings towards math,” “Intentionality by instructor for real-world connections,” and “Students link class sizes with relationship opportunities with peers and instructor.” These subcodes were then reorganized further and folded into larger 18 parent codes such as “Relationship with Math,” “Students’ perceptions of pedagogy

techniques used by instructor," and "Course logistics." This stage took approximately two months to complete (February through March 2024; see *Appendix A Codebook*)

Once the data has been reassembled, themes can be established through the **interpretation** stage. The subcodes that were reassembled by the team of researchers were taken up to establish themes. Essentially a smaller scale version of thematic analysis was taken up as the subcodes were compiled and the researchers familiarized themselves with the data. The subcodes were then disassembled into categories, then reassembled into smaller condensed groups. There were quite a few rounds of disassembling and reassembling the subcodes until salient themes could emerge. This process took approximately a month to complete (April 2024).

After this stage, the researcher is in position to begin describing the essence of the phenomenon (Creswell & Poth, 2016). This then leads to the final stage of thematic analysis where conclusions are made in response to the research question(s) posed for the study (see

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3.4.2 Case Studies

For the second research question, we are interested in how experiences impact women and gender fluid students' math identity. We answer this question through the description of our cases.

From the Pre-Math Identity survey, participants' pre-mathematics identity was determined through their responses to the interest and recognition items. With our ten participants, five were categorized with a pre-math identity of High Interest and High Recognition, one was categorized with a pre-math identity of High Interest and Low Recognition, one was categorized with a pre-math identity of Low Interest and High Recognition, and three were categorized with pre-math identity of Low Interest and Low Recognition (see Tables 3.2 and 3.3).

Given this spread, three math groups were considered to select cases to describe:

- High Math Identity
- Mid Math Identity, and
- Low Math Identity

Participants in the High Math Identity group consisted of four business calculus students (Mabel Wyler, M, Sappho, and Ally Jackson) and one long calculus student (Joselyn) all with the Pre-Math identity of High Interest and High Recognition.

Participants in the Mid Math Identity group consisted of one business calculus student (Elizabeth) whose pre-math identity was High Interest and Low Recognition and

one long calculus student (Nadia) whose pre-math identity was Low Interest and High Recognition.

Participants in the Low Math Identity group consisted of one business calculus student (Olivia) and two long calculus students (Aves and Dylan) all with the Pre-Math identity of Low Interest and Low Recognition.

The Post-Math Identity survey was sent to participants after their individual interview. As for the Pre-Math Identity survey their post-mathematics identity was determined through their responses to the same interest and recognition items.

The mathematical macro-identities for three of the ten participants changed—one from each of three math groups. It is these three case studies (Sappho, Elizabeth, and Aves) that we discuss in

CHAPTER FOUR.

CHAPTER FOUR

RESULTS

My class experience with math has always impacted my opinion on math. I used to say, I was a heavy math person, and then I had a not-so-great teacher and kind of ruined it. (Nadia Video Journal #4)

Storyline Illustration

Picture this. You have collected data from student participants regarding their experiences in a coordinated course. You have familiarized yourself with the data and gone through cycles of analysis to determine what salient themes are there. You've done the painstaking work to finally find meaningful results. But how do you go about sharing your findings?

You are excited to share with your colleagues the findings that have emerged from your classroom but how do you best describe the impact of course aspects on student experiences? You think of the time you had a cast and how difficult it was to write anything down. You think of the experiences students in your study shared and know the best way to narrate your results.

Reflective Summary

The power of storytelling is how it can capture details from moments and help with understanding positioning and students' mathematics identity constructed through interactions and reflection.

In this chapter, we share the results from analyzing the data as detailed in the previous chapter. We start with sharing out the six themes found from the thematic

analysis done from the video journals and the semi-structured individual student interviews (*Section 4.1 Coordinated and Uncoordinated Course Aspects that Influence Student* Experiences). These six themes answer Research Question 1, "What coordinated and uncoordinated course aspects influence student experiences?"

After we present the themes, we then discuss the three participants whose mathematical macro-identities changed from the start of the semester. Each of the case studies is presented as a storyline (*Section 4.2 Experiences Impacting Women and Gender Fluid Students' Math Identity*). The storylines of the participants answer Research Question 2, "How do the experiences within a coordinated math course impact women and gender fluid students' math identity?"

The theoretical framework of positioning was leveraged to a greater extent during the design stages of the study and data collection. During the analysis we allowed for inductive coding and were less closely tied to our theoretical framework, as we wanted the data and student voices to drive our findings. In this results section, we will make use of the framework referring to positions and storylines when applicable.

4.1 Coordinated and Uncoordinated Course Aspects that Influence Student Experiences

From thematic analysis of the student data, there were six themes to emerge. We present the six themes before describing them in greater detail respectively.

1. Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning.
2. Uniform and coordinated policies around timing provided structure and supported engagement.
3. Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding.
4. Instructor pedagogy was more salient in students described experience than their awareness of uniform elements.
5. Embedded additional resources when utilized by students contributed to positive views of mathematical ability.
6. Small class sizes and instructional format support developing relationships with instructors and peers especially when instructors are able to facilitate interactive lessons.

4.1.1 Theme 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning.

This theme encapsulates the reported difficulties and challenges participants faced with their learning when uniform elements were not coupled with mechanisms to meet their individual needs. This theme also includes the reported strengths and opportunities participants felt with their learning when uniform elements were coupled with mechanisms to meet their learning needs. By mechanisms we mean an embedded process and/or procedure that could be in tandem with a uniform element that could help facilitate learning such as responsive feedback.

In this theme, we highlight three uniform elements that participants discussed and the mechanisms or lack of mechanisms that either facilitate or inhibit their learning. These uniform elements being: (1) Lecture Videos, (2) Online Homework, and (3) Exams.

As uniform elements can't position students, it is important to note how students go about positioning themselves with respect to uniform elements given the presence or lack of mechanism to meet their needs.

Lecture Videos: For the uniform element of lecture videos, we saw how variability of instructional videos and their quality led to inconsistent learning experiences. However, when coupled with a mechanism such as making videos on demand, students did report positive feedback in their learning as they could position themselves as mathematical inquirers. We also saw how the static nature of instructional videos prohibited real-time questions which inhibited learning as not all students could position themselves positively in math.

For students with a flipped structure format, like business calculus, their first exposure to the material is through lecture videos. Lecture videos were the same for all students. They were pre-recorded by different instructors whom the coordinator rotated between across the lessons. Participants reported that the variability of instructors led to inconsistent learning experiences. Participants, like M and Elizabeth, expressed finding certain instructors more helpful than others.

I know they all do it kind of differently, like one of them writes the questions while she's teaching it, and then, like 2 other people, have them pre-written. and I like I kinda like the prewritten ones more cause then I can write them down while I'm listening, instead of having to wait, and then, like being like behind. (M Interview)

It honestly depends on some of the people in the video for me, like, there's some people I'm like, 'Oh, my gosh! I hear their voice, and I'm so happy that they're like the assigned teacher for this section.' And then sometimes I'm like, 'Oh, my God, not them. because they're not helpful.' (Elizabeth Interview)

M and Elizabeth expressed having preferences for the instructors who oversaw certain lecture videos. As Elizabeth described, she found some instructors more helpful than others. With a variety of instructors, came a variety of instructional approaches. Participants, like Olivia, expressed difficulty altogether with adapting to the rotation of instructors.

Cause, I feel like every video lecture that we watch, it's from a different person. So, each different person has a different way of their teaching styles. [If] you have like one professor that's teaching you, you kinda have to get used to that one professor, instead of every different person's teaching styles. (Olivia Interview)

When interviewed at the start of the semester, the coordinator for business calculus informed us that the intention behind the rotation of instructors for the videos was because when she had only one individual teach the videos students complained about not seeing their instructor when the one individual wasn't actually their instructor.

The confusion being that if there was only one person doing the videos that students may think the individual doing the videos was their instructor.

In the study, participants did not report confusion of who their instructor was but they did discuss their confusion of understanding the material from the videos. As mentioned by Olivia and Elizabeth, different teaching styles resulted in varying qualities of instruction leaving students with insufficient explanations to the lesson's content.

> *I wish the videos were more detailed. How [do] you get this answer? What do you do next? And that's where I'm kind of having a hard time with math right now."* (Olivia Video Journal #4)
>
> *I do wish they explain themselves a little bit more. They will go through the steps they take to get an answer in an example in the book. but I feel like sometimes they do lack an explanation as to why they are doing the steps they're doing, and although it would add a little bit more time to the overall duration of these videos and the length. I think in the long run it will be appreciated by a lot of students just because it would eliminate a lot of confusion we may have about why is this equation working for whatever? Xyz? yeah, just being a little bit more. giving a little bit more detail behind what they're doing, why, they're doing it. Instead of just saying, you take this number and do this with it*. (Elizabeth Video Journal #4)

Here, the reported variability of instructional videos and their quality leads to inconsistent learning experiences. With the lecture videos being pre-recorded and established prior to the start of the semester, the mechanism of making additional videos

on demand could aid in providing necessary details that students may need, like in the case for Joselyn's instructor.

> *He's always giving us these extra videos as extra help. So, it's like I do feel like I have the best teacher because of all the help he gives us. With all the help he gives us with the way he explains this stuff to us. It just feels like he's the best teacher to take this course with.* (Joselyn Interview)

For participants that had the lecture style format in long calculus, they also had lecture videos like the participants for business calculus. However, their lecture videos were supplemental material and available to them as additional resources. However, Joselyn's instructor would make extra videos for his students based on observations of content they were struggling with and even requests. With this mechanism, students can position themselves as mathematical inquiries and explorers by wanting more information regarding certain topics. These positions are then affirmed by their instructor making and/or providing custom videos on the topics the students inquired about.

Along with the quality of the videos, business calculus participants reported the time-consuming nature of the videos. While students have the option to pace themselves with the videos, in terms of pausing or rewinding, there can be instances where students may not have time at all to watch the videos. Participants Sappho mentioned falling behind with watching the videos.

However, Sappho goes on to say that she is able to utilize other assignments in the course to learn the material instead of depending on the video lectures. She's able to position herself as a mathematical learner and substitute her learning through other course

material. However, not every student may be able to position themselves similarly and teach the material to themselves. And, as indicated by M, the static nature of lecture videos also prevents students from asking real-time questions.

> *If they're really busy, they don't have time to watch the lecture videos outside the class, which could be a struggle. I can see how it could be like a struggle if, like, during the process of learning. Someone has a question, but they can't really ask the question to a video.* (M Interview)

As not all students feel comfortable talking with their instructor and may fear "asking a stupid question," students in this situation may not come to class to ask their questions or email their instructor and instead try to make up for the learning elsewhere. Olivia is one of these students who, due to the static nature of lecture videos, reported struggling with learning the content. If you remember in *Section 3.4.2 Case Studies*, Olivia started the course with mathematical macro-identity in the Low Math Identity group. Unlike Sappho, who started the course with a mathematical macro-identity in the High Math Identity group and was able to compensate for her learning through other assignments, Olivia could not.

> *Having like the learning activities like, I understand, like we need them. But at the same time, I feel like there's a lot of just busy work. And it's like, when I am doing learning activities, I'm not doing it because it's going to get graded. Right or wrong, it's just going to get graded like if I did it or not. So, I feel like in that aspect, like, I'm not really learning like what I'm doing right, what I'm doing wrong, you know. At the same time.* (Olivia Video Journal #4)

For Olivia, the connection between the assignments and their contribution to her learning is not entirely clear. She feels that they are tasks that need to be done for the sake of needing to complete them and not necessarily to further her understanding. As Olivia is unable to compensate for her learning from the lectures through the in-class activities, she could benefit from a mechanism to be coupled with the lecture videos in which she could position herself mathematically positively as a learner or inquirer of math.

Online Homework: For the uniform element of online homework, participants described how the mechanisms of multiple chances and ability to receive instructor assistance facilitated their learning as students can position themselves as mathematical investigators working on finding the solution. However, participants expressed frustration with the homework software not being able to assist students sufficiently when they are wrong, inhibiting learning independently of the instructor and self-positioning as mathematically incapable.

For the uniform element of online homework, participants reported a benefit to their learning process was that the software consisted of mechanisms that allowed multiple chances to submit problems and the ability to receive instructor assistance.

> *Oh, I like the website we use for our homework. It might be a little specific at times which gets frustrating. But I can-- I can ask my teacher without having to email her. And that is super helpful cause it's just easier to ask my question. And then she knows exactly which problem I'm talking about to get back to me in my own time, and is right there, for when I'm looking at and trying to solve it again.*

And I like how the homework you have multiple chances on, and it tells you little hints to help you figure out what you're doing wrong. That's nice, too. (Mabel Wyler Video Journal #4)

With the online homework having an option to contact the instructor, it allows students another medium to communicate with their instructor by sending a direct snapshot of the problem in question. This mechanism gives students a chance to position themselves as mathematical investigators and get reaffirmed by their instructor when the instructor responds.

However, a disadvantage was that students felt they could not always learn on their own as the software would not sufficiently assist them when they are wrong.

The only thing that I wish the [homework] did was like if I got something wrong. Tell me what I got wrong. or like, help me guide me in the right direction. So yeah, I--that's something that bothers me a lot like when I'm like, let's say I have 5 tries for like a certain problem, and I put something in wrong like I wish it [gave] something to help me like, guide me along and be like, Okay, you did this wrong, or Hey, you need to try and work it out like this, because sometimes I go to look at the online textbook, and it has the example problem. It's very similar to it, just with like different numbers. And it only shows the answer but isn't sure you have the steps to work through it. So, it's kind of hard like. If I'm confused on an issue. I can see an answer for a set, a different type of problem, but I don't know how to work through it, and which is what I'm always trying to figure out how to do so.

That's something that frustrates me about [my homework]. (Ally Jackson Interview)

While the mechanisms of multiple chances do help with alleviating pressure while doing homework, students like Ally Jackson describe a desire for more provided assistance in conjunction with those chances as she wanted to figure out the problems independently of her instructor. It could be that having to reach out to her instructor may position herself as mathematically incapable but if she could find a solution herself, Ally Jackson could then position herself as mathematically capable. Students like Ally Jackson who express the desire to solve problems independently could benefit from an additional mechanism to be coupled with the online homework.

Exams: Another uniform element that participants reported inhibited their learning when not coupled with responsive mechanisms was centered around exams and the weight they carried. Participants reported exams as a source of stress and how they felt the pressure of the weights set by the grading system. Because of this, participants described their desire for more learning checkpoints prior to exams to facilitate learning.

We were surprised to see how little the topics of exams came up in the video journals and interviews given the emphasis in prior literature. We attribute this to the fact that seven of the ten participants in the study started with a relatively strong math identity (see *Section 3.3.8 Post-Math Identity Survey* for tables of participants). And these participants tended to report performing well on the exams.

I do have an A in the course. So, I do have a little bit of an advantage, like I've done really well on my exams, and I've gotten As on both of them. So, there I do have a little bit of privilege to say, oh, well, I do like the grading system. When I came into the course. exams are worth 70% of your grade which did scare me. I was really nervous, but I was like, I'm just gonna have to really study. So, in the aspect, because I do well like that's reflected in my grade but I definitely. if I didn't do well on the exams, I'd be really upset that my exams are worth 70%.

(Ally Jackson Interview)

Although performance is an indirect influencer on math identity ((Cribbs et al., 2015)), grades significantly influence students' views of themselves. As seen with Ally Jackson, she positions herself as mathematically capable which is reaffirmed by doing well on the exams and consequently the course. Similarly, Olivia reported how performing well would have contributed to feeling more confident in herself and her mathematical abilities.

Although Olivia did not perform well, she believed that successful performance would have also supported feelings of confidence. With Elizabeth, we also saw how test performance influenced affective views. Elizabeth described the nervousness she had for the weights of the exams at the beginning of the course, but, because of her performance, was not too concerned about the overall grading system.

Obviously, your exams are like, always have the greatest weight in your overall grade, which is probably why I was most nervous about it, because if you want to do well, and of course you have to do well on the exams and it I would also say

out of everything else I guess that'd be my main focus and my main like stress. Not even that. It's like a stressor. But that definitely still would be like my biggest source of nerves, but I wouldn't say it's as high as it was when I first started the class. I haven't really like questioned [the grading system]. I think that's mostly in part because I have a grade I'm really satisfied and happy with. But for someone who isn't. Then I could see why they would have stuff to say about like how the grades are distributed and in what ways. (Elizabeth Interview)

Both Elizabeth and Ally Jackon highlight the weights of the exams and the psychological factor the weights have in terms of stress. However, due to their performance, they're able to reaffirm themselves as being mathematically capable and feel less of that psychological pressure. With students, like Dylan, we saw the pressure students feel with the weights of exams when not performing well.

The more anxious that I feel, and the more stressed I am especially with a subject that I really do dread and I'm not the most confident, nor am I going to be the most comfortable, the quicker that my performance begins to suffer the harder it's going to be for me to get back on track. (Dylan Video Journal #2)

Dylan provided the analogy of getting off track. We expand upon this driving illustration by describing the course as a racetrack. All students are driving the same cart as indicated by the uniform elements prescribed by the coordinator. Given the weights, each exam–including the final–is a tire. If a student does poorly on an exam, it can be likened to a tire losing air making it difficult to drive and to keep up with the other drivers. As anyone who's ever had car troubles knows, headaches and frustration can

ensue from not having a fully functioning vehicle. And as Dylan described, this then places even more of a psychological strain than before.

> *Yeah, as this is something that can really break--make or break a person. Not everyone is good at taking tests, you know whether it's anxiety, poor study habits. Whatever you know. And while I understand that this may be the only way to evaluate a student's performance. I feel as though it does more harm than good, especially when a student is trying, but really can't perform well enough to pass those exams or high marks. I feel as though you know it does more harm than good.* (Dylan Video Journal #4)

For Dylan, who came into the course with a weak math identity, her self-evaluation of her testing abilities has her positioning herself as mathematically incapable which is then reinforced by her poor test performance. Each subsequent poor test grade resulted in even more car trouble through her course journey, getting off track even more and feeling unable to continue.

> *[I feel like my instructor helped] partially. I feel like I was too far gone at a point. There were certain things I didn't know exactly what I needed help with until you took the exam, and you're just like, Oh, that's not good.* (Dylan Interview)

For students like Dylan, who may suffer from test anxiety, exams alone may be doing "more harm than good" and inhibit learning. Utilizing a mechanism of learning checkpoints could relieve pressure prior to exams and also help with informing students of areas they need help with, which was a mechanism suggested by Aves.

Maybe it would be good if we had like non graded, but like small quizzes throughout, so you could see how your progression with understanding certain topics is going before the exam, because the exams are a way to see how you're doing, but then they're graded. So, by the time you see how you're doing, you don't really have time to improve, because it's already gone in the grade book. (Aves Interview)

For students like Dylan, learning checkpoints could act as car maintenance for accident prevention. In any case, the uniform element of exams needs to be coupled with a mechanism to help facilitate learning and relieve the pressure students feel with the assigned weights.

In summary, it was seen in the data that uniform elements, such as lecture videos, online homework, and exams, when not coupled with mechanisms to meet student needs inhibited learning and productive positions of mathematical capabilities.

4.1.2 Theme 2: Uniform and coordinated policies around timing provided structure and supported engagement.

As in the pilot project, the element of time reappeared in the study. This theme encapsulates uniform and coordinated policies around timing such as: (1) Time of class, (2) Contact hours, and (3) Course calendar.

We saw time as an element related to both engagement and structure. Participants reported various degrees of engagement for when a class was scheduled and how often their class met. Participants also reported relief in knowing about important dates in advance and how they were able to establish a routine.

We acknowledge the fact that the time of classes is usually not considered a uniform element and was not the case for this study. The other aspects that will be discussed within this theme, the number of contact hours and the course calendar, were the same for students in the coordinated system. Although time of class was not a uniform element and directly related to course coordination it *could* be. Due to the salient findings from the data, we include this element in the results and discuss it further in *Section 5.2 Recommendations*.

Time of Class: Participants reported different experiences depending on their time of class with students who had morning and afternoon classes describing difficulty being able to engage with the material which in turn can impact their ability to accept or reject positions afforded to them in the classroom.

From the data, there was an incongruence in the level of engagement depending on the time of day the class was scheduled, with students in the early morning and later afternoon classes reporting difficulty with paying attention to instruction. When talking about how experience may be different from other students across sections, Joselyn refers to her friend whose section was in the afternoon (after 3 pm):

> *Because that's her last class. By the time that class starts she's already ready to go home. She's like, you know, she's just ready to get out of there.* (Joselyn Video Journal #3)

Joselyn reported that her friend would text her while in class to inform her of how tired she was and express her difficulty to pay attention, the time of class impacting their

experience with the subject. We also saw a similarity in difficulty to engage for students who had morning classes like Aves.

> *When you have an 8 am, you know, people have to get up at 7 or earlier to get ready for the class. They're not quite awake by the time they're in the class, and math is a subject that you have to be like present, for, like you have to have your cognitive function like really there. So, the fact that our class happens earlier means that it takes a little more work for us to learn the content, I would say, compared to classes that are later in the day because we're still kind of shaking off sleep. Like it just jumped from nothing into intensive work.* (Aves Video Journal #3)

As stated by Aves, students who have class early in the morning are still in the process of waking up and may not be entirely present for the content that is being taught that day. Students' level of engagement can impact their ability to claim, take up, or deny duties in class that may help with understanding the content such as taking notes, listening to lectures, and asking questions. This in turn can impact positions they may accept or reject. Again, time of day is not coordinated, but it's a course structure that contributes to variability in student experiences, which is in direct tension with the aims of course coordination.

Contact hours: Participants reported how their preference to cover content (i.e., inside or outside the classroom) related to their desire for more or less contact hours, positioning themselves as mathematical explorers engaging with the content.

Another aspect of time that influenced student experiences was related to the contact hours of the course. We saw participants linking content coverage with contact hours. For the courses involved in the study, business calculus students met three days a week for 50 minute class periods, with lecture videos outside of class, and long calculus students met four days a week for 50 minute class periods.

Across both courses, participants associated the number of contact hours with the coverage of content. Coverage of content referring to the ways in which students were exposed to the content and how they interacted with the content. For instance, participants who experienced a flipped structure covered the content both outside the classroom through lecture videos and inside the class through learning activities. They reported an increased time spent with the material due to watching the videos outside of class which helped with engaging more with the material in class.

Business calculus students were able to familiarize themselves with the material before coming to class, preparing to engage themselves for the day's activities and other related assignments as described by Elizabeth and Mabel Wyler.

> *[Class time is] also helpful for me to get feedback and answers to questions. So, I can move forward, and, you know, eliminate any confusion I have with a topic*. (Elizabeth Video Journal #4)
>
> *Since we are allowed to ask multiple questions. And had-- She [instructor] has multiple TAs circulate, circulating the classroom throughout the classroom, helping us understand the work we are assigned, and I enjoy that.* (Mabel Wyler Video Journal #2)

Inside the classroom, business calculus students can ask questions of both their peers and instructor as they work on the assignment for the day and work with the content, having both independent time with watching the videos outside of class and their regular scheduled contact hours inside the classroom. As some participants expressed their frustration with the time-consuming nature of the lecture videos (see *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning.), some described their desire for even more contact time with the material.

> *I feel that if the classes were longer then we could do notes and the worksheet. That's what I would hope at least to be able to take the time to talk about it in person, because sometimes I understand better in person. So, if at least, if that was like an option to think about, you can either do the notes like, come for this set of time. We'll do the notes in person*. (Ally Jackson Interview)

Ally Jackson, who had a strong math identity, shared her inclination for more internal settings to further engage with the content through either longer classes or additional days, perhaps even a 3-hour lab. She was a huge fan of the flipped classroom but as a mathematical explorer she wanted more contact hours to spend with the content in a classroom setting.

Participants who experienced only covering the content inside the classroom with a lecture style course, reported advantages and disadvantages to how they covered content. Aves and Joselyn expressed their preference for the lecture style as they reported

that the classroom setting was their ideal learning environment, better supporting their engagement with the material.

> *I have always struggled with the online videos, like, especially in quarantine in high school. I feel like I can't concentrate at home like I'm very much a person who needs a physical distinction between what I'm doing in this space versus what I'm doing in this space.* (Aves Interview)
>
> *I cannot focus on lectures outside the classroom. If I'm going to be in a lecture it's going to have to be in the classroom. Like videos online, I can't sit through them. Those are the hardest things for me to do, especially me. I have ADHD and I can't focus.* (Joselyn Interview)

Similar to Ally Jackson, Aves and Joselyn, reported how a classroom setting helped them in positioning themselves as mathematical explorers. They found that the classroom contact was more beneficial to their engagement with mathematics than an external setting like a video. In fact, for Aves, meeting for four days was not enough. She found that spending more time with the material during the week helped with her understanding of the concepts and expressed her desire for even more contact hours.

> *Being in class, being in a math environment that helps me, you know, the more I'm in class, the more I'm in that environment the better my performance is. So already it's better than other classes being 4 days a week. But it could be even better if it were 5, and I don't think that would be too much time in class since, like I said, it's a short amount of time in class. I can do 50 min every day, like you know. I did an hour and a half every day when I was in high school. 50 min is*

nothing, and I genuinely do like being in math. So, I don't think it'd be a drain or anything. (Aves Video Journal #4)

Aves, who started with a weak math identity, expressed a similar desire as Ally Jackson for even more contact time to engage with the material further. Although we discuss Aves in greater detail in *Section 4.2 Experiences Impacting Women and Gender Fluid Students' Math Identity*, we note here that Aves' mathematical macro-identity did change over the course of the semester. In particular, her interest in mathematics rose.

Where Aves, whose enjoyment in learning mathematics increased, wanted to meet more, participants, like Nadia, whose interest in mathematics remained low from start to finish, believed that the frequency of contact periods in the week could have been less.

I feel like honestly, it's overkill and I've never been good at paying attention while I'm in math classes like I learn from the outside class stuff. So really for me, even when I go into it wanting to try. It feels like a waste of 50 min. That's 4 days a week but that is generally just a personal thing. I know a lot of people benefit from the 4 day thing. So, I'm not complaining about it. (Nadia Video Journal #4)

With Nadia's mathematical identity not changing, we contribute her desire for less contact hours due to her low interest in mathematics and her desire to explore math in more external environments like a flipped structure. She expressed that a better learning environment for her may be outside the classroom where she can pull up content videos and work on homework while the videos play.

As we saw with these participants, the number of contact hours, whether more or fewer, supported different levels of engagement with the content. Those who preferred

engaging with the content in the classroom preferred more contact hours than those who preferred engaging with the content outside the classroom.

Course Calendar: Participants reported appreciating the ability to prepare and feelings of relief through the structure provided by the course calendar regarding knowing when topics would be covered and when the exams were.

Both business calculus and long calculus had what were referred to as common exam times. In fact, when scheduling for their classes, the common exam time is part of the course section that students register for. Participants reported the advantages of having a common exam time were that it helped with relieving anxiety and preparing appropriately as stated by Joselyn and Ally Jackson.

> *I love having a set time for these exams. It prepares me because I like being able to take it at the same time with everybody else cause we're all struggling at the same time. We're all passing or failing at the same time. I like that. I feel like making them all at a certain time like work to not make me so anxious*. (Joselyn Interview)

> *I do like having the math exams outside the course, and we already have all our exam dates listed, and everything like I've had it marked in my calendar since we got our syllabus. So that's been nice, that way I can prepare, and I know what to study and what not to study.* (Ally Jackson Interview)

Participants also reported that the advantages to a predetermined course calendar was the transparent communication of coverage topics which helped with establishing a structured routine as described by Elizabeth.

With the course calendar, participants described that having knowledge of when topics were covered and when exams were helped with establishing structure and letting them prepare. Having advance knowledge of when the exams were scheduled helped to relieve stress as students were able to mentally plan for those important dates. In the next theme, we discuss how participants felt when something unexpected came up that conflicted with the dates scheduled in advance by the course calendar.

In summary, it was seen in the data that the uniform and coordinated policies involving timing such as time of class, contact hours, and course calendar provided structure and supported engagement.

4.1.3 Theme 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding.

As seen in *4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement., participants viewed time as an element of relief when providing structure. However, they viewed time as an element of stress when seen as a barrier when having to adhere to a strict uniform schedule and rigid due dates.

In this theme, we report the impact of instructors accommodating student needs by adjusting uniform and coordinated policies such as: (1) Time spent on topics, and (2) Flexibility with due dates.

Through these accommodations we saw participants feeling they were being positioned as mathematically capable by their instructor promoting content understanding.

Time spent on topics: In the previous theme (*4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement.), the course calendar was seen as a uniform element that participants reported provided structure and helped them prepare. However, participants also reported that time spent on topics was not always enough, feeling mathematically incapable if they did not understand the topic sufficiently within the prescribed time frame. Participants expressed the importance and appreciation of their instructor being able to adjust time spent on topics appropriately.

Most participants reported general positivity about the pacing of the material across both courses already set by the course calendar. As expressed by Mabel Wyler, she appreciated how the calendar had taken account the difficulty of certain sections and had allotted instructors to spend more time with the content to help with understanding.

> *I also like that. She will spend multiple days on the harder parts, like, for example, 1.6 was supposed to be harder to comprehend. So, we spent 2 days on it, and then right now we're working on tangent lines. So that's a little bit easier to understand and we are only spending one day on it, or one day on the part. So, it's like 2.1, and then 2.2 the next day, instead of just doing 2 days of 2.1, like we did with 1.6, because 1.6 was harder and we needed more time.* (Mabel Wyler Video Journal #2)

Through the feature of regular instructor communication, the coordinator was able to determine topics that were deemed challenging by students from previous semesters and made an executive decision, as choice architect, to adjust pacing for the collective

whole, allotting more days for certain sections and less for others. Here we can see a direct link from the course coordinator, how it's implemented by the instructor, and the resulting experience of the student.

While coordinators may make informed decisions based on previous semesters regarding the course calendar, some participants still felt that time spent on topics was too little and not enough for their content understanding. Participants like Dylan, who had a weak math identity, reported the difficulty of falling behind in a fast-paced course.

> *Currently, I think that her methods are a bit more on the get it and go side of things which really just means well, I've been trying to adapt to her methods. It's a very fast paced course. So, if you snooze, you really do snooze, and I've had to learn that the hard way.* (Dylan Video Journal # 2)

In *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning., Dylan provided an analogy of getting off track. We expanded upon this driving illustration by relating the course to a racetrack with all students driving the same cart as indicated by the uniform elements prescribed by the coordinator. We can think of the course calendar in this analogy as the GPS system in the car, providing the same navigational route. We add to this analogy the drivers themselves and the individual differences they bring.

Now, as anyone who has been on the road can relate, not everyone drives the same. There are cautious drivers, reckless drivers, those who miss turns, and those who can parallel park (and those who can’t), impacting their ability and the time it takes for them to follow the assigned route. Some might even be familiar enough with the area to

know shortcuts and/or to navigate traffic more efficiently. This relates to how there can be differences in students ranging from their math background, their math identity, their workload, and more that can impact their ability and time to process information. As Dylan continued to report in her interview, she expressed her large course workload that she had to juggle along with the fast pace of her calculus course.

> *I felt like there was a lot of material that we were learning in a short amount of time, especially for, like STEM majors, you know. You're taking so many different STEM classes at once. If you don't have the time to focus, you either fall behind, or you just suffer.* (Dylan Interview)

She described the challenges of falling behind which we illustrate with having a delayed time to your original destination time. There can be a range of emotions when one's expected time gets delayed, even more so when you can't be late. Missing a lesson, either physically or mentally, can have students position themselves as being mathematically incapable for that lesson and consequently future ones as they stress about how they may finish the course. As we saw with Dylan, her performance suffered throughout the semester and so did her relationship with math.

Falling behind, Dylan continued throughout the semester to position herself negatively and may have benefited from her instructor making adjustments to the course calendar. Aves described the importance of an instructor being able to adjust uniform and coordinated policies to accommodate student needs and promote student content understanding.

> *If a class is struggling with a particular concept or like a test was taken, and a lot of people got some problems wrong, like the ability to go back and say, 'Hey, we need to review this again, even though what's even though, like the schedule might say, you need to do this instead', like the teacher being willing to say, 'no, this is more important that I need to make sure they get this. You know, we can squeeze that in another time. But this is a really important concept, too.' I think that's something that's very important for students to like. Make sure they hammer down the important concepts. And if teachers were forced day to day to an exact lesson plan, I feel like that wouldn't work very well, because every class and every teacher is different. So really, it's up to the teacher to know their individual class needs so they can adjust it to make it fix that or make it fit that.* (Aves Video Journal #2)

Course coordinators may be able to use past information to make adjustments to the course calendar the following semester. However, during the semester itself, Aves touches on the fact that, because every class is different, instructors may be in the best position to make informed decisions on any necessary adjustments to help with promoting content understanding, such as time spent on topics. For students, like Dylan, who feel like they are falling behind, this adjustment would be like the GPS offering a detour to allow drivers a chance to keep moving forward to their relative destinations.

Flexibility with due dates: In the previous theme (*4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement.), due dates such as common exam time were seen as a uniform element that participants

reported provided relief. However, participants also reported that rigid due dates and lack of extensions caused them stress and scrambling to submit work on time. The restriction of not being able to submit work limiting positive positions afforded to participants.

When due dates were too rigid, participants reported feeling stressed and scrambling to submit work in time as reported by Sappho.

> *I felt like I tried to get extensions on some of them, and it just didn't happen. So, I found myself a lot of times just scrambling to guess answers, just to get as many points wrapped up on those as possible*. (Sappho Interview)

For students in Sappho's situation, the inability to get extensions resulted in a lack of content understanding as she rushed to submit the assignment. Instead of having adequate time to spend with the content and position herself as a mathematical investigator or a mathematical explorer, Sappho had to sometimes forgo those positions just to get a submission. We discuss in greater detail Sappho's change in math identity in *Section 4.2 Experiences Impacting Women and Gender Fluid Students' Math Identity*, but it should be noted that because of her lack of recognition over the course of the semester, Sappho's math identity weakened. If her instructor allowed extensions, her instructor could have positioned her as mathematically capable, recognizing her ability to do mathematics.

When due dates are rigid, it may also lead to issues where students have done the work but can't submit the work as in the case of Olivia.

[There's no flexibility in due dates]. There would be sometimes where I would do the lecture check and you have to upload it from a Pdf, and so I try to do it with my computer. But sometimes it would just like take a while, so then I would go to bed, and then I'd wake up in the morning, I'd think, oh, my gosh! Like I forgot to submit it, even though I did it. I just didn't get enough time to submit it. So, I wish almost like it was due, maybe like an hour before the class started. Just so. I have that time to wake up and remember what I need to do and do it, you know. (Olivia Interview)

Unable to submit work, not only can't students receive a grade for the assignment, but they also can't receive any necessary feedback either they may need to help with their content understanding. For students like Olivia, who maintained a Low Math Identity, not being able to submit work she's completed inhibits her content understanding and limits the possibilities of positive positions from her instructor.

With Aves, we saw how she was positioned by her instructor as being mathematically capable through continuous extensions he offered. She shared how her instructor's flexibility helped with meeting her needs and demonstrating to her that he cared about her understanding. In turn, this recognition had an impact in strengthening her math identity (discussed in more detail in *Section 4.2 Experiences Impacting Women and Gender Fluid Students' Math Identity*).

And in the course, we had a lot of assignments that were assigned, and due the same day. I was having issues completing them because the turnaround was really fast, and I wouldn't have a lot of time to do it because of the--um you know,

because I'm rowing all the time, and he's been really understanding with that. And he never made an issue with me, getting extension, basically every single time, like, just for one day. Him being understanding with that has really made it easier for me to approach this class, you know, because I know if I'm having issues like I can just explain it to him, and he'll like, hear me out on it, even if he can't do anything about it. (Aves Interview)

Her instructor's willingness to accommodate her athletic schedule positioned Aves as mathematically capable, giving her a chance to complete the required assignments and demonstrate her knowledge of the material. It is important to note that when her instructor was interviewed, he reported his subversion of coordinated policies. The flexibility he allowed Aves was one he made an independent decision for. He expressed not wanting to share this information with the course coordinator as he was hesitant of her approval of his decision. It was this specific subservice practice that fostered equity and bolstered the positioning for students.

We saw the importance of instructor flexibility with Ally Jackson as well. Her instructor wasn't subverting coordinated policies, like Aves, but still demonstrated accommodating student needs when a section assignment was taking longer than expected. Ally Jackson was appreciative of her instructor's willingness to adjust as she knew not all instructors were as flexible. In turn, with the accommodation, Ally Jackson made use of the extra time by visiting her TA in their office hours later that day. Not only did her instructor position her as mathematically capable with believing she could

complete the assignment with more time, but the opportunity allowed for greater content understanding and positive positions as Ally Jackson worked with her TA through the quiz.

> *Before our unit two exam, we did a unit two big quiz, and no one finished it, and it was supposed to be due at 12 pm. We get out of class at 11. And she said, 'I'm gonna extend it because I know that the majority of you are not finished. I want you to be able to not be stressed about it, especially if you have. You know, classes back-to-back. I want you to be able to take the time to finish the quiz.' And I really appreciated that, like her realizing, 'Almost none of my students finished it, and they still have a-- I would say about, like, you know. 5 to 10 questions left. Let me push back the time.' I thought that was really nice for being flexible, instead of being like 'well, good luck, you know. Try and get it done as quick as you can.' I know not all the professors are that flexible.* (Ally Jackson Interview)

As described by Ally Jackson and Aves, their instructors' decision to extend the due date by just a small window promoted their content understanding and positively positioned them in math. Participants like Sappho and Olivia, their instructors' decision to not extend due dates impeded their content understanding and negatively positioned them in math.

As mentioned in *Section 2.4 Affordance to Research*, instructors play an instrumental role in student interest and engagement with mathematics. Teachers have the power to make positive acts more likely to occur such as their flexibility with assignments and adjustment to time spent on topics to accommodate student needs and

promote content understanding. We see the importance of instructor pedagogy in the following theme.

4.1.4 Theme 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements.

This theme encapsulates the importance of instructor pedagogy participants reported in their described experiences. Participants described how the intentionality by the instructor for real-world connections and dynamic teaching methods helped with their engagement and interest. In particular, when participants mentioned awareness of differences across sections the differences they reported were centered around the instructor. Thus, we saw that overall instructor pedagogy was more salient in their described experiences. We describe three major qualities that are captured in this theme: (1) Instructor pedagogy, (2) Learned differences informed by peers, and (3) Unawareness of differences.

Instructor Pedagogy: We concluded *4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding. with stating the instrumental role instructors can play in student interest and engagement with mathematics. Not only do teachers have the power to make positive acts more likely to occur through accommodating student needs by adjusting course policies, but instructors can also impact student experiences through their pedagogy. Participants reported the benefits to their experiences when their instructor was intentional in their teaching to make real-world connections and to include dynamic methods.

For the courses involved in the study, the uniform element of a lecture-note-taking guide was implemented. Students in business calculus took notes through the lecture videos and students in long calculus took notes in class during lectures. We already discussed the variability of instructional videos in *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning. led to inconsistent learning experiences. However, the videos were the same for all students in the course. The instructors of the students themselves and the instructional approaches were not the same.

Participants with instructors who utilized techniques such as making real-world connections reported benefits to their learning experiences, like Joselyn. She described how her teacher provided a story of when he used limits to get out of a speeding ticket. For Joselyn, this integration of the content into real life had a way of catching her attention.

> *Something I've really enjoyed is how my teacher gives us, like real life situations where he had to use math to prove something. And recently, that's one of the things I've enjoyed about math is finding a way to integrate it into my life, because I'm majoring in mechanical engineering. So, math is going to stick with me throughout basically the rest of my life. And I like to go ahead and get used to that. Go ahead and get used to using math in anything*. (Joselyn Video Journal #4)

For students like Joselyn, who started the semester with a High Math Identity and already a high interest in mathematics, the intentionality of her instructor to make these

real-world connections not only maintained her interest but strengthened it as well. By relating content to the real world, her instructor is positioning all his students as mathematical explorers, encouraging them in making connections with the content. For participants like Aves, who started the semester with a Low Math Identity and a low interest in mathematics, we saw how this intentionality increased her interest in math.

> *We're allowed the chance to be wrong, which I think is very important, and like being wrong isn't a bad thing. We're also allowed the chance to try and figure things out, using non-traditional methods like going about things different ways. So, I think that the chance to be wrong makes math more approachable*. (Aves Video Journal #4)

Aves described appreciating that her instructor worked out suggestions by students, encouraging them to be engaged with the math. Together, the instructor and students explored math either discovering why an approach was wrong, which helped with understanding, or learning how to figure out a problem in a different way. As Aves shared, this made the math more approachable for her and she reported enjoying learning mathematics.

As mentioned in *Section 2.4 Affordance to Research*, teachers have the power to make positive acts more likely to occur for more students (Cobb et al., 2009). These acts don't go unnoticed as Aves also described how her instructor kept class interesting through his dynamic teaching methods. We discussed in *4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement. the impact of time of class on engagement. Aves shared how her instructor's use of a free

response question at the start of class helped make the class enjoyable. Seeing him put time and effort, made Aves want to reciprocate.

> *Something else he does is that you know he knows that it's an 8 Am class. We're all tired. We all got up early. He doesn't make us do actual math problems which I always found annoying in high school. You know, I'm barely awake to do math first thing in the morning. [He'll] take attendance [by asking], like a really funny, open, ended question. It's great to be able to answer those instead of having to do math. So being able to think of random things like that to start your day like it gets your brain open without immediately shoving into the hard material.*
>
> *It really feels like he does understand the student experience, and he's trying to make it good for us, like he's putting in a lot of time and effort to making sure that we know the content and we like learning the content. The overall experience is good, and it's coming across really well.* (Aves Video Journal #2)

We discussed in 4.1.1 Theme 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning. how Joselyn's instructor provision of custom videos for topics suggested by students affirmed positions of students as mathematical inquirers. Dynamic teaching methods that keep class interesting, like Aves described, and that encourage questions, such as to provide instructional videos, have positive benefits to student experiences due to the positions afforded to students.

As mentioned in *Section 2.3.3 Mathematics Identity Studies with Positioning Theory* with the Boaler and Greeno study, differences between learning spaces, and the

opportunities provided, can have a significant impact on how students position themselves as learners. When it comes to students' learning in the mathematics classroom, it has been found that teachers' positioning of their students can be more influential than classroom resources (Tait & Loveridge, 2016). Joselyn and Aves reported being active agents, being able to construct their understandings through non-traditional methods implemented by their instructors. The affordances allotted by their instructors allowed them to position themselves or be positioned by others as learners and doers of mathematics. We discuss these positions in greater detail for Aves *in Section 4.2 Experiences Impacting Women and Gender Fluid Students' Math Identity* as we saw her math identity strengthen over the course of the semester.

Furthermore, Joselyn described how important her instructor was to her class experience, even going so far as to claim she had the best section.

> *[My friend] tells me a lot that doesn't feel like she's understanding. What she's doing is she keeps hearing from others about how great this teacher is, how she should have taken this teacher, and I feel like my experience is different from others in other sections based on the teachers.* (Joselyn Video Journal #3)

In a similar vein, Aves describes how an instructor can "make or break" a classroom, reiterating the instrumental role instructors can have for students' interest and engagement with mathematics.

> *So, teaching style, of course, makes an enormous difference between sections of [long calculus]. Whether [students] have similar experiences, honestly, I would say overall no, because the difference between teachers is just so important. It's*

that much of a difference between your math experience. A good teacher, a bad teacher, the same course. It can be exponentially harder. It's not even close because even though it's the same material that they're teaching the way they teach it, how they approach teaching it, the way they run their classroom, all that it makes and breaks the classroom. So, even though it's the same material, I would say that honestly, we really don't have the same experiences. (Aves Video Journal #3)

Both Joselyn and Aves reported how the aspects of the course they enjoy are somewhat dependent on their professor, specifically the environment created. Instructional practices have been found to predict higher levels of students' mathematics identity, particularly, high amount of interaction and activities involving conceptual learning (Boaler & Greeno, 2000; J. Cribbs et al., 2021). We saw the impact of the intentionality of their instructors for dynamic teaching methods and real-world connections had on their experiences, opening them to be more positively positioned in math. Instructor student-centered pedagogy like these methods can be fostered through regular instructor communication as an element of course coordination.

Learned Differences Informed by Peers: Participants reported learning of differences across sections by gathering information from peers whether directly, in-person, or indirectly, such as through websites like rate-my-professor. Differences that participants reported were centered around the instructor such as resources instructors provided to their students, assistance instructors gave to students, and teaching style.

When participants were aware of differences across course sections by talking to peers from other sections, these differences were centered around their instructor, such as teaching style. One of the reasons Joselyn claimed she had the best section was because of the experiences she heard from her friend in another section.

> *And so, my teacher, he does a great job in explaining like he'll give us real life examples. But her teacher doesn't. Her teacher just goes through the notes. My friend sometimes tells me that sometimes it feels like her teacher is not really teaching, but like reviewing. even when it's like new material.* (Joselyn Interview)

For Joselyn, she discovered how much more involved her instructor was with her learning than her friend's instructor in another section. Not only was her instructor teaching differently by leveraging real-world connections, but her instructor was also providing additional resources that her friend was not receiving.

> *I do understand that some teachers have their own way of doing stuff, but I do feel like, even though they're teaching the same material. I do feel like I do feel like there is that I wish everyone was on the same page about what materials they would give out to their students and whatnot*. (Joselyn Interview)

We want to highlight this dichotomy (and irony) that exists in course coordination. From the storyline illustration in CHAPTER ONE, course coordination tames the "wild wild west" by bringing in consistency and stability. Uniform elements are used to establish fairness and treat every student the same. However, as indicated by Joselyn, differences still exist across sections as was the hot topic of discussion when peers talked with their peers–particularly differences in their instructors.

Which makes sense as instructors are humans. Humans are fallible, complex, and unique individuals. Instructors will bring their individual style and approach to the classroom even with uniform elements of what to teach and when to teach. This was seen with Sappho who expressed her desire that her instructor was more involved with her learning as compared to what she had heard from other sections.

> *I definitely heard from other sections that their professors specifically were a little more helpful in class. Like my professor, specifically, just wouldn't go over a lot of the material. He would be helpful if you asked him a question. But, like I heard a lot of some of the other sections had actually done, like mini lectures in class which I never got the opportunity to have*. (Sappho Interview)

As in the case of Sappho, she learned of differences in the level of involvement of her instructor by talking to peers from other sections. As mentioned in *4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding. and discussed in greater detail in *Section 4.2 Experiences Impacting Women and Gender Fluid Students' Math Identity*, Sappho's math identity weakened due to lack of recognition. Due to her instructor's lack of involvement, Sappho did not have opportunities to be publicly recognized for her mathematical capabilities. Thus, we see the importance the instructor can have on the positions afforded to students.

While participants gathered information from talking with peers currently taking the course, they also reported how they acquired information about instructors by utilizing other resources such as RateMyProfessors.com. Joselyn, Dylan, and Aves shared

how they looked at RateMyProfessor to read up on the different instructors for the course. For Aves, she researched instructors strategically to decide what section would best meet her needs.

> *I looked up every single professor who's teaching [long calculus] on rate my professor and it. And I looked at all of the reviews, and they all kind of seemed universally like neutral to negative, except for [my instructor], who had, like 17 glowing reviews, and the only section he taught was an 8 am. But I decided that a good professor was worth it, especially with my background in math, like I need to have a professor who understands. So, I decided the 8 Am. Was worth it, and I asked for him in specific, and I got it, and I'm glad I did, because he is a great professor.* (Aves Interview)

As seen with Aves, all the material and assignments in the course may have been uniform, but the reviews of the instructors were not. Due to a scheduling error, Aves had the opportunity to be able to pick any section of her choosing and specifically picked a section based on the instructor. When classes fill up, students sometimes miss their first or even second picks, having to settle for instructors they may have not wanted and who utilize different techniques as described by Dylan.

> *I know with teaching people say, go on rate my professor, you have to read but a lot of times, even if you do that, the sections are closed and you kinda get stuck with that, professor. So now it's like, if you get stuck with a discouraging professor, you know, you wanna make the best out of the situation. But if what everyone is saying about that professor doesn't give much wiggle room, doesn't,*

you know, help their student? Now you're practically teaching yourself where there's another section that feels their teacher is so helpful and she always provides this. She gives extra credit. She does that now. It's like, wow, we're in the same course. But it's as if we're taking 2 different ones just because of the teacher's personal methods. (Dylan Interview)

As described by Dylan, an instructor's personal touches and approaches can create different experiences across sections of a coordinated course. And different instructor pedagogical techniques were something that participants reported learning and actively discussing with others more than uniform elements as we share out next.

Unawareness of Uniform Elements: Participants reported uncertainty about what was similar and/or different for other sections of the course.

As described in CHAPTER ONE and CHAPTER TWO, course coordination arose from the need to foster fair experiences for students through the feature of uniform elements like lecture videos and due dates. However, it is important to note that participants like Elizabeth, M, and Mabel Wyler, reported an unawareness of the extent to which coordination maintained equality.

Hmm! I guess I wouldn't necessarily know, because I don't know what other sections are doing. I think we all watch the same lecture videos. But off the top of my head, I can't think of anything really specific that I'm aware of. (Elizabeth Interview)

I don't really know how other sections work, like, if they're flipped like ours or not, because if they're not flipped, I guess it'd be quite a different experience. But

if they are flipped. They're probably just watching the same video. So, it'd be quite similar. (M Video Journal #3)

No clue? I think they're just for my class, but I don't know for sure. (Mabel Wyler Interview)

When asked about what information was communicated to students about what's the same for each section, the coordinator stated that it should be obvious that students are watching the same videos and working through the same assignments. However, when participants, like Elizabeth, Mabel Wyler, and M, were asked about their knowledge of what's similar across sections, they reported not knowing what other sections were doing. They did not know any students outside their class to discuss any similarities and differences and did not make assumptions about what elements were uniform like the course calendar, lecture videos, online homeworks, and exams.

Again, we want to highlight this dichotomy. Uniform elements are used to establish fairness and treat every student the same, taming the wild wild west, but some students express an unawareness to this feature of course coordination. Instead, participants reported the pedagogy of their instructor was more salient to their experiences.

4.1.5 Theme 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability.

Participants reported an appreciation of the resources provided, sharing that a variety of resources were advertised and available to them. Participants with strong math identities expressed a self-awareness of their needs and were able to navigate the

resources available to them. Participants with weak math identities shared an awareness of resources but expressed challenges with not knowing how and when to use resources. It was seen that embedded additional resources, such as communication platforms, when utilized by students contributed to positive views of mathematical ability. In this theme, we report participants' navigation of resources, in particular their: (1) Utilization of resources provided through coordination and (2) Utilization of embedded resources.

Utilization of Resources Provided Through Coordination: Participants agreed that resources were well advertised. However, there were differences in the navigation of resources based on participants' math identity. Participants that had relatively strong math identities reported a strong sense of how to navigate resources and know when to seek help. Participants with a weak math identity reported challenges with help seeking behaviors. When resources were utilized, participants positioned themselves positively which contributed to more positive views of mathematical ability.

Across the board, participants reported that resources were well advertised and shared their appreciation for the provision of resources as shared by Nadia who described the variety of materials available to them.

> *I feel like, if you actually look even just on the canvas page, there's a ton of resources like I mentioned the lecture videos. There are the past exams. There's a lot of stuff you can look over that. I feel like it appeals to different learning types as well. Like, if you're a visual learner. If you're good at just reading stuff. If you're good at hearing the stuff like in the videos*. (Nadia Interview)

Nadia mentioned resources of additional course materials that students had access to such as videos and past exams. In addition to these resources there were also the tutoring services available to students as brought up by Ally Jackson.

> *I feel that the math department has been really good about making sure I know what I'm doing. And like that there are extra resources available. An aspect of the course that I do enjoy is knowing that I have access to PAL tutoring. Now I will admit I haven't taken advantage of the PAL tutoring because I have felt really confident in my work. So, I can't speak on how that impacts my grade. But it's nice to know that resource is there, for when I do need it*. (Ally Jackson Video Journal #4)

We note here that Ally Jackson included the fact that she didn't need to attend extra tutoring. Like Ally Jackson, other participants with a relatively strong math identity described not feeling the need to go to tutoring, acknowledging their confidence in their mathematical ability. We saw this self-awareness of needs and how and when to ask for them among many participants with a relatively strong math identity. They expressed their awareness of resources and how they intentionally went about navigating the existence of these resources such as additional course materials, leveraging their peers and/or instructor, and making use of tutoring services.

We saw that participants that already had positive views of their mathematical ability had a strong sense of how to navigate resources and know when to seek help. We also saw that participants with a weak math identity reported challenges with resources and shared barriers they faced with help seeking behaviors.

Consider the challenges faced by Olivia. We touched in earlier themes how Olivia had difficulty with learning the content from the lecture videos and was unable to supplement her learning through other assignments (*4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning.) and how the lack of extensions further impeded her content understanding and negatively positioned her in math (*4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding.). We will touch in *4.1.6 Theme* 6: the difficulty Olivia had with getting help from her instructor and peers inside the classroom, missing out on precious opportunities to be positioned more positively in everyday lessons. In this theme, we touch on how Olivia expressed the personal challenges she faced taking advantage of resources and consequently getting help outside of the classroom.

> *I wasn't going to the PAL [sessions], cause there was like a little bit that I could understand. [But] then we got to a point where, like we were doing derivatives, and I just kind of stopped doing my work. And I was like I don't know what I'm doing and I'm in a really tough spot. I think that's why I really did not do well this semester because I didn't take advantage of the PAL sessions. And it's only like these last few weeks I've been going to PAL, and I should've come here from the beginning, because there's not many kids that show up to the PAL section. So, it really gives you that one on one time that I really need that I don't get in class. So, I feel like I really should have taken advantage of that. A little more at the beginning of the semester*. (Olivia Interview)

Olivia blamed herself for not taking advantage of the PAL sessions. We want to take a pause here and repeat this once more. Olivia blamed herself. Although we discuss the need to rehumanize mathematics more in CHAPTER FIVE, we wanted to take a note of it here given Olivia's self-assessment. The blame game is an event often undertaken especially in academia. For example, a common trope is that college professors blame the quality of their students' education on the high school teachers and the cycle continues down the line.

For students like Olivia, we don't want to partake in this game by saying what Olivia should have done but ask what could have been in place to help Olivia utilize the resources available to her? We also find it important to mention that her designated PAL leader could not attend class and she shared that because she didn't really know her PAL leader, she did not feel super comfortable going to ask questions.

Tutoring was a resource available to Olivia, but she did not know how to navigate the service. It wasn't until her grades were really suffering did, she seek her PAL leader. By going and making use of PAL, Olivia started to feel hope.

> *I think going to PAL helped me change my view of this course. Before going to PAL, I was just like, I'm gonna fail this class. I know I am. There's no hope. But now, going to PAL, I'm a little more hopeful that I can like, do better and be more successful, even if I do fail at this time. I know that next semester I know that I can go to PAL like whenever I need to, and want to, and then I know I can get that attention that I need and like. Take advantage of that and help myself, truly*. (Olivia Interview)

Upon utilizing the tutoring resources, Olivia opened herself to positions such as a mathematical learner, inquirer, and doer, by getting the help she needs, which contributed to more positive views of her mathematical ability as she felt she could be more successful next semester. We saw in her Post-Math Identity survey, she responded higher to all the recognition items.

> *Yeah, I think it's more just advocating for yourself to get yourself help and like being more motivational to like, wanting to learn the material to do better*. (Olivia Interview)

There was a noticeable difference between Olivia's view of the course between her fourth video journal and her interview. In between that time, she had started going to PAL. In such a short time frame, the interactions between her and her PAL leader were contributing to much more positive views.

Utilization of Embedded Additional Resources: Embedded additional resources from instructors were found in helping participants of all degrees of math identities in taking advantage of resources. More than just advertising resources, instructors leveraging of embedded additional resources encouraged students to utilize resources and in turn contributed to positive views of mathematical ability.

For students like Olivia, where they may not possess the knowledge of how and when to use resources, course coordination can utilize embedded additional resources. For example, Aves reported how her instructor offered flexible office hours and was available both virtually and physically. Her instructor also provided an additional resource of setting up a discord for the class. Discord is a social platform which allows

communication between members of a community. Students in Aves class were able to access Discord to communicate questions of each other and their instructor.

> *But even when I can't physically go to a PAL session, something that I really appreciate is that the professor has made a discord, and so I can always add questions in there. So, when I struggle you know, even if I can't go to PAL office hours, I can always ask in there*. (Aves Video Journal #1)

This additional resource helped with combatting challenges students had with using resources such as office hours and tutoring due to schedule conflict. It also served as additional opportunities for students to be positioned as either a mathematical inquirer or even a mathematical explainer as shared by Aves when she described a situation in which she helped a girl in her class with their homework on the class discord.

> *So, I wasn't sure that I knew it, but I offered to help in any way I could, and I actually was able to help her complete like her whole assignment, and explain why in reasons that she understood not just like what the answer is, but why the answer is, and I've never been able to do that. Not for math. Like I can help people with other subjects. But math has always been like this mystical thing for me like I'm barely keeping afloat. So being able to help someone in a meaningful way, like being on the other side of that interaction was really meaningful to me. It represented like a sign of my progress in my confidence in math. Even if I wasn't certain I would be able to help, I still offered, and then I was able to help. I was confident enough to try. But then, like my skills were actually up to par. So, I'm just really glad that I was able to help her out. Because I've been in turn*

helped by many, many people. So, it feels good to pay that back. (Aves Video Journal #3)

Without the embedded additional resource of a class discord, Aves would have never had the interaction as shared above. As a mathematical explainer, Aves felt confident in her mathematical abilities in a way she had never had before. As we saw with Aves and Olivia, two participants who started with a weak math identity, being able to interact with other students through utilizing resources contributed to positive views of their mathematical ability.

Olivia may have accessed PAL sooner if her class had an embedded additional resource like additional engagement points, like Elizabeth and Mabel Wyler's sections. Additional engagement points were designed by an instructor in business calculus and utilized in her teaching. Students were required to earn a certain amount of additional engagement points before an exam, but they could choose how they went about earning those points, as explained by Elizabeth and Mabel Wyler.

You have multiple options like asking for questions, going in for office hours, or just doing extra assignments to reinforce the information you've learned. And I really enjoy having multiple options because I don't always have questions. And I don't want to go to office hours, because I don't have a question to ask but having the option to do extra work to get points instead or attend a PAL session that's been really beneficial. (Mabel Wyler Video Journal #4)

[Additional engagement points are] basically just a goal, almost of how many points we need to get before our exam. You could get them through doing little

mini reviews, going to PA, asking questions, and a few other extra worksheets. So, what you pick and what you do is technically optional. But she does want us to hit a certain goal of a certain amount of points by the time our first or second exam rolls around. I would say that has benefited my experience in this class. just because extra practice is extra practice. Practice makes perfect. You're going to do a little bit better. You're gonna learn more just through doing extra practice asking questions. You're obviously gonna realize your mistakes. Learn from those. So yeah. I would say, while it sounds time consuming and maybe a little annoying from an outsider perspective for those who may not have to do the Additional Engagement Points at the end of the day. In the long run they're really beneficial. So, I would say that has impacted my experience. (Elizabeth Video Journal #3)

Additional engagement points essentially encouraged students to make use of resources as part of their grade. The options provided to earn points were a way to advertise the resources available to them and require them to choose which ones to take advantage of before the exam. This policy of additional engagement points was a decision made by an instructor for their students' section work grade in which instructors had agency to control. It is important to note that the instructor was also the course coordinator of business calculus and did not embed this idea for the entire coordinated system.

Like the discord, additional engagement points were creative embedded additional resources offered by individual instructors that when utilized by students contributed to positive views of mathematical ability. What these have in common is the encouragement

of resources by instructors. More than just the advertisement of resources, course coordination can promote ways for instructors to encourage students to use resources through the feature of regular instructor communication.

4.1.6 Theme 6: Small class sizes and instructional format support developing relationships with instructors and peers especially when instructors are able to facilitate interactive lessons.

As supported in the literature, interactions are important in influencing mathematical identity (see CHAPTER TWO). In this last theme, we discuss participants' descriptions of their class size and how the size influenced their ability to form relationships with peers. In conjunction with class sizes, participants also reported how the instructional format, either a flipped classroom or a lecture style, impacted how participants developed relationships especially when instructors were able to facilitate interactive lessons. Course coordination aspects that had an influence on relationship development were: (1) Class size and (2) Instructional format.

Class Size: Participants shared the benefits of a small class size in engaging with peers and their instructor.

We'll start this portion by stating the fact that, similar to time in *4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement., the size of classes is not a common uniform element. However, in this study, both courses had all sections capped at the same number of students, lending to class size being a uniform element, if not explicitly intended. Due to the salient findings from the data, we include this element in the results and discuss it further in *Section 5.2 Recommendations*.

Also, similar to time, this isn't the first instance we've seen the influence of class size playing a part in relationships (see *Section 3.2.2 Pilot Project Results*). As seen in the pilot project, participants in the dissertation study also linked the size of their class with relationship opportunities with their instructors and peers. There were participants who were proponents of the small class sizes as participants like Dylan and Ally Jackson described the benefits of small class sizes with building relationships.

> *I feel as though having a smaller class size gives a more personal feel to the class, you know. So, for a person with terrible anxiety like myself, not only just to make it easier to engage with those around you.* (Dylan Video Journal #4)
>
> *I think that's really nice to have that smaller classroom feeling and I feel that I can grow more of a relationship with my professor*. (Ally Jackson Interview)

For students like Dylan who have anxiety, a classroom with a small feel can help relieve some of that unease. Not only can a small size help with engaging with peers, but as described by Ally Jackson, the size could also help with engaging with the instructor. Ally Jackson reported that her instructor knew who she was and was able to because of the number of students in the classroom.

Instructional format: Participants in long calculus reported that small class sizes and lecture style helped with developing relationships when their instructor facilitated interactive lessons and/or assigned groups. Participants in business calculus reported that small class sizes and flipped format helped with developing relationships when their instructor had sufficient instructional aide to support them.

Participants in long calculus, a lecture style course, shared how instructional format and small class size influenced developing relationships. As Aves reported the size of the class was small enough for her instructor to get to everyone.

> *We have a small enough classroom size that [my instructor] doesn't struggle with getting to everyone and their questions. It's not like we have to fight for his attention, for help or anything*. (Aves Interview)

We shared in *4.1.4 Theme* 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements. how Aves' instructor made use of dynamic teaching methods to keep class interesting and how in *4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability. the provision of a class discord helped with students utilizing resources and developing relationships. In this theme, we see how her instructor's approach and embedded additional resources helps with facilitating interactions both inside and outside the classroom supporting the development of relationships and the positions afforded to students.

While participants, like Dylan, expressed their small class size can help with engagement, Dylan also communicated how a small class size could be a barrier. Throughout the semester, Dylan struggled with forging connections with peers such as forming study groups. While small class sizes give a more "personal feel" it can also provide a limited list of options in connection opportunities.

> *But the small classes also limit you in that aspect. It's less people for you to try to talk to. Let's say you tried to talk to one person you were like and didn't go too*

well. You tried to speak to another one, but they weren't compatible with you. Now it's like darn 6 more people left. (Dylan Interview)

Dylan, who had a weak math identity, struggled with building relationships with her peers, going as far to say that she feels alone in the classroom. There was a viewed advantage of friendships among peers among participants. However, for Dylan her one friendship was with a student not taking the course.

In this theme, we see how the lack of meaningful everyday interactions resulted in a lack of positive positions afforded to Dylan. We leverage this driving analogy once more. When on a road trip, individuals tend to have a more enjoyable driving experience when not driving alone especially in an unfamiliar environment. This could be through either phoning a friend for support or by having others in the vehicle that can help with navigating through the landscape. If stuck in traffic or missing a turn, personal connections can help with getting back on track by offering assistance. Much like how in the classroom relationships with peers and instructors can help students with understanding the content.

Dylan expressed a desire for her instructor to facilitate interactive lessons and assign groups in the class as she believed this could have had a positive impact in her ability to form relationships with her peers.

I think [interactive lessons] definitely helps with the dynamics cause. If there was a student next to me who was always getting eighties and above on the exam. And I knew them personally, or at least, you know, met them through the class. I could say, Hey, can you help me with Number 8? Or do you think I can study with you

one day? But if you've never said a word to this person, you're just like it's like a waste of opportunity. (Dylan Interview)

Participants reported that relationships among peers helped with sharing resources and studying. However, participants like Dylan who struggled with developing relationships with her peers and instructor did not get to leverage this support which is why she wished there were more opportunities to interact in class to help students get to know each other a little more personally.

We discussed in *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning. the psychological strain Dylan felt from not doing well on exams. She expressed getting off track and we added to this analogy that learning checkpoints could act as car maintenance for accident prevention. In *4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding., Dylan reported falling behind in the fast-paced course which we continued this illustration to being delayed to your original destination time and how adjustments to the time spent on topics would be like offering a detour to help students with moving forward. Here, Dylan described her desire to connect but ran into difficulties finding peers to connect with in her class to do so which could have been supported if her instructor had facilitated interactive lessons.

Participants in business calculus, a flipped structure course, similarly shared how instructional format and small class size influenced developing relationships. As participants alluded to the size of their class aiding in engagement opportunities, one

participant touched on the lack of engagement with her instructor and not being able to receive the attention she needs.

> *I definitely think it depends on the class size, or just having more hands involved. Cause, I think it's hard for 2 people to accommodate 40 kids in one classroom. So, I think either having smaller classes or just maybe more people to help attend to others would help the class be more successful.* (Olivia Interview)

The two people Olivia is referring to are her instructor and an instructor's aide. Both business calculus and long calculus have a program called Peer Assisted Learning (PAL) where former students who did well in the class attend classes to help and hold help sessions. There are some instances where instructors can also have Teaching Assistants (TAs) providing instances where a classroom could have three people to attend to students.

All sections of both business calculus and long calculus were capped at 45 students establishing an equal classroom size for all students. However, not all sections had an equal number of aides. For instance, Ally Jackson and Elizabeth, both in business calculus, reported having a PAL leader and a TA, while Olivia only reported having a TA in the class along with her instructor and how both were too busy to help her and the students at her table. Having access to their peers, instructor, and the instructor aides, Elizabeth reported the benefit of these interaction opportunities during class time to building relationships.

> *I'd say my peers in my class really helped me learn the material because I'm the type of person that needs to talk things out when I'm learning. So being able to*

> *just talk things out like different processes or different steps of whatever mathematics equation we're doing whatever it may be. It really helps me just talk it out even. And if someone asks me how I got a question. Being able to teach them helps me learn. So not only can I talk through the steps of things, but I can also easily turn to my friend and ask. 'How did you get that?' Or 'can we compare our work? Because I think I did something wrong?' So that's another easy way to really learn from my mistakes and overall make sure I'm understanding the information correctly.* (Elizabeth Video Journal #3)

As seen in Elizabeth's video journal response, she expresses how being able to teach her peers helps her with learning the material. Here, we can see her positioning herself as a mathematical explainer and through other interactions with her friends such as when she asks to compare their work or how they got their answer we can see her positioning herself as a mathematical investigator.

In this dynamic setting of class work time, we can see there are greater opportunities for students to be positioned by themselves or those around them. As mentioned by participants and confirmed in the classroom observations, there were several interactions among business calculus students. Peers worked together at their tables while the instructor and instructor aides circulated offering assistance. In turn, these increased interactions not only provide opportunities for building relationships, but opportunities for students to be positively positioned.

For business calculus, a flipped structure course, participants with enough instructional aide support inside the classroom felt they were being able to adequately

build relationships through classroom interactions. Students with limited instructor support, like Olivia, did not share the same sentiment as Ally Jackson and Elizabeth, reporting that the lack of assistance impacted her understanding of the content.

> *So, it's kind of hard for them to spread it. So that's why I think what impacts me is like my ability to understand, because I'm not getting the help that I need*. (Olivia Video Journal #2)

If you recall from *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning., we brought up the fact that Olivia could not compensate for her learning from the videos from the assignments in class. The lack of insufficient instructional assistance for her section contributed to this inability to compensate for her learning inside the classroom. We discuss further in the next section the importance relationships had with strengthening Elizabeth's math identity over the course of the semester. If Olivia had "more hands involved" like Ally Jackson and Elizabeth, she may have also been able to develop more relationships with her peers and instructor.

Small class sizes were seen to have advantages in students' ability to engage with peers. Like seen with resources in *4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability., participants' level of engagement with their peers and instructor was influenced by the instructors' encouragement of working with others. When instructors had sufficient instructional aide, as seen in a flipped classroom, and when they facilitated interactive lessons, these aspects helped with supporting the development of relationships.

4.2 Experiences Impacting Women and Gender Fluid Students' Math Identity

From the Pre- and Post-Math Identity surveys participants' mathematical macro-identities were determined. We described in *Section 3.4.2 Case Studies* how we grouped participants into one of three math identity groups based on their interest and recognition with mathematics. These three math identity groups being:

- High Math Identity
- Mid Math Identity, and
- Low Math Identity

Participants were in the High Math Identity group if they identified High Interest and High Recognition from the survey. From the Pre-Math Identity survey participants Mabel Wyler, M, Sappho, Ally Jackson, and Joselyn were all grouped as starting with a High Math Identity. They expressed a strong interest in mathematics describing it as their favorite subject and as something that was easy to them. Many of the participants in this group had taken calculus in high school and felt prepared going into the course and/or looking forward to learning the topics.

With course performance, participants in this group reported doing well on the exams and overall in the course. They demonstrated a self-awareness of their needs and how and when to use resources, visit office hours, and ask questions. Interestingly, most participants in this group tended to work alone or with another peer and made conscious efforts to talk with their instructor when needed.

Throughout the semester participants from this group described their relationship with math as positive, confident, and comforting, maintaining a positive math relationship.

Participants were in the Mid Math Identity group if they identified with a mix of High and Low Interest and Recognition from the survey. From the Pre-Math Identity survey participants Elizabeth and Nadi were grouped as starting with a Mid Math Identity.

They expressed varying levels of interest and recognition in mathematics. The participants in this group did not describe math as their favorite subject but a subject in which they know what necessary work is needed to succeed. The participants in this group discussed mathematics backgrounds, such as taking or not taking calculus in high school, could have present advantages and disadvantages as some may have already learned the material.

With course performance, participants in this group reported doing well on the exams and overall in the course, feeling proud with how they were doing. They shared about the friendships they developed in the class and how they leveraged these relationships in learning the material and working through assignments.

Throughout the semester participants from this group described their relationship with math as indifferent, relaxed, and successful.

Participants were in the Low Math Identity group if they identified Low Interest and Low Recognition from the survey. From the Pre-Math Identity survey participants Olivia, Aves, and Dylan were all grouped with a Low Math Identity.

They expressed a weak interest in mathematics describing it as a subject they hate and struggle with. All of the participants in this group had not taken calculus before. Their gap in mathematics was a huge concern they had regarding their understanding of the material.

With course performance, participants in this group reported not doing well on the exams and expressed concerns about failing. They reported challenges with resources and barriers to help seeking behaviors such as limited instructor support, barriers to peer support, and mental health. Participants in this group expressed a desire for more peer and instructor interaction.

Throughout the semester participants from this group described their relationship with math as hate, struggle, and unqualified, maintaining a negative math relationship.

Three of the ten participants (Sapho, Elizabeth, and Aves) switched math identity groups by the end of the semester. Given these changes for these three participants we examine more closely the experiences that impacted these students as illustrative case studies.

4.2.1 Storyline of Sappho

In this storyline we consider the participant Sappho. Sappho identifies as a white transgender woman. She went into business calculus with a Pre-Math Identity of High Interest and High Recognition, grouping into the High Math Identity group, and ended the semester with a Post-Math Identity of High Interest and Low Recognition, grouping into the Mid Math Identity group.

When asked what three words describe her current relationship with math, Sappho answered with the following descriptions across the four video journals:

Table 4.1
Sappho's Relationship with Math. The three keywords Sappho used to describe her relationship with math over the course of the semester.

Three Key Words			
Video Journal #1	Video Journal #2	Video Journal #3	Video Journal #4
Rusty	Thriving	Confusing	Growing
Forgetful	Ahead	Time-Consuming	Clicking
Skilled	Confident	Rewarding	Derusting

In her first video journal, although Sappho expressed concern with not having taken a math class in a few years she confirmed her high interest in mathematics by describing her excitement with reintroducing herself to calculus concepts.

> *I would describe my relationship with math as rusty and forgetful, but I would also use skilled cause when I stayed on top of my learning. I was very proficient and passionate about math*. (Sappho Video Journal #1)

We continued to see her report her high interest in mathematics throughout the semester. When faced with a challenge with math, Sappho positioned herself as mathematically capable. She took the necessary time to understand the content. Although the material was confusing, she studied and practiced until she was able to figure it out. As mentioned in *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning., Sappho was even able to compensate for her learning from the lecture videos by working through the assignments in class.

> *So, my 3 words this week to describe my relationship with math would probably be confusing, time consuming, and rewarding which aren't super related. But the*

reason I picked these is the activities this week and the lectures were very time consuming and took quite a bit of trial and error in figuring out exactly what was going on. But as I did it more and studied more and did more of the in-class activities. It kind of started to click, and once it started to click. It was very satisfying. And I felt very proud of myself for working through it all. (Sappho Video Journal #3)

Sappho expressed an intrinsic interest in mathematics continually describing her enjoyment in learning new material. It was no surprise that for her Post-Math Identity survey, Sappho still reported High Interest. However, she went from High to Low Recognition at the end of the course. In particular, on the Post-Math Identity survey where she originally put a four (on a scale of 1-5), she responded with a one to the question "*Do other students and friends see you as a mathematics person*?"

This drop had her mathematical macro-identity shift from the High Math Identity group to the Mid Math Identity group. We ascribe the reason for this shift was the lack of positions afforded to Sappho by others. Without these positions, Sappho did not have opportunities to be publicly recognized for her mathematical capabilities.

Sappho described her relationship with her instructor as minimal, mostly interacting with him through emails. She reported he had an inactive approach to teaching stating that she didn't see him helping towards her performance in the course. We discussed in *4.1.4 Theme* 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements., how Sappho expressed a desire for her instructor to be more involved. With teachers' positioning of students being more

influential than classroom resources, her instructor's inactive teaching methods contributed to an absence in meaningful interactions between Sappho and her instructor in which her instructor could have positioned her as a mathematical explainer.

Similarly, there was an absence of positioning seen from her peers as Sappho reported tending to work better independently.

> *So, I think the biggest way my experience is different from others in my class is how I work more independently than most in the class seem to. I work much better alone. And I'm also a bit nervous talking to people which probably impacts my ability to cooperate effectively. I have a cordial relationship with [my peers], though I really wouldn't consider myself friends with most of them. Nor do I really work alongside them very often. There is one girl that sits next to me in class who has been really helpful. This semester she's always been able to answer my questions effectively, and I've been more than happy to help her when needed*. (Sappho Video Journal #3)

While Sappho did share she worked with one peer, it was often the case that Sappho was positioned as a mathematical learner. Sappho was still seen as mathematically capable but was not positioned in a way to be recognized.

> *And one story that particularly resonated with me in class was when I asked one of my friends for help with a recent topic, derivatives of composite functions. When I'd asked her, she explained in a very practical way and I just kind of clicked*. (Sappho Video Journal #4)

It was most likely the case that Sappho did not want to bring attention to herself as she expressed being uncomfortable with peers in her class.

> *I generally just find it hard to talk to people that I'm not comfortable with in general. but I think on top of that there were definitely a lot of people in my section specifically, that definitely I could tell, shared much different views than I did, and probably wouldn't have been as kind to me, or maybe not. That's a bold assumption to make, but just like my head didn't think that they would be as kind to me as some might*. (Sappho Interview)

As a transgender woman, Sappho experienced anxious thoughts that weren't even on the radar for most of her peers. She had to actively think about navigational strategies with who was safe to interact with (Voigt et al., 2023). While other students in the class may have freely talked with one another, opening them up to more positions, Sappho hid her voice and made herself smaller.

As a macro-identity is a thickening of micro-identities, we saw how this stretch of time of Sappho not being positioned by her peers and instructor as a mathematical explainer and more resulted in a negative shift in her mathematics identity.

> *I view myself. honestly, pretty, middle of the road, like, I feel like. I have a decent understanding of math whenever I do take the classes, but I never felt like I particularly excelled*. (Sappho Interview)

For students like Sappho, we see the importance of developing and nurturing a positive class environment fostering relationships between students and teachers as she experienced the class differently due to her social identity as a transgender woman,

necessitating research that examines these differences and coordination that aims for equity and equality. Conversely, we have Elizabeth who because of these relationships shifted to a higher math identity.

4.2.2 Storyline of Elizabeth

In this storyline we consider the participant Elizabeth. Elizabeth identifies as a white cisgender woman. She went into business calculus with a Pre-Math Identity of High Interest and Low Recognition—the math identity Sappho ended with–grouping Elizabeth into the Mid Math Identity group and ended the semester with a Post-Math Identity of High Interest and High Recognition, grouping into the High Math Identity group.

When asked what three words describe her current relationship with math, Elizabeth answered with the following descriptions across the four video journals:

Table 4.2
Elizabeth's Relationship with Math. The three keywords Elizabeth used to describe her relationship with math over the course of the semester.

Three Key Words			
Video Journal #1	Video Journal #2	Video Journal #3	Video Journal #4
Indifferent	Indifferent	Indifferent	Indifferent
Successful	Success	Growth	Uninterested
Time-consuming	Simple	Routinely	Successful

In her first video journal, Elizabeth expressed her excitement to learn and work with peers in the class, a sentiment that continued throughout the semester as seen in her Video Journal 3 and interview.

> *I work at a table with about 5 other girls. And I'd say we all have a great relationship. We actually became good friends through this class. For the most*

part we're really on top of our work. We actually almost always finish early. which is really good. That shows that we're working hard and absorbing and obtaining the information necessary. (Elizabeth Video Journal #3)

For my table group, I would describe this as actually really lively, like, I've met a few friends in that class. and we always get our work done. (Elizabeth Interview)

Unlike Sappho, Elizabeth expressed greater comfort with working with her peers, more so her women peers. And we saw the impact these relationships had for Elizabeth's math identity as more interactions led to more positive positions for Elizabeth to accept. For example, Elizabeth described how she positioned herself as a mathematical explainer when talking about the material to her friends.

I'd say my peers in my class really helped me learn the material because I'm the type of person that needs to talk things out when I'm learning. So being able to just talk things out like different processes or different steps of whatever mathematical equation we're doing whatever it may be. It really helps me just talk it out even. And if someone asks me how I got a question. Being able to teach them helps me learn. (Elizabeth Video Journal #3)

Her friends also positioned her as a mathematical explainer when asking her to teach them, allowing Elizabeth to embrace her mathematical capability in a way Sappho didn't. Elizabeth's peers recognized her math abilities by asking her to explain her solution. Elizabeth also positioned herself as a mathematical inquirer.

So not only can I talk through the steps of things, but I can also easily turn to my friend and ask. How did you get that? Or can we compare our work? Because I

think I did something wrong? So that's another easy way to really learn from my mistakes and overall make sure I'm understanding the information correctly. (Elizabeth Video Journal #3)

Not only does Elizabeth share that she helped explain the material to her peers, but she also felt comfortable to ask them questions, especially to clear any misconceptions and rectify mistakes. We saw Sappho also leverage his one peer by asking for assistance but not to the extent that Elizabeth did as Elizabeth communicated with more than one person, which she utilized to investigate the content in class.

These forms of communication. This helps me learn from my mistakes. Basically, every single class time we have to work on our learning activity, we're always talking through what we're doing and going back on questions and confirming that we all got the right answer. And if we don't get the right answer and our answers are different. We'll look through all of our papers, and see who went wrong, where they went wrong. Why, they went wrong and just kind of talked it through until we got to the right answer. (Elizabeth Video Journal #3)

Here Elizabeth describes being a mathematical investigator, working with the peers at her table to investigate solutions. Elizabeth claimed that the table group she sat with made math fun and enjoyable. Working with her peers, Elizabeth was able to regularly and consistently reaffirm herself as mathematically capable every class period. And as mentioned in *4.1.6 Theme* 6: Small class sizes and instructional format support developing relationships with instructors and peers especially when instructors are able to facilitate interactive lessons., Elizabeth had access to more than just her peers.

I have quick, easy access to people in the room that are eligible to help me. You have not only your teacher, but you have TAs in the room to help you with questions. I like that easy, quick access. You don't need to really wait for one person to get around to all the questions. There's a lot of people willing and eligible to help you in class. (Elizabeth Video Journal #4)

Because of the number of instructional aides in the classroom, Elizabeth was able to take advantage of not only her peers but her instructor and instructional assistants as well. Elizabeth was able to leverage and develop these relationships to help with understanding the content.

[My instructor is] always there for questions when I come in the next day. I found her, as well as my TA and PAL leaders, to be very helpful when I do have questions about the lectures or the assignment I'm doing in class. I think that my relationship with her and my ability to connect and contact her when I need to have helped me succeed and learn a lot in this class. (Elizabeth Video Journal #2)

Elizabeth had opportunities to be publicly recognized for her mathematical capabilities. For her Post-Math Identity survey, Elizabeth still reported High Interest. However, she went from Low to High Recognition at the end of the course. She responded higher on all survey items related to recognition. In particular, on the Post-Math Identity survey where she originally put a two (on a scale of 1-5), she responded with a four to the question "*Do you see yourself as a mathematics person*?"

This rise had her mathematical macro-identity shift from the Mid Math Identity group to the High Math Identity group. We ascribe the reason for this shift was due to the

abundance of positions afforded to Elizabeth by others. Between Sappho and Elizabeth, we saw the importance interactions had on their respective math identities. The relationships Elizabeth was able to leverage helped with a positive shift in her math identity where for Sappho the lack of relationships between peers and instructor she could leverage resulted in a negative shift in her math identity.

With the role of gender, Elizabeth reported how she sat with a table full of women and how her instructor being a woman impacted her experience in the classroom.

> *I think the fact that my professor is a girl we become kind of close with her, and almost makes me feel like I'm in high school again, like this is probably one of the only professors I've actually had multiple conversations with which I think is really cool*. (Elizabeth Interview)

We saw a level of comfort Elizabeth had that Sappho did not which reiterates the importance of developing and nurturing a positive class environment fostering relationships between students and teachers. We saw a similar positive shift because of these relationships for Aves.

4.2.3 Storyline of Aves

In this storyline we consider the participant Aves. Aves identifies as a white cisgender woman. She went into long calculus with a Pre-Math Identity of Low Interest and Low Recognition, grouping into the Low Math Identity group, and ended the semester with a Post-Math Identity of High Interest and Low Recognition, grouping into the Mid Math Identity group.

When asked what three words describe her current relationship with math, Aves answered with the following descriptions across the four video journals:

Table 4.3
Aves' Relationship with Math. The three keywords' Aves used to describe her relationship with math over the course of the semester.

Three Key Words			
Video Journal #1	Video Journal #2	Video Journal #3	Video Journal #4
Unqualified	Tentative	Comfortable	Perseverance
Strained	Open	Challenging	Gradual
Drowning	Surprised	Achievable	Optimistic

In her first video journal, Aves described her math background of being homeschooled, sharing how she feels behind compared to her peers with knowing basic math concepts. As we saw with Sappho, and what was reported by other participants, students' math backgrounds are seen as advantages or disadvantages for the course. Aves expressed her concern with the influence of her math background for her understanding of the concepts in the course.

> *Something that concerns me about the class, I was homeschooled from first to ninth grade. So, since math is a cumulative skill. I entered ninth grade essentially with the math skills of a first grader, which is something extremely hard for me, and that took a lot of work over my entire high school career. And even now, in college, I'm always keeping my eye out for things that I never learned, and that everyone else did. And so, the fact that I don't have the years of foundational framework makes it very hard for me to understand the why of concepts, because*

it's a lot of theory that other people got introduced to them slowly. But to me it's like I'm hearing about it all for the very first time. So, it's kind of like just a constant deluge of things that are important that I don't know why they relate, and I don't know how they relate, so I'm kind of concerned about that holding me back. (Aves Video Journal #1)

For Aves, this concern is on the forefront of her thoughts. Much aligned with what we saw other participants who had not taken calculus in high school report. Students whose math background differed from peers who had already taken calculus shared their anxiety about understanding calculus concepts which Aves expressed in greater detail in her first video journal at the start of the semester. Aves worried about being unqualified compared to her peers and the extra mental load she would need to carry through the course.

Three words to describe my relationship with math. So, relating to what I said before about not knowing anything, and kind of having to jump right in and sink or swim, I would describe it as unqualified, strained, and drowning like every time I'm in math class. I mean other classes, too, but especially math. I feel like I'm always trying to make new connections that other students don't have to do, because they just understand from their past but if I don't do that then I always get taken by surprise, surprise by new concepts. So, I have to go out of my way. I have to do a bunch of extra mental work that I feel like doesn't really come across. So, it kind of drains me of my energy, just being in math, which is why I'm kind of glad that it's a pretty short class. I just have it more times a week. So, like

I said underqualified, because I feel like I'm behind my peers, strained because of all that extra mental load I have. And then, drowning, because of all the information that I don't know that I'm expected to know, and that I have to catch up on. (Aves Video Journal #1)

Like many students with low math identity, there can be an additional mental strain with taking a math course as we saw with Dylan and Olivia. In turn, this strain could create barriers to utilize resources, participate in the course, and overall performance. Which is why attending to micro-identities is critical in determining what experiences may influence a more positive math identity.

We were able to see just how Aves, through her experiences in the course, was able to be positively positioned and have a dramatic shift in her math identity over the course of the semester. In her second video journal, she described the environment created by her instructor, reinforcing the instrumental role instructors can play with students' interest and engagement in mathematics.

Aves listed the pedagogy techniques used by her instructor and how his decisions, his teaching style, and personality helped with shaping a classroom environment in which Aves was surprised to find herself learning mathematics.

[My instructor] is a genuinely good teacher, and I find that I don't dread it like the way I did the way I used to dread my math classes in high school, like he has a genuinely open and approachable and kind of fun energy about him that makes it not like soul sucking in a way, you know, just being in the classroom like, I genuinely actually want to learn the content. It's not just something I have to do,

because I'm required to. You really get the vibe that he actually wants to make sure that we know what we're doing. And he's invested in us. And I really appreciate that. (Aves Video Journal #2)

As we shared out in *4.1.4 Theme* 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements., Aves reported enjoying learning mathematics due to her instructor's pedagogical techniques making the math more approachable. Her instructor's dynamic teaching methods kept class interesting and encouraged questions impacting her experience for the better.

As mentioned in *4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding., her instructor was flexible with her athletic schedule by offering continuous extensions for assignment. And as discussed in *4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability., Aves also found her instructor was flexible with his office hours, both in time and modality. He also created a class discord for the students to ask questions about the homework and genuinely encouraged questions inside the classroom.

Something that I definitely appreciate that [he] has done is he's made a discord survey for our class, and that is so useful because it means that even outside of class, I can talk to my classmates and ask them questions about the homework. You know, without having to like to message them personally, like it's not high stakes or anything, it's casual. And I can look [to see if he] is on the discord, too. So, he is available for questions, even outside of class, even outside of office

hours, basically anytime, which is incredibly helpful when I'm doing homework like later just being able to ping him, and he might not get back immediately, but he always does get back, which I appreciate. It's just another step in the whole thing about being open and approachable, you know. If I need help. I know that I could get it through several needs, and that's very, very nice to have as a student. (Aves Video Journal #2)

Aves described that this additional embedded resource of a class discord contributed to showing her that for her instructor their understanding was a genuine priority. From his flexible office hours and his availability to be reached through discord, Aves felt that her instructor went out of his way to be accessible to students.

Like I can tell that he cares, and it makes me in return, want to put in time and effort into his class, and it makes me like want to pay attention to him, and it makes me want to do well in that class, because, you know, if someone cares, I want to care back. (Aves Video Journal #2)

As Aves reports, the care she feels from her instructor, especially regarding his care for students' understanding, makes her want to care in return. Through her instructor's flexibility with office hours and due dates and approachability with asking questions in person, discord, and office hours, he had fostered a classroom environment that encouraged positive mathematical micro-identities to develop as seen in Aves' description of her relationship with math in her second video journal.

So, I know in my last entry I you know the words that I described my relationship with math were kind of negative. I talked about why, a little bit. But if I'm talking

about just right now, not anytime in the past. I think that I would use the words tentative, open, and surprised a little bit more like not coming into it with my past ideas. You know, I found that just this class specifically, has been so much of a better experience compared to all of my previous math classes. It's kind of like shaking up my view on my relationship personally with math that I've had before, like. It's so different, this class experience. I genuinely and truly enjoy learning math, which is something that I've never been able to do before. So, I'm open to liking this whole concept. And that's a little bit surprising for me, because I thought that it would always be kind of awful because I don't have a lot of good skills in math. But even with that, it's still calm and a good learning environment for me. It's just really nice to have a sort of blank slate getting to learn math without the pressures that I've described before. It's just really calming. I would say I'm tentatively open to being able to like this whole concept that has always been kind of negative to me before. So that's really nice. And I really appreciate the things that [my instructor] does to make that happen for us. (Aves Video Journal #2)

As the semester progressed, we saw how Aves' experiences continued to "shake up" her view with her relationship with math. By her third video journal, we can start to see how the accumulation of positive micro-identities is already having an influence on her overall math identity. We attribute this shift due to the environment that her instructor fostered. With his flexibility in due dates for her athletics, he gives necessary accommodations to her schedule that allows her to demonstrate her mathematical

capabilities (*4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding.). With his accessibility in flexible office hours and modality, he demonstrated to students his approachability and positioned them as mathematical inquiries and explorers (*4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability.). This positioning continued in his teaching with his pedagogy of non-traditional approaches and encouraging questions (*4.1.4 Theme* 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements.).

With the embedded resource of Discord, Aves had her most meaningful interaction yet as we discussed in *4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability. when Aves helped her peer with their homework. As we mentioned, embedded additional resources when utilized by students contributed to positive views of mathematical ability. In her third video journal, after helping her peer on the classroom discord, Aves reported how she was able to position herself as a mathematical explainer and how that impacted her relationship with math.

> *But math has always been like this mystical thing for me like I'm barely keeping afloat. So being able to help someone in a meaningful way, like being on the other side of that interaction was just really meaningful to me. See like it just represented like a sign of my progress in my confidence in math. Like even if I wasn't certain I would be able to help. I still offered, and then I was able to help.*

So, you know, I was confident enough to try. But then, my skills were actually up to par. (Aves Video Journal #3)

It is important to note that even though her instructor was not present, the environment he created heavily influenced Aves confidence in her skills to help her peer as a mathematical explainer. With Aves' description, we saw how meaningful it was for her to position herself as a mathematical explainer and for that to be reaffirmed. By the time she described her current relationship with math in her third video journal, we saw a much more optimistic view of mathematics. Where Aves originally described herself as unqualified and learning mathematics was straining, she starts by describing math as a comfortable challenge.

It's a comfortable challenge. It's not something that's completely impossible. It's a challenge every day. But it's something that I like. It's a challenge that I've grown used to. And I'm used to it at this point. I know it's gonna be hard. But I also know that I can do it. So, I've grown used to like my skills being challenged as I learn more about math. It. It's not something I can just breeze through like there's definitely that compared to other subjects. But it's not unmanageable, either, is the point. So even though it's hard, it's not daunting anymore. I would say. (Aves Video Journal #3)

Aves originally described that being in a math classroom was feeling like she was drowning in information. We saw how participants with weak math identities, like Dylan and Olivia, were similarly drowning in the course. For Dylan, there was an accumulation of aspects in which she “got off track” and struggled to get back on track, going as far to

say she was “too far gone.” By going to PAL, Olivia was able to start treading water, but this was only at the very end of the semester. Here in the middle of the semester with Aves, we see her now referring to math as a challenge she is willing and able to conquer, going as far to say that math is achievable.

> *And that leads me to my last word and that is achievable. The entire attitude towards math and college is completely different than how it was in high school. And I know that in some way, if I apply my resources, I can do it. This isn't impossible. I can get there at some point somehow, and because I can get there, I know that I will get there. So, if it helps me start something that may seem like really challenging or daunting, because I know that it's possible, so I have to try. When I was in previous math courses, I would see problems, and I would just have no idea what they were saying or asking, and I would just skip over them because I was like I don't know how to do this at all. There's no way for me to solve this. But now I see problems that I don't know how to do, and instead of just wanting to skip over them, now I look at them and I try different techniques. And sometimes because of that, then I'll figure out how it relates and then I can get through to an answer, even if it's not a correct answer. Just being able to try and fail is, it's helping me a lot more than just looking at it and giving up before I even start.* (Aves Video Journal #3)

As Aves described, because of her change in mindset–this belief in her mathematical abilities–she started to have a new approach to math than she did before the

course. We saw how for Olivia, the hope she started to feel about math upon attending PAL services building towards this idea that Aves expressed with math being achievable.

Aves did report difficulties with finishing exams because she was unaware she could have received accommodations for extra time. However, on exams Aves still had a goal of not leaving questions blank, believing that it was possible for her to figure out problems if she tried as she attempted to get as much done as she can. Again, we attribute this belief to the positions afforded to Aves over the course of the semester. Being positively positioned to be mathematically capable influenced a much more optimistic attitude towards exams whereas participants like Dylan expressed that extra time wouldn't have helped her because she didn't understand. As we reported in the previous section, Dylan had different experiences than Aves that were not as rich in micro-identities to impact her identity. For Aves, her experiences had a way of strengthening her relationship with math as she shared.

> *So, this course has just really shaped my experience with math in a way that I have not had before, and I think it's for the better, like I'm definitely more positive towards math right now. It's not something that makes me on edge just thinking about it. And before I used to get really stressed out just from the concept of having math class that day. So, I mean now I honestly enjoy it because the challenge is comfortable and like I've grown used to it, and the feeling of figuring out a problem that was hard and then being able to solve it in the future and knowing that it was hard before that's just a kind of joy that is really unique. So, honestly, I really like math, like as the concept I struggle with it. But I don't hate it*

anymore. So, I really think that this math class has changed a lot of my opinions regarding math. So, I'm really glad for that. And I'm really glad for [my instructor], too, because he's definitely responsible for, like most of it. (Aves Video Journal #3)

With Aves, we saw the power that positive positionings had in shifting her math identity. At the beginning of the semester, Aves described her relationship with math as one that would drain her energy, being glad that her class was short and a few times a week. As we touched in *4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement., by the end of the semester, she wished there were more contact hours, the class environment energizing her instead of draining.

Being in a math environment that helps me, the more I'm in that environment the better my performance is. So already it's better than other classes being 4 days a week. But it could be even better if it were 5, and I don't think that would be too much time in class since it's a short amount of time in class. I can do 50 min every day. I did an hour and a half every day when I was in high school. 50 min is nothing, and I genuinely do like being in math, so I don't think it'd be a drain or anything. (Aves Video Journal #4)

In Aves' first video journal, Aves reported that math was draining. Now by the fourth video journal, Aves has had such a “shake up” in her relationship with math that she finds the math environment cultivated by her instructor as one that she enjoys being in unlike her previous experiences. Instead of describing her relationship with math as

one of her being unqualified as she did at the start of the semester, by her fourth video journal she recognizes her gradual improvement in math.

> *So, I would say that the 3 words this week would be perseverance, gradual and optimistic. And the reason I would say that is because on my first exam, I barely passed, and I wasn't too happy about that, especially since I did do some studying. This exam, I ended up with a 74. Still not as high as I would like, but a significant improvement from last time. So, I think that that shows me like that you know it's not about getting it right all at once. It's about the slow improvement. So, like just the perseverance of doing the homework every week, the gradual improvement of going to office hours and seeing my skills improve just shows, like the definite result of that. I know that the exam itself, like the content, is different, but I feel my understanding of math has also improved. I felt a little bit more confident going into it than I was the first one*. (Aves Video Journal #4)

No longer is Aves unqualified in learning and understanding the information as Aves reported a growing confidence in her mathematical capability. She expressed a change in attitude as recognized the progress she made and the progress she would continue to make.

> *I know I'm not performing at my best right now, but I can see that I can change, and I can get better. So, I think that I can perform my best by the time I'm done, and that's important to me. So that's why I would say you know the perseverance, the gradual change, the optimism regarding that*. (Aves Video Journal #4)

This optimism in her relationship with math, had her mathematical macro-identity shift from the Low Math Identity group to the Mid Math Identity group. On the Post-Math Identity survey, she responded with a higher interest in mathematics, agreeing that she enjoys learning mathematics. Aves ended the semester with a Post-Math Identity of High Interest and Low Recognition. However, it is important to note that, like Elizabeth, Aves responded higher on all the survey items related to recognition. In fact, Aves responded two items higher than she did earlier for the recognition items "*Do others/friends see you as a math person*?" and "*Do you see yourself as a math person?*"

As with Elizabth, Aves was able to leverage relationships with her peers and instructor which resulted in a positive shift in her math identity. Aves even reported the importance these interactions had towards her math relationship.

> *[My relationship with math has] definitely been an uphill climb. It's never not been an uphill climb. It's always been something difficult. I feel like before. It was kind of like climbing an icy mountain on my own, and if I messed up then that was my own deal, and I had to struggle and deal with it, and I never understood, like why things were the way they were, and no one was willing to explain it to me. It was always kind of just like me struggling to learn things by myself online. And sometimes that doesn't match up with what we're doing in the course. Right? But I feel like now it is still mountain climbing. But now we're all like we're all in a line together, you know. We're all climbing together. So, it helps for me to be able to see other people doing and see other people struggling the same way. I am so it's still difficult, but it's difficult together*. (Aves Interview)

Here Aves' analogy of climbing a mountain parallels the illustration we have been using with students driving through the racetrack of the course. At the start of the semester, Aves viewed her climb as one that was solitary. However, now she views the climb as a group effort–a journey in which she doesn't have to go through alone. As we described in *4.1.6 Theme* 6: Small class sizes and instructional format support developing relationships with instructors and peers especially when instructors are able to facilitate interactive lessons., classroom relationships with peers and instructors can help students with navigating the terrain. These meaningful everyday interactions resulted in positive positions afforded to Aves as she described her icy climb as one that was achievable because of the people around her.

> *And it's more achievable. It's more achievable as a group. I don't feel like this is just my personal struggle with math, and everyone else is doing their own thing. This is our struggle with math. And we're gonna achieve this*. (Aves Interview)

From Aves, we saw her experiences impacted her math identity, increasing both her interest and recognition in mathematics over just a semester. She initially viewed math as something she had to struggle with alone. Now, she views math as an achievable feat by which she can work with others to overcome any challenges she faces.

Among the three case studies, Sappho, Elizabeth, and Aves, we saw how their experiences around relationships impacted their math identities. Elizabeth and Aves were able to strengthen their math identities by interacting with their peers and instructor. Elizabeth's class had sufficient instructional aide support that allowed her access to people in her classroom for help and the interactions facilitated by Aves' instructor

assisted her in viewing math as a group effort (*4.1.6 Theme* 6: Small class sizes and instructional format support developing relationships with instructors and peers especially when instructors are able to facilitate interactive lessons.*)* we also saw how his pedagogy of non-traditional approaches and encouraging questions (*4.1.4 Theme* 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements.) helped position Aves mathematically positively.

Course coordination can ensure instructors have sufficient instructional aide support to developing relationships in the classroom and through the feature of regular instructor communication, nudge instructors to facilitate interactive lessons and student-centered pedagogy. Course coordinators can also allow instructors agency for flexibility in due dates as we saw the impact this had on Aves to demonstrate her mathematical abilities (*4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding.) and encourage instructors to utilize embedded additional resources, like additional engagement points and/or discord (*4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability.) to provide even more opportunities for students to interact.

This accessibility to others, both inside and outside the classroom, afforded Elizabeth and Aves greater opportunities to be positively positioned such as mathematical explainers. As we saw, enough of these moments impacted their overall math identities.

In the case of Sappho, she had access to people inside the classroom, just like Elizabeth. However, her level of comfort with interacting with peers demonstrated that

access alone isn't enough as she desired her instructor to be more involved (*4.1.4 Theme* 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements.). Instructors need to foster a positive classroom environment, especially for women and gender fluid students, to aid in facilitating respectful interactions. Course coordinators can have professional developments to equip instructors on the skills needed to do so.

CHAPTER FIVE

DISCUSSION AND IMPLICATIONS

So, I think that's also something that is important in understanding mathematics, or at least learning for me, is the person who's teaching me. I think it's beneficial for the teacher and I to have a relationship, or I enjoy the teacher. (Ally Jackson Interview)

Storyline Illustration

Picture this. Your journey started with taking Calculus 1 where there was absolutely no stability and students in every section were having different experiences. Then you took Calculus 1 again the following semester under a coordinated system where everything was required to be consistent and fair. Now you have done research on student experiences writing and sharing your findings.

And the crowd goes wild. The university loves your findings and is completely behind you one hundred percent. The university gives you the green light to implement your findings to the coordinated system for calculus. You have power like you have never had before. Now the next part of your journey is to consider, with your results, how would you design a coordinated system?

The system of course coordination can be illustrated as an academic neighborhood with students, instructors, and course coordinators all having parts to play. Course coordinators, as choice architects, create the necessary blueprint for the neighborhood. They decide the overall grand design, selecting the features and qualities that will be included. With the suburban housing system there are various types of

communities depending on the types of infrastructure and amenities that are available much like how coordinated systems can vary across courses and institutions based on the number of uniform elements employed and to what extent. Here the infrastructure of housing would be related to the individual sections and the amenities corresponding with resources.

In this academic neighborhood, instructors are the builders constructing the vision laid out by the choice architect. If it's a tight coordinated system, instructors might have little control over their individual classroom similar to how one might describe a "cookie cutter" suburb in which the houses are constructed similarly with subtle differences in appearance. If instructors have more agency, this may be likened to suburbs with more variety of housing options like apartments, duplexes, and townhouses.

With the vision executed by the choice architect and the housing constructed by the builders, the residents can then move in. But what kind of neighborhood are they joining? Are there houses with ramps and wide doors for those with accessibility needs? What kind of amenities are there and are there safe and convenient ways of accessing them? How's the homeowner association? Do they fine residents for having their car parked on the side of the street but not help when there's a pothole? Do they run toy drives for the holidays for children in the neighborhood or food drives for neighbors in between jobs?

We lean into this neighborhood analogy to point out the influential impact that previous stakeholders had on the residents who live there and their quality of life. We described in *Section 2.1.5 Gaps in the Course Coordination Literature* the focal

interactions mapped out by Williams and colleagues (2021). Their diagram consisted of multiple embedded instructional triangles and focused on the inner triangle of the instructors, course coordinator(s), and the course content. The outer triangles connected instructors, students, and the course content. Even though students may not have a direct connection with course coordinator(s), we can still draw a line between them.

As we see with the neighborhood analogy and as we discussed in the results (

CHAPTER FOUR), aspects of course coordination can influence student experiences. With women being 50% more likely than men to leave the calculus sequence (Hagman et al., 2017) the following discussion and recommendations describe how course coordination can be a vehicle of change to act in making a difference to marginalized groups (Apkarian et al., 2021) especially with the recruitment and retention of women and gender fluid students in STEM. In this chapter we discuss how results on student-centered pedagogy and flexibility in coordinated and uncoordinated aspects maintained or improved students' math identity. As discussed in Chapter 2, a stronger mathematics identity predicts higher student interest in pursuing certain STEM careers (Cribbs et al., 2021). For those desiring to improve recruitment and retention of women and gender fluid individuals in STEM spaces this chapter may be of particular interest as we share the importance of attending to students in a coordinated system by rehumanizing mathematics, *Section 5.1,* and recommendations for a coordinated system that can positively impact women and gender fluid students experiences and their math identity in their design of a coordinated system *Section 5.2*.

5.1 The Need to Rehumanize Course Coordination

In the academic neighborhood of a coordinated system, it is important to remember that this entity is for people–for the students. Past studies in course coordination have showcased the benefits to instructors and briefly discussed the implicit benefits to students (Section *2.1.5 Gaps in the Course Coordination Literature*). However, strict consistency may be a detriment to students, especially those with less

robust math identities, if the system stresses fairness more than equity. In this section we discuss what may be more beneficial to students is a system that rehumanizes mathematics.

As we mentioned in *Section 1.1 Calculus 1 Across the United States*, Calculus 1 is successful in lowering students' affective beliefs towards mathematics in terms of their confidence, enjoyment, and desire to continue. And as discussed in *Section 1.2 Course Coordination and Calculus 1*, the feature of uniform elements was the feature that institutions reported similar levels of importance and success for their programs. Course coordinated systems are successful in stressing consistency and fairness. However, excessive rule following can have students feel dehumanized and even convinced they are no longer mathematical (Goffney et al., 2018).

Coordinated systems should stress less having to follow certain procedures to induce fairness and more on how to equip instructors to promote positive course experiences that can develop and strengthen positive math identity formations for students. This can be done through the idea of rehumanizing mathematics which assumes a relational view is important (Goffney et al., 2018).

Rehumanizing mathematics is an ideology suggested by Goffney (2018) as an active process to reconnect people with math by finding joy and belonging. Goffney provides eight dimensions that contribute to rehumanizing mathematics: (1) participation/positioning, (2) cultures/histories, (3) windows/mirrors, (4) living practice, (5) creation, (6) broadening mathematics, (7) body/emotions, (8) ownership (Goffney et al., 2018). Dimensions such as participation/positioning aligns with our theoretical

framework and the importance of students "responding more to each other" (Goffney et al., 2018, p. 5). As we discussed in previous literature and the results, more interactions help increase the likelihood of students being positively positioned as doers and learners of mathematics. Dimensions such as cultures/histories and windows/mirrors involve students' views of belonging and self-positioning with how students see themselves in the curriculum. The dimension of living practice is important for students to see mathematics as something they can contribute discussion towards, that it is not a field that has been set in stone and is static. The final dimension encompasses the need for students to explore and play with mathematics and to "conjure up feelings of joy" with doing mathematics (Goffney et al., 2018, p. 5).

Rehumanizing is still aligned with our equity center analysis as Goffney views rehumanizing as an ongoing action towards equity. We find this terminology fitting for two reasons:

1. The importance of constant vigilance with adapting to students' needs: We saw how a stagnant nature of uniform elements impacted participants' experiences. As discussed in *4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement., uniform elements do help with providing structure and even supporting engagement with coordinated policies around timing. However, uniform elements are often inelastic and stagnant which is why we also saw the need for instructor agency to make necessary adjustments in *4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted

student content understanding. and the importance of coupling uniform elements to meet student needs in *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning.. In the blueprint of the course, coordinators can intentionally include facets that are adaptable for the current needs of students.

2. The importance of interactions and relationships for students' math identity. From the results, there was one salient element cutting across the aspects of course coordination that influence student experiences and that was the human element.

Recall that in *Section 2.2 Mathematics Identity Research Motivation and Contexts* we defined mathematics identity as being constructed through interactions, which is why among our case studies, we saw the importance that the experiences involving relationships had in impacting women and gender fluid students' math identities. The quantity and quality of relations among students were important in positively positioning them. The interactions Aves and Elizabeth had both resulted in a positive shift in their mathematics identity. The lack of interactions for Sappho led to a negative shift in her mathematics identity.

We stated in *Section 4.1 Coordinated and Uncoordinated Course Aspects that Influence Student* Experiences how uniform elements can't position students. Within the parameters and constraints set by uniform elements, participants went about positioning themselves or being positioned by others. More so, we saw the instrumental role instructors played in positioning students as seen in *4.1.4 Theme* 4: Instructor pedagogy

was more salient in students described experiences than their awareness of uniform elements. with instructors' pedagogical techniques being more salient in students described experiences. In *4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability., instructors' encouragement of resources through their embedded additional resources helped students with various math identities in utilizing resources. And of course, we saw how critical instructors' ability to facilitate interactive lessons supported developing relationships in *4.1.6 Theme* 6: Small class sizes and instructional format support developing relationships with instructors and peers especially when instructors are able to facilitate interactive lessons.

Across our results, we saw the important relational role people–coordinators, instructors, and students–play in influencing student experiences. We also saw that because instructors had direct relations with their students, they were in the best position to make informed decisions of necessary adjustments to meet individual student needs. Positioning can contribute to rehumanizing mathematics by focusing more on creating meaningful relationships among students and with their instructor (Goffney et al., 2018). As choice architects, course coordinators serve a critical role in designing a system to support **both** instructors and students and the relationships between them.

In the next section, we discuss how coordinators can utilize both features of coordination to rehumanize mathematics for students by sharing recommendations to consider in their design.

5.2 Recommendations

Course coordination at its core is about establishing consistency and fairness. We want to preface that this isn't entirely a bad thing. As illustrated in the storyline in CHAPTER ONE and discussed in the literature review in CHAPTER TWO, course coordination is a characteristic of a successful calculus program providing stability across multiple sections and accessibility to resources. When present, it can help with establishing an even distribution of grades across a multi-section course, which maybe an indicator of equitable access to learning opportunities.

Below are our suggestions of aspects of an ideal academic neighborhood we would include with a coordinated mathematics course. We present them in Figure 5.1 before discussing them in more detail. We have organized our suggestions by the features in which we believe they can be implemented through a coordinated system which include uniform elements, regular instructor communication, and their intersection.

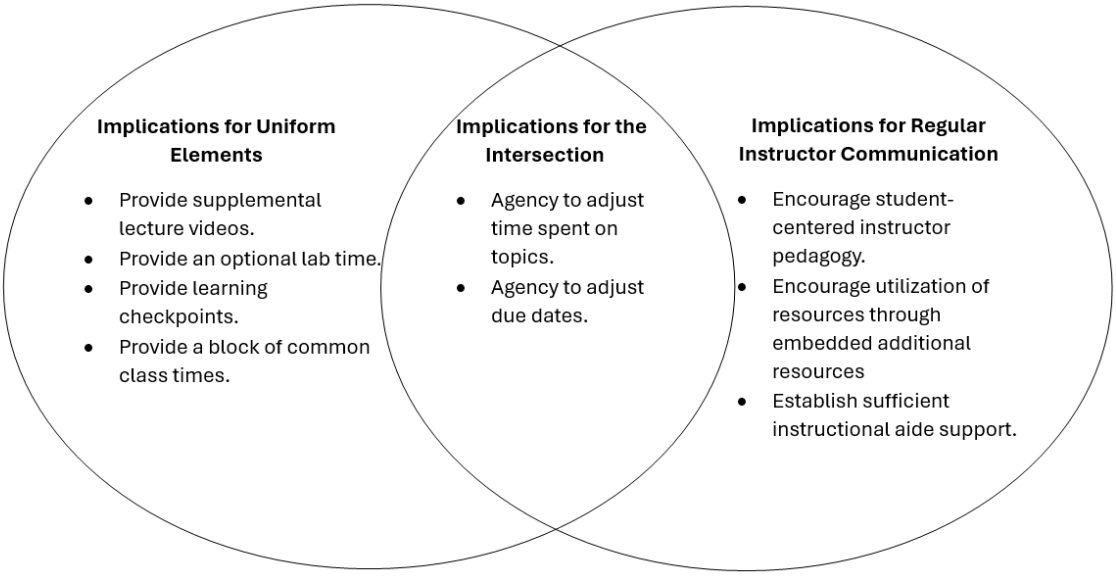

Figure 5.1: Recommendations for a coordinated system to rehumanize the mathematical learning space.

5.2.1 Implications for Uniform Elements in Course Coordination

Under the feature of uniform elements, we recommend that course coordinators consider weaving in mechanics to uniform elements that can assist counteracting the static nature of these elements that may inhibit learning. As we saw in *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning., uniform elements when not coupled with mechanisms to meet student needs inhibited learning. Participants with relatively strong math identities were able to still find ways to succeed, as we saw with Sappho who compensated for her learning from the lecture videos through the in-class activities. However, participants with weaker math identities could not manage the same feat, like Olivia. But in a course where the lecture videos are students' main source of the content, students shouldn't have the struggle of needing to figure out another way to understand the material.

Let's visit our neighborhood analogy. Uniform elements can be likened to the layout of housing built for students. If we imagine lecture videos to be stairs leading to the front door, residents without accessibility issues would not have difficulty accessing their home. Those with motor disabilities may still be able to go through the front door but not easily. It may take them some time to maneuver up the stairs–like how Sappho took a little longer to learn the content by making use of class time. For residents who may be paraplegic, the front door is not a feasible option. Instead, they must maybe go

through the garage where there might not be stairs. But by going through the garage, they sacrifice the use of the front door that was not designed with them in mind.

In *4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability., we brought up the notion of the blame game when discussing Olivia not taking advantage of the PAL tutoring services. We acknowledge that there are responsibilities for a student. We also acknowledge the obstacles and challenges that can exist that can add burdens for a student and make their responsibilities a little more difficult such as Olivia's inhibited learning from the source content itself.

Much like for architecture there is a need to attend to accessibility needs, choice architects need to attend to students' learning needs, designing a system aligned with the educational framework of Universal Design for Learning (UDL). UDL is about the need to develop flexible learning environments that can accommodate individual learning differences to meet the needs of students (Capp, 2017; Ralabate, 2011; Rose, 2000). When it comes to uniform elements, it's critical for course coordinators to consider more than just establishing elements that are common but also elements that have mechanisms built in place to accommodate student needs much like buildings with accessibility structures in mind. How uniform elements are constructed, whether uncoupled with mechanisms or not coupled, impacts how students view their sense of belonging and how they position themselves in the curriculum and can contribute to rehumanizing mathematics.

Based on the data, we suggest the recommendations for the following mechanisms that can be coupled with uniform elements: (1) Provide supplemental lecture videos, (2) Provide an optional lab time, (3) Provide learning checkpoints, and (4) Provide a block of common class times.

Provide Supplemental Lecture Videos (or if utilizing a flipped classroom provide a communication platform for students to ask questions)

We saw in *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning. how Joselyn's provision of supplemental videos positioned students as mathematical inquirers and explorers in their quest for more information. As we discussed in that section, there was already a supply of videos that instructors could point students to, but having individual videos be from students' own instructors is a way to foster relationships. Customizable videos upon request or through observations of a collective struggle is one way to rehumanize mathematics as they leverage the relationship between the instructor and students and support the ongoing process of adapting to students' needs (Elliot et al., 2020; Falkenstein-Smith et al., 2016; Ljubojevic et al., 2014).

If a coordinated system is utilizing a flipped classroom approach where videos are already made for students, we suggest pairing the videos with some sort of embedded questions and/or targeted feedback like a communication platform that students can take advantage of to further their understanding (Deng & Gao, 2023; Torres et al., 2022). For instance, if a discord channel was used or a shared Google Doc, students could pose their questions in real-time while watching the videos that could then be answered and

addressed. There could even be a survey for students to fill out after watching the video for students to communicate to instructors which topics they would like a greater explanation. These sorts of mechanisms would help students position themselves as mathematical investigators while giving them agency to address their learning needs early on. In turn, this information would help instructors with the knowledge they need to make any necessary adjustments.

Given business calculus participants assessment of the variability of instruction and quality for the lecture videos, we also suggest the importance of receiving student feedback to make any necessary changes and updates to videos if no supplemental videos will be made over the semester and the lecture videos remain the primary source of information. Course coordinators may reference Figure 5.2 for a sample statement of what can be included in a syllabus to acknowledge this mechanism.

Information on Modality: Lectures will primarily be delivered asynchronously through prerecorded videos produced by University instructors specifically for students enrolled in this course. Video links will be provided along with a Q & A link to ask questions while watching the lectures (example provided below). You are welcome to ask questions about any clarity points you may need and even to help your peers out by responding to any unanswered questions. Answers will be provided through the Q & A link and/or through supplementary instruction that will take place in class.

Example of Q & A:

Question	Time in Video	Answer
What did the instructor do to get from line 3 to line 4 in the third example?	5:34	Great question! The instructor combined liked terms to simplify the equation. Here's a quick video you can watch that provides more details.
I'm still confused on how limits work. Can we discuss this more in class?	NA	Yes, I can spend more time addressing this topic in class. Let's check in after the lesson to see we feel about them.

Information on Modality: Lectures will primarily be delivered in-person. I am willing to record and upload videos within reason upon request. You may submit your requests either in person or through the link on the website. I will check the list at the end of the week.

Figure 5.2: A sample syllabus statement of how lectures delivered asynchronously through prerecorded videos can incorporate student feedback (top) and how lectures delivered in-person can inform students about requesting supplemental videos (bottom).

Provide an Optional Lab Time

We saw in *4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement. some participants described their desire for even more contact time with the material. For them, they reported that the classroom environment was conducive to their learning. Providing an optional lab time will give students the power of choice which can assist with rehumanizing mathematics as they can have more opportunities to participate with other students and to take ownership as they continue to work with math problems outside of regular class (Bowers et al., 2019; Goffney et al., 2018; Kazemi et al., 2018).

An optional lab time can also allow students to receive necessary assistance for their assignments, such as the uniform element of online homework. This would be different from office hours as lab time would be designed with the intention to be a part of students' schedule and be in the same space as the classroom allowing for relationships in class to continue to develop. We discussed in *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning., Ally Jackson's desire to figure out how to solve problems on her own but expressed frustration that the homework software did not appropriately assist her. With online homework we acknowledge that depending on the software it may be impossible

for it to have the capability to have this mechanism. An optional lab time can substitute for this limitation. Students like Ally Jackson could better leverage support from either her instructor or peers with communicating her needs.

While a feature does exist to be able to ask an instructor question, this feature is entirely online and can place unforeseen strains on students. For instance, Aves reported that she would be worried that she could only ask big or relevant questions instead of small comprehension ones. Having an in-person mechanism can provide richer interactions where it will be easier for students to articulate their needs, like Ally Jackson wanting soft nudges, and for the instructor to explain solutions.

With a lab, we acknowledge this may influence the number of credit hours of a course and, as such, for courses like long calculus that are already four credit hours, an additional lab time would then place the course at five credit hours. Because of this we lean and stress for an *optional* lab time.

We also want to make the distinction that lab time would and should be different from tutoring resources that already exist as lab times should be presented and communicated to students as part of the course and would feature a TA and/or instructor to further build these relationships as opposed to tutoring. A lab time would be a communal learning space that is planned ahead when students register for class and will have access to their peers and instructional aides. Tutoring resources tend to operate in tandem with the course but are still separate and removed from the everyday workings. Tutoring resources also have their own prominence and meaning to students as does the association of what a lab means for a class.

For courses like long calculus that do meet four days a week an optional lab period can be placed on the day their class isn't scheduled to meet but their classroom space is still available, as desired by Aves. This lab period could be run by TAs as part of their office hours but labeled as lab time. For courses like business calculus that meet three days a week an optional lab period can be placed in the same slot as the common exam night as it is already a time marked off in students' schedule. Having a lab time scheduled during the common exam night block can even transcend sections. This lab time can be co-taught and run by multiple instructors and TAs that take shifts allowing for students to interact with peers across different sections of the course and develop impactful relationships and scaffolding additional instruction.

We saw how participants like Olivia reported that not knowing who her PAL leader was contributed to her delay for going to tutoring. For a lab time, students would know instructors and peers and hopefully would feel comfortable going. We saw how participants like Sappho felt uncomfortable interacting with people in her classroom. A lab time that transcends sections could provide an opportunity for students to see various role models with matching social identities. Exposure to other instructors may help with boosting math identity (Sullivan et al., 2021). Course coordinators may reference Figure 5.3 for a sample statement of what can be included in a syllabus to acknowledge this mechanism.

Lab: For those needing additional instruction and/or a space to work on assignments, labs can be used to have more class time to spend with the material. Labs are different than tutoring services and office hours (see more details in their respective sections) as labs will take place in our regular classroom and you will have access to instructors, TAs, and your peers. In labs you can:

- Work on homework assignments.
- Finish in-class assignments.
- Explore and enjoy mathematical topics.
- Ask for additional instruction of topics covered from the past week.

Labs are scheduled on Wednesday nights at 5:30 pm Eastern and are optional to attend. There will not be labs on weeks when there is a common exam.

Figure 5.3: A sample syllabus statement for how a lab time can be structured and established in students' schedule. For classes that meet four days a week this can be adjusted by having lab on the day classes are not regularly scheduled.

Provide Learning Checkpoints

We saw in *4.1.1 Theme* 1: Uniform elements when not coupled with mechanism to meet student needs such as responsive feedback inhibited learning. how participants reported the pressure of weights set by the grading system. This is where we introduced the racetrack illustration with Dylan describing getting off track, comparing exams to the wheels on a car. A car depends on wheels much like a student's course grade depends on how they perform on exams. Due to this weight, participants expressed how exams were a source of stress, desiring learning checkpoints so they can self-assess their knowledge in low-stakes situations.

We recommend that course coordinators implement the mechanism of learning checkpoints to alleviate the pressure of exams. Learning checkpoints can provide more opportunities for students to position themselves more positively throughout the semester instead of the few opportunities of exams.

Learning checkpoints can come in the form of formative feedback which identifies areas of improvement for students. Usually, formative feedback is given immediately to help catch any misunderstandings early on (Irons & Elkington, 2021; Juwah et al., 2004; Shute, 2007). For flipped classrooms, this can be in the form of having embedded questions in the videos as recommended in the previous section, and/or having students take proficiency quizzes after watching the videos. For lecture style classes, instructors can also utilize proficiency quizzes to check on students' understandings and inform on topics that may need to be revisited (Toledo & Dubas, 2017). An important component of formative feedback is allowing students to resubmit their work to check their understanding. As a resource to instructors and students, coordinators can have detailed feedback integrated into the proficiency quizzes to help with providing the immediate feedback and correction of errors. Course coordinators may reference Figure 5.4 for a sample statement of what can be included in a syllabus to acknowledge this mechanism.

Grading Policies:

Section Work (15% of course grade)

A grade in this category reflects student performance on in-class activities, proficiency quizzes, and homework assignments that are not part of your online homework. These are assignments chosen by your instructor to promote active learning through group discussion, problem solving, and interpreting various mathematical forms and are described below.

- Proficiency Quizzes. Over the course of the semester, proficiency quizzes will be tasked to check on your understandings of the content. These quizzes will be done online and scored automatically. You will be able to see what you got wrong along with detailed feedback. You are allowed to redo proficiency quizzes for a higher grade and to correct previous misunderstandings. You may take another attempt on these quizzes at office hours, lab, and/or review day.

Figure 5.4: A sample syllabus statement for how learning checkpoints like proficiency quizzes can integrated into section work.

Provide a Block of Common Class Times

We saw in *4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement. how participants reported that the time of their class had an impact on their ability to engage with the material. Participants like Aves described the difficulty with waking up for her 8 am class and Joselyn shared how her friend struggled with paying attention in her late afternoon class. The impact of time on day is supported by literature as there are biological mechanisms that influence optimal times that students learn (Ammons, 1995; Beşoluk et al., 2011; Hines, 2004; Wile & Shouppe, 2011).

As Dylan described in *4.1.4 Theme* 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements., preferred sections may close on students before they have a chance to register for classes, leaving some students with less desirable times that can impact their attention. With courses at this university already having a common exam time for students to register for along with scheduled course sections, it would not be too much of a stretch for there to be a block of common class times. Providing more options of sections within a viable window could help with establishing consistent engagement levels. We know this might not be a feasible strategy for all universities but provide it as a way to re-imagine mathematics and call into question the extent to which uniformity fosters fairness.

5.2.2 Implications for the Intersection of Uniform Elements and Regular Instructor Communication

A component in the effort to rehumanize mathematics is the importance of constant vigilance with adapting to students' needs. While constructing uniform elements with mechanisms to meet student needs can help support their learning, sometimes the mechanisms that are needed are the ones in which humans can make necessary adjustments. If given agency, instructors are in the best position to make informed decisions to accommodate student needs as they have a direct link to students. In doing so, instructor agency can bridge the gap between the two features of course coordination.

As we saw in *4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding., instructors' agency to adjust uniform and coordinated policies to accommodate student needs promoted student content understanding. We saw how rigid due dates and lack of extensions caused students' stress. Participants like Sappho scrambled to submit work on time. There were times when Olivia was unable to submit her work due to uploading issues and was unable to receive necessary feedback. The inability to get extensions resulted in a lack of content understanding and limits the possibilities of positive positions from instructors. As we discussed in *Section 4.2 Experiences Impacting Women and Gender Fluid Students' Math Identity*, Sappho's math identity weakened from lack of recognition. Conversely, in the same section we discussed how Aves' math identity strengthened from her instructor positioning her as mathematically capable and allowing small extensions. Her instructor's subversion of

coordinated policies with his flexibility helped to meet her needs and demonstrated he cared about her understanding.

Let's visit our neighborhood analogy. Instructor agency to make necessary adjustments can be likened to maintenance for houses. There are times when the air conditioning can go out (always during the worst time like the summer), pipes can get clogged, and lights may need to be replaced. We can imagine these housing issues that can arise as being similar to when students have life get in the way. Much like how Aves had a busy schedule with athletics and had difficulties turning in homework on a daily basis, students have more than just their class workload. Some students even have work on top of their classes. Allowing instructors to make necessary adjustments can be likened to filling out maintenance requests so that residents don't have to worry about living with no AC, unclean water, or even living in the dark.

When it comes to instructor agency, it's critical for course coordinators to embrace the role instructors play in being able to assess and address individual section needs. Instructors are the link between students and course coordinators. Through the feature of regular instructor communication, instructors can be the bridge for communicating how their students are being impacted by the feature of uniform elements and for communicating what accommodations their students may need much like buildings may need different types of maintenance from time to time. Based on the data, we suggest that instructors (1) have agency to adjust time spent on topics and (2) have agency to adjust due dates. This should be clearly communicated and encouraged from the course coordinator.

Agency to Adjust Time Spent on Topics

We saw in *4.1.2 Theme* 2: Uniform and coordinated policies around timing provided structure and supported engagement. That participants reported that the provision of coverage topics helped with providing structure. However, in *4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding., we discussed how the course calendar was negatively viewed by participants when viewed as a barrier such as when not enough time is spent on topics.

We discussed how coordinators were already making use of the feature of regular instructor communication by having instructors inform them of topics students struggled to understand. From this information, coordinators were able to adjust pacing for the collective whole, reformatting the course calendar for the following semester. However, this adjustment after the fact does not actively accommodate current student needs. While coordinators may be able to use past information to make adjustments to the course calendar, instructors can use present knowledge to make necessary small adjustments in the time spent on topics.

Participants like Dylan, who had a weaker math identity, reported the difficulty of falling behind in a fast-paced course. For students who feel like they're falling behind, like Dylan, they could benefit from their instructor being able to adjust how much time is spent on topics. We returned to the driving analogy and likened the course calendar to a GPS. Instructor's agency to adjust could be likened to offering a detour to allow drivers a chance to keep moving forward.

For this recommendation of instructor agency to adjust time spent on topics, we suggest that course coordinators allow instructors bounds in which instructors can be flexible. By bounds we're referring to the range of time between exams in which different topics are covered as often coordinated systems utilize the uniform element of a common exam. These boundaries would still work in establishing consistency as instructors would have to adhere to covering the same topics as all other sections and for providing flexibility as instructors could make necessary modifications within the small window that can contribute to inclusive teaching (Hoover, 1990; Ruhela, 2024). Additionally, as discussed in the 5.2.1 Implications for Uniform Elements in Course Coordination, supplemental lecture videos and/or an optional lab time could also help with providing necessary time on topics to support student content understanding if this suggestion is seen as not feasible given the amount of topics that must be covered.

Agency to Adjust Due Dates

We saw in *4.1.3 Theme* 3: Instructors' agency to adjust uniform and coordinated policies accommodated student needs and promoted student content understanding. That participants reported instructors' adjustments of due dates–by just offering small extensions–positioned participants as mathematically capable and promoted content understanding. Participants like Ally Jackson expressed her appreciation of her instructor's willingness to adjust the due date of a quiz. She took advantage of the accommodation to visit her TA's office hours, allowing for greater content understanding and positive positions. Similarly, participants like Aves shared how her instructor's

flexibility demonstrated to her that he cared about her understanding and how that impacted Aves' math identity.

From this study, the results support the positive impact leniency in due dates can have on the student experience and with strengthening relationships with math. The positive impact of extensions on students' stress and performance is also supported by the literature on UDL, which has an extension without penalty model in which the policy offers both ideal and extended due dates (Ruesch & Sarvary, 2024). With this built-in provision of extended due dates without penalty it allows students who may be dealing with external stressors such as illness or work around the ideal due date a chance to still participate in their learning process without further penalization. For a coordinated system that's primary principle is consistency, the extension without penalty model is a way for there to still be structure, by having the ideal due dates, and to build in flexibility, by having extended due dates already part included.

In our neighborhood analogy, we could think about how a resident may have a lightbulb go out and need a replacement much like a student may miss an upload window, like Olivia, on one occasion. However, there could be times when residents have recurring problems, much like Aves who had regular interference with turning in assignments or our storyline example in CHAPTER TWO with our character getting injured. If the set extended due dates aren't enough for these situations but flexibility is still needed, we recommend allowing instructors' agency to make necessary adjustments.

For extensions that are more specific to accommodate student needs we suggest leveraging transparency to upheld consistency across the multiple sections. When

meeting with the coordinators, instructors can be transparent in the accommodations they want to give and why. To then be transparent to the students, decisions made with granting extensions could be communicated to students. Both courses in the study had a course website. We suggest that coordinators could link a document on the website for students to access to be aware of extensions and for what reasons. Course coordinators may reference Figure 5.5 for a sample statement of what can be included in a syllabus to acknowledge this mechanism.

Late Work Policy: All assignments that are the same across all sections of the course (i.e., learning activities, online homework) have assigned due dates color coded in blue in the course calendar. If you have an illness, some other event, or need more time to work with the content material then you may submit the assignment by the extended due dates color coded in red in the course calendar. You may make use of the lab time, office hours, and tutoring to assist in related content.

In the case for extenuating circumstances further extensions may be determined.

Extensions Granted		
Assignment Extension	**Extenuating Circumstance**	**Extension Length**
Learning Activity 3.2	Injured wrist	Two more days past the extended due date
Exam 1	Death of Extended Family Member	One week
Homework Assignment 1.4	Personal Struggle/Mental Health	Two more days past the extended due date
Online Homework 2.4	Student is out for flu	Three days upon their return to school

Figure 5.5: A sample syllabus statement for how to utilize an extension without penalty model (top) and an example of transparent communication for extensions given (bottom).

5.2.3 Implications for Regular Instructor Communication Recommendations

Under the feature of regular instructor communication, we recommend that course coordinators embrace and nurture this community of instructors to develop instructional practices and provide instructional support that can impact student experiences.

As we saw in *4.1.4 Theme* 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements., instructor pedagogy was more salient in students' described experiences than their awareness in uniform elements. Participants like Joselyn shared how her instructor's intentional use of making real-world connections made her excited to learn. Her instructor's pedagogy was one of the contributing factors to her claims that she had the best instructor. For participants like Aves who had a weaker math identity, her instructor's dynamic teaching methods increased her interest in mathematics as she expressed enjoying learning math.

In *4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability., we saw how instructors embedded additional resources like a discord survey and additional engagement points encouraged students to utilize resources which were more beneficial than just the advertisement of resources. We discussed how participants like Olivia who had a weaker math identity and difficulty with navigating resources could have benefited from an embedded resource that would have stimulated her to access tutoring services earlier and contributed to positive views of her mathematical ability sooner.

And in *4.1.6 Theme* 6: Small class sizes and instructional format support developing relationships with instructors and peers especially when instructors are able to facilitate interactive lessons., we saw how when instructors were able to facilitate interactive lessons, they were able to support developing relationships among students. Participants like Elizabeth were able to be positively positioned by their peers and instructional aides strengthening her relationship with math as the semester progressed. When participants did not have this support, like Sappho, their relationship with math weakened.

Let's visit our neighborhood analogy. Instructors can be likened as the builders adding personal signatures to their creations when they can while still executing the design of the blueprint. We can imagine that a choice architect may provide a list of limited options for builders to choose from such as Roof A, Roof B, or Roof C and so forth as found in a "cookie cutter" suburb or a wider list of a variety of housing options like apartments, duplexes, and townhouses. Some residents may want a house and a yard to take care of while others may be content with an apartment. Much like residents may desire various forms of housing to meet their needs, students desire various forms of instruction to meet their needs such as how participants like Dylan desired more interactive lessons to help her with forming connections and how participants like Olivia wished there was more support in the classroom to help her.

The types of options that are available to builders are from what the choice architect provides. Course coordinators can influence instructors to make a desired choice by setting default options in their designs and nudging them to implement certain

pedagogical techniques that are beneficial to students' content understanding and experience. Through the feature of regular instructor communication, course coordinators can facilitate discussions on teaching practices, encouraging resources, and checking to see if instructors have sufficient instructional aide support to help their students.

When it comes to regular instructor communication, it is critical for course coordinators to leverage its community of instructors to discuss how to best support students. Based on the data, we suggest the following recommendations for coordinators to consider when communicating with instructors: (1) encourage student-centered instructor pedagogy, (2) encourage utilization of resources through embedded resources, and (3) establish sufficient instructional aide support.

Encourage Student-Centered Instructor Pedagogy

We saw in *4.1.4 Theme* 4: Instructor pedagogy was more salient in students described experiences than their awareness of uniform elements. That participants reported that instructor pedagogy was more salient to their experiences than their awareness of uniform elements. When participants learned differences the topic of discussion was mostly about instructors. Participants like Dylan, Aves, and Joselyn shared how they looked at RateMyProfessor.com with Aves intentionally selecting her instructor based on the reviews and his teaching. Participants like Sappho learned how inactive her instructor was compared to other instructors and wished that he was more involved in her learning process. Participants like Joselyn learned how different her learning experience was than her friend due to her instructor's intentional use to make real-world connections.

The use of student-centered pedagogies and active-learning strategies were a characteristic of successful calculus programs (Bressoud & Rasmussen, 2015). The characteristic of course coordination can leverage this other characteristic especially by building a community of practice with its instructors. As discussed *in Section 2.1.4 Course Coordination in Other Studies*, effective instructor regular communication can help ensure a positive community of instructors (Apkarian et al., 2018, 2019; Williams et al., 2021).

Because of how salient instructor pedagogy was on students' experiences, we recommend that course coordinators communicate and promote pedagogical techniques to help personalize learning environments. One such example is through the utilization of a dynamic calendar (Oliver et al., 2023; Oliver & Olkin, 2020). A dynamic calendar serves as a tool coordinators can use to provide instructors with "embedded live links to a set of in-class activities, videos, and worksheets" that are aligned with the topics that will be covered (Oliver et al., 2023, p. 318). These embedded links can also include student-centered instructor pedagogy such as active learning strategies that are tied to the lesson. The calendar is dynamic in the sense that in the community of instructors it can be edited and adapted over the semesters based on feedback and changes informed from the semester.

In this community of instructors, experienced instructors can share which dynamic methods they have tried to facilitate interactive lessons for and any observations or feedback related to student engagement. With this discussion, they would both be providing information to newer instructors and also using the space for ideas and

strategies to be exchanged for what worked and what didn't. This in turn can contribute to another characteristic of successful calculus programs with effective training of graduate teaching assistants (Bressoud & Rasmussen, 2015).

With a list of options and resources for student-centered teaching methods provided in a dynamic calendar, instructors can have agency in which methods they may prefer to use in their classroom, but the choices would still contribute to facilitating interactive lessons in some way. Some instructors may gravitate toward what Aves' instructor did with starting class with a free-response non-math question. Other instructors may find the approach of assigning groups and encouraging teamwork to be the approach for them to help with developing relationships.

Due to the time and nature constraints of developing active lessons, course coordination is perfect in that it can design and provide these resources for instructors, resources that can be improved and added to each semester (Milbourne, 2018; Williams et al., 2021). By having resources already made and by discussing them with instructors, course coordinators can nudge instructors to include dynamic teaching methods in their lessons (Williams et al., 2021).

In this community of instructors, course coordinators can also have a resource for real-world connections. As it can be challenging to think of real-world connections for every topic, a provided resource embedded in the dynamic calendar that has a list could assist and encourage instructors with weaving it in their lectures. Much like the dynamic teaching methods, instructors can discuss which connections seemed to pique student

interest and make suggestions to add to the list to increase teaching effectiveness (Arthur et al., 2018; Mhlolo et al., 2012).

Encourage Utilization of Resources Through Embedded Resources

We saw in *4.1.5 Theme* 5: Embedded additional resources when utilized by students contributed to positive views of mathematical ability. How embedded additional resources when utilized by students contributed to positive views of mathematics ability. Participants with a weaker math identity, like Olivia, faced challenges with navigating the resources available to them. She expressed her awareness of resources but not knowing how and when to use them. Participants with a strong math identity, like M, shared their self-awareness of their needs and how and when to ask for them. They expressed knowing when they needed to use resources and when they didn't. However, when instructors encouraged students to utilize resources through creative embedded additional resources participants reported finding them beneficial. Participants like Mabel Wyler and Elizabeth shared how their instructor's additional engagement points which encouraged them to accumulate a certain number of points prior to each exam from a list of options benefited their experience by having them practice more with the content. This approach of additional engagement points can be used to list the lab time as mentioned above as an option for students to earn additional engagement points.

Participants like Aves shared how her instructor's implementation of a class discord helped her ability to access support from her and her peers especially since there were schedule conflicts with PAL sessions. We discussed how this utilization contributed to strengthening Aves' math identity. By intentionally providing these options of teaching

methods and discussing them through regular instructor communication, coordinators can nudge instructors to utilize these methods that are student-centered.

We recommend for course coordinators to communicate with instructors the importance of them leveraging embedded additional resources in their sections as instructors who incorporate these innovative methods can facilitate students learning (Randi & Corno, 2000; Reeve, 2006). Much like we discussed above, providing a list of options would allow instructors agency and also allow for this encouragement of resources to still occur. And like the student-centered teaching methods, this list can grow through suggestions and discussion made by instructors through the community of instructors. Course coordinators may reference Figure 5.6 for a sample statement of what can be included in a syllabus to acknowledge this mechanism.

Grading Policies:

Section Work (15% of course grade)

A grade in this category reflects student performance on in-class activities, proficiency quizzes, and homework assignments that are not part of your online homework. These are assignments chosen by your instructor to promote active learning through group discussion, problem solving, and interpreting various mathematical forms and are described below.

- Additional Engagement (AE) Points: Each unit there will be a required number of AE points. These AE point assignments are part of the section work part of the course grade. AE points can be earned by the following options listed below. You do not need to do all of these listed below but may choose which option(s) to fulfill to earn AE points.
    - Communicate with your instructor by email about the course content. This could include using the online homework feature to send your instructor a question. 1-10 pts. per week
    - Attend a Zoom office hour to talk about the course content. 1-10 pts. per session.
    - Attend PAL session or ASC tutoring. Submit proof of attendance (i.e., signature of leader with your name, date and time, picture of you and the leader) and send it to your instructor. 5 pts. per session.
    - Attend a lab section to talk about the course content. 5 pts. per session.
    - Complete additional homework assignments that may be offered beyond Learning Activities. 1-10 pts. per assignment.
    - Complete additional Canvas quizzes that may be offered beyond those used as Learning Activities. 1-20 pts per assignment.
    - Submit in-depth summaries concerning the curriculum learned that week. 1-5 pts. per week.
- Points will be determined by your instructor based on the quality of the additional engagement. These points accumulate during the unit (i.e., earning 2 or 3 points from one option does not limit you from earning more AE points).
- It is allowed to exceed an AE goal but accumulated points for a unit cannot exceed 5 extra points. Your points will be reduced at the end of the unit if you exceed 5 extra points.

Figure 5.6: A sample syllabus statement for how an embedded resource like additional engagement points can be utilized by providing an option of resources for students to select from to earn points.

Establish Sufficient Instructional Aide Support

We saw in *4.1.6 Theme* 6: Small class sizes and instructional format support developing relationships with instructors and peers especially when instructors are able to facilitate interactive lessons. how small class sizes and instructional format support developing relationships with instructors and peers especially when instructors are able to facilitate interactive lessons. Participants like Elizabeth, whose math identity

strengthened, reported the benefits to her learning experience from having access to different people to help her. In her classroom, she had an instructor and two instructor aides, having sufficient support to build relationships. Participants like Olivia, whose weaker math identity stayed the same, reported the difficulties she had with her learning experience from not having sufficient support in the classroom. With her instructor and one instructional aide, there were not enough hands to help. This absence of receiving help were missed opportunities of possible positions for Olivia that could have promoted positive math identity formation.

It is critical to create moments in mathematical learning spaces that can position students towards being mathematically capable learners. With mathematics identity as being an iterative process where identity is constructed through interactions, it is important for instructors to have sufficient support in the classroom to be able to develop relationships and interactions as instructional aides can help with scaffolding learning (Gomez Johnson et al., 2021; Kornreich-Leshem et al., 2022).

We recommend that course coordinators ensure that instructors have sufficient instructional aide support especially given the instructional format of the course. Course coordinators may want to consider a balance between the number of instructional aides an instructor has for the size of the class and the instructional format of the course. For instance, for a lecture style course in which there are less interactions to facilitate, we recommend that coordinators try to establish at least one instructional aide for each section of the course. However, if an instructor plans to implement more dynamic teaching methods, more instructional aide should be provided. For a flipped classroom in

which students are interacting the entire class period, we recommend that coordinators try to establish at least two instructional aides for each section of the course.

We acknowledge coordinated systems may face challenges with the number of instructional aides that are available for the multiple sections of the course. Given this limitation we suggest course coordinators to keep an open dialogue with instructors about the support they may need. If there are not enough instructional aides to provide to instructors than the previous recommendations of embedded additional resources and making real-world connections may need to be leveraged more to help compensate.

CHAPTER SIX

CONCLUSIONS

We started this study motivated to attend to the student experiences in course coordination, specifically marginalized students like women and gender fluid students. Past studies on course coordination were primarily focused on the importance of consistency and the benefits coordination has for instructors as a way to provide a repository of resources to support them, especially graduate teaching assistants. Often, if students were discussed it was mainly about their academic success with coordination in place. We hoped to add to the literature by attending to the student perspective and addressing issues of equity.

We collected data from ten students, six from business calculus and four from long calculus, through different sources like math identity surveys, video journals, and interviews. From thematic analysis, we were able to determine what aspects of course coordination influenced their experiences. Then using a case study approach, we focused on three participants whose math identity changed from the beginning of the semester to discuss what experiences impacted their identities.

From the results, we expressed the need to rehumanize mathematics with the importance of adapting to students' needs and facilitating interactions and relationships among students to support their math identity. We then followed it with implications for course coordination and suggested recommendations for coordinators to consider in their design that can positively impact students' experiences and, in turn, strengthen their math identities.

In this chapter, we discuss the limitations of the study and then follow it with future directions that can be taken with this research.

6.1 Limitations

Limitations will exist in any study and this study is no exception. In this section, we take the time to acknowledge the potential bias or exclusions in the research design. The first limitation we acknowledge is that the study was done at one institution, limiting the generalizability of the results. The study took place as a predominantly White R1 land-grant university in the southeast, limiting the diversity of the population to be studied. Being located in the southeast, educational systems are underfunded and there have been political attacks on diversity, equity and inclusion which may limit potential willingness to partake in a study focused on equity such as this one. The region location of the institution also limits exploring the implementation and effectiveness of course coordination in other educational contexts. Researching at predominantly White institution also limits a broader understanding of how course coordination impacts students with varying backgrounds and experiences.

We were also limited in the study in that the math identities did not represent a range of different perspectives. Over half of the participants started with a strong math identity limiting the richness of the data provided as students with a strong math identity tend to do well regardless of learning environment.

We also did not attend to intersectionality of their identities that may have influenced our findings. As multidimensional beings, people have many facets of their identity that can influence their experience. A limitation was that intersectionality was

not addressed in the study. Although we did classroom observations, we were unable to observe every single participant's classroom and those we could we only observed once as we wanted more of a broad stroke for contextualization. Since we did not observe every classroom and only observed a single lesson there might have been missed instances of capturing more details.

Data were collected from course coordinators and instructors, but the data collected from them were not analyzed and also used for contextualization. Not analyzing this data along with the student data prevented making further connections between all three stakeholders and course coordination as a whole.

6.2 Reflections on Own Practice and Future Work

Through this process I have come to discover that I find more enjoyment from teaching than I do research. In this final section, I provide suggestions of what others could do to continue this research. I then end with reflections on my own practice and how I will use this research in my own teaching.

For those interested in continuing the work I started, future work can consist of analyzing all stakeholders in a coordinated system. Past studies have focused on coordinators and instructors and my study focused primarily on students to fill that missing gap. However, more work is needed to look at the system as a whole and all the parts in play. Future work can also expand institution types such as smaller universities, community colleges, or minority-serving institutions and include more robust identities such as intersectionality. Given the qualitative nature of the dissertation study, future work can also draw on larger quantitative data to make more causal claims.

Course coordination is defined as having two features: uniform elements and regular instructor communication for a multi-section course. It does not distinguish the caveat to have multiple instructors thus by definition, I am also a course coordinator. The multiple sections for the courses I teach are small enough (~3 sections) that I also instruct all of them. I am also in charge of all the teaching assistants involved and ensuring that grading is consistent and that the teaching assistants are equipped to properly aid students which I do by communicating with them their duties and expectations. Along with managing the teaching assistants, I also accumulate and edit resources for future use not just for myself but anyone else who may instruct the course and given the rising enrollment of elementary education majors it is possible that even more sections may be needed.

I started this journey with the vision of course coordination being able to be more, not just success in pass rates and retention. How could I as coordinator for my students design a system that was both fair and one that also was able to accommodate student needs? How could I strengthen their relationship with math? As I shared in my positionality in *Section 1.4 Prior Relevant Experience and Positionality*, I teach mostly cisgender women who will be future elementary teachers. A lot of them report having a weaker math identity coming in and some, like Dylan and Olivia, I watched continue to struggle throughout the semester, their math identity not strengthening.

While sitting with the themes as they were coming together, I reflected on my own practice and how I may enact some of the recommendations I suggested in

CHAPTER FIVE. My past years as a lecturer I have tried structures like contract-based grading, group exams, and adjustments to lessons and the time spent on topics to make improvements—much of my focus being on the uniform elements across my sections. And I observed the (1) withdrawal of engagement of my students, (2) an absence of understanding in the content and material, and (3) lack of mathematics identity strengthening, prompting me to make the following changes to my own design.

To help with supporting engagement levels of my students, I plan to no longer request to teach at 8 am. For my department, teachers share their preferred times to each when filling out teaching preferences for the upcoming semester. As I observed personally the stark difference in the engagement of my students in the 8 am class compared to later sections, this is recommendation I'm going to implement especially for when I have multiple sections of the same course. To also aid in increasing student interest and engagement with mathematics, I am planning to incorporate gamification of my lessons in which students will have to work with their teams through the activities to support more student-centered pedagogy.

As coordinator I plan to construct my own dynamic calendar to add and edit strategies, resources, and ideas to support more active lessons with the expectation that sections of this course will increase and number and that I will not always be the sole instructor of the course, this dynamic calendar can be a tool for future instructors and to help with professional development of my teaching assistants who will be future teachers and assisting me with these lessons. I also plan to start constructing references to real-world connections that can be leveraged in lessons.

To help with deepening understanding of the content and material I plan to employ my Tas to provide supplemental lecture videos upon request or through observations on topics that students seem to struggle with. Flexibility in due dates is something that I've always been a supporter of but have found it challenging to be both consistent and accommodating. The extension without penalty model and the transparency of extensions granted are recommendations that I am planning to incorporate to help find this balance.

To facilitate interactions in the classroom and with getting necessary support to help strengthen students' relationship with math, I am planning to have two instructional aides in the classroom. The courses I teach are lecture style, but I have found that one instructional aide is not enough to help with my class of 40 students with our activities. I unfortunately had students like Olivia that I was not able to sufficiently support.

I am grateful for the insight that I have obtained through this research and how I can apply my findings to my own coordination. I look forward to being able to commit these results into practice and hopefully strengthen my students' math relationship.

APPENDICES

Appendix A Codebook

Code	Definition	Exemplar
Course Logistics		
Class time linked with engagement	Students mention the time of class such as their feelings and/or experiences related their class time.	*My class, is an 8 Am. And other classes are, you know, later in the day. And that's a small thing. But it really makes a huge impact*
Students link class sizes with relationship opportunities with peers and instructor	Students mention the size of their class and how the size of the class impacts engaging with peers and their instructor.	*So, I think that's nice to have that smaller classroom feeling and I feel that I can grow more of a relationship with my professor*
Students link contact time with content coverage	Students mention the number of contact hours such as their feelings and/or experiences related to the number of contact hours and content coverage.	*Being in class, being in a math environment that helps me, you know, the more I'm in class, the more I'm in that environment the better my performance is. So already it's better than other classes being 4 days a week. But it could be even better if it were 5*
Positive Affective Views Towards Flipped Structure		
Flipped structure helps with pacing and preparation due to predetermined course calendar	Students mention the layout of a flipped structure helps with establishing pacing and allowing them to come to class prepared.	*The flipped classroom layout format you get to essentially come in prepared and see ahead of time what you are going to be working on.*
Flipped structure helps with building relationships due to increase classroom interactions	Students mention the layout of a flipped structure allows them access to people in the classroom and helps a relationship with their instructor.	*I also like this flip classroom aspect, just because I like being able to have the homework assignment or the learning activity in front of me, and I have quick, easy access to people in the room that are eligible to help me.*

Code	Definition	Exemplar
Flipped structure helps with understanding the material due to increase contact time	Students mention the layout of a flipped structure of increased contact time helps with learning and understanding material as they can use class time to ask questions.	*I do like this layout for a math class because it gives me the opportunity to like, apply what I've learned in the video. And also it lets me come in with questions I may have had during the lecture.*
Negative Affective Views Towards Flipped Structure		
Flipped structure has a negative impact on student due to videos being time-consuming and large workload	Students mention a negative impact related to external pieces of a flipped structure like videos being time-consuming and a large workload.	*If they're busy, they don't have time to watch the lecture videos outside the class that could be a struggle.*
Variability of instructional videos and their quality leads to inconsistent learning experiences	Students mention the variability and/or quality of instructional videos and how these videos may have a negative impact on their learning.	*The lecture videos I got, I didn't think we're the greatest or the most helpful.*
Nature of static instructional videos prohibits real-time questions	Students mention not being able to ask questions right away when watching lecture videos for a flipped structure.	*Someone has a question, but they can't really ask the question to a video.*
Affective Views Towards Lecture Style		
Student enjoys lecture style because external environments are not conductive to learning	Students mention enjoying lecture style specifically because a flipped structure with videos would not be a conducive environment for learning.	*I don't do well with videos. I feel like I can't concentrate at home like I'm very much a person who needs like a physical distinction between, like what I'm doing in this space versus what I'm doing in this space.*

Code	Definition	Exemplar
Student would prefer a flipped structure because it establishes a problem-solving space in the classroom	Students mention wanting to change from lecture style to a flipped structure because they would prefer a problem-solving space.	*And I also feel like that flipped classroom structure would get me to a point where I can bring myself to sit down and do math*
Lecture style helps with understanding the material due to pacing	Students mention how the layout of a lecture style course helps with establishing better pacing.	*I do like the slow down pace. But the slow down pace makes it so that it's it. It's less of the emergency every single day.*
Lecture style has a negative impact on students due to the pacing of assignments and amount of material	Students mention how the layout of a lecture style had a negative impact due the amount of material being covered and the number of assignments in circulation.	*I felt like there was a lot of material that we were learning in a short amount of time*
Perceived Transparency of Grading System and Provision of Resources		
Transparent communication of policies and scoring help students establish routine and review mistakes	Students mention the communication of the grading system, specifically the transparency of its policies and scoring.	*I feel like everything is well communicated with us. We know over what's expected.*
Rigid due dates and lack of extensions cause students stress and scrambling to submit work on time	Students mention due dates, specifically not being able to get extensions and stress related to due dates.	*I would change the timing everything is due. I prefer it to be due at midnight or by the starting point of the next class, because I don't always have time to get it done before 10, and then I'm just stressing over getting it done.*
Unclear communication of grading system	Students mention the communication of the grading system, specifically policies and scoring that were unclear.	*I do not know of any curves, but she might just be adding them on, and not telling us to the exams.*

Code	Definition	Exemplar
Students are aware that the syllabus outlines important information to prepare them for success	Students mention the syllabus and how it outlines important information.	*The section of the course syllabus that most aligns with this goal is simply the learning objectives. Because if I want to succeed and I want to do well, I must learn obviously, what are listed in the learning objectives*
Students appreciate and recognize the value of advertisement of academic resources	Students mention the communication of resources and their appreciation of the resources provided.	*And then, just there are so many other opportunities like how sessions as well offered for my calculus course. So, if I won't help outside the classroom, I have those opportunities as well.*
Students want more learning checkpoints	Students mention their desire for more formative assessments.	*Maybe it would be good if we had like non graded small quizzes throughout, so you could like see how your progression with understanding certain topics is going before the exam.*
Students' Positive Views Towards Coordinated Assessments and Grading System		
Homework software allows multiple chances and instructor assistance	Students describe the homework software they use in class and their positive views towards the assessment.	*I like how the homework you have multiple chances on, and it tells you little hints to help you figure out what you're doing wrong.*
Common exam times relieve anxiety	Students mention the common exam time and their positive views towards it.	*I feel like making them all a certain time like works to not make me so anxious.*
Students have a neutral feeling towards grading system	Students describe their feelings towards the grading system. These feelings are neutral such as mentioning they have no issue or find anything unfair.	*I don't think it's unfair at all. I think that it makes sense the way it's weighted the way it is.*

Code	Definition	Exemplar
Successful performance with the grading system contributes to pride	Students describe their performance in the class and/or on exams and may include details about feelings of pride related to performance.	*I'm proud to say I'm doing well in the class. I'm happy with where my grade stands have done well on the exam. So, the success is definitely there in like the work I've accomplished and improved on is definitely there.*
Students' Negative Views Towards Coordinated Assessments and Grading System		
Homework software does not assist students sufficiently when they are wrong	Students describe the homework software they use in class and their negative views towards the assessment.	*And it only shows the answer but not the steps to work through it. So, it's kind of hard like. If I'm confused on an issue. I can see an answer for a set, a different type of problem, but I don't know how to work through it, and which is what I'm always trying to figure out how to do so.*
Grading assessments based on accuracy can bring down grade	Students mention their negative views when assignments are graded for accuracy such as their concern for their grade.	*And then, even when we did have equations to try out like the homework. it was graded on accuracy. So, it's like you can't get too many attempts because it takes away points, and the more you get wrong the less points you have. And obviously every point matter*
Grading assessments based on completion can prevent learning	Students mention their negative views when assignments are graded for completion such as their concern with learning what they did wrong.	*The hard thing about grading for completion is that if I am doing the work totally wrong, I still have no clue that I'm doing it wrong. I'm still thinking it's right because I'm still getting full points for everything.*
Exams a source of stress	Students mention their negative views towards exams such as feelings of stress.	*I'm most nervous about exams. I tend to get really anxious prior to exams and the time leading up to exams.*

Code	Definition	Exemplar
Students feel pressure from the weights set by the grading system	Students describe their negative feelings towards the grading system especially about the weights.	*Your exams have the greatest weight in your overall grade, which is probably why I was most nervous about it, because if you want to do well, and of course you have to do well on the exams*
Students' Navigation of Resources and Help Seeking Behaviors		
Students find course material and resources helpful towards grade and exams	Students mention either the course material and/or the resources provided and how the provision of these helps them going into the exams and with their grade.	*Having those extra resources has made me feel a lot more confident going into my math exam.*
Extra support and resources for those in campus learning and living community	Student describes how being in a special section helps with working with peers outside class and providing additional tutoring services.	*Being in the living, learning community that I am, they offer tutoring just for us as well. So, I'm able to have that opportunity which benefits me, because if I need the tutoring or I need the help, or if I know somebody who went, I can ask them like any questions I might have had if I wasn't able to make it so.*
Attending tutoring services help students towards success and bettering grade	Students describe going to tutoring services and how taking advantage of these resources help with improving their grade.	*So then, going to [tutoring] and like having, like the [tutor] like help me and everything…I really should like take advantage of this and help myself out to like help better my grade.*
Students recognize and value the ability to ask questions and get help through visiting office hours	Students mention asking questions and/or visiting their instructor for help.	*If I'm struggling, I can just go right from class to office hours, and he's always available and doesn't mind if, like. I just do work in there and ask him.*

Code	Definition	Exemplar
Students appreciate the ability to ask instructor questions through various platforms	Students mention their ability to communicate with their instructor through via email or Discord and being able to ask questions and get help.	*I have emailed my teacher a lot. I'm asking different questions*
Students' self-awareness of their needs and how and when to ask for them	Students describe their self-awareness of their needs such as making use of resources, asking questions, and/or working with others or alone.	*Now I will admit I haven't taken advantage of the [tutoring] because I have felt confident in my work.*
Student Challenges with Resources and Barriers to Help Seeking Behaviors		
Limited instructor support inside the classroom	Students mention finding it hard to get help in class because the instructor is too busy.	*I see him just too busy with the other kids where I don't wanna ask for help because I'm just like you're not gonna come over in the time amount. anyway. So, I just kind of leave it alone.*
Barriers to peer support	Students describe challenges with working and/or getting help with peers.	*I wouldn't really say that any of my peers help me achieve my goals for the semester, inside or outside the classroom, because then, again, like, we're all kind of still struggling*
Financial constraints as a disadvantage in using resources	Student mentions feeling disadvantaged because of finances such as not being able to afford private tutors and/or technology like ipads.	*So, for me, I think the students who have ipads definitely are at an advantage because of the different software, since it's easier. I think the students who print the stuff about the same. But I think the students who just write in a notebook, unless you really understand what's going on, it puts you at a disadvantage.*

Code	Definition	Exemplar
Awareness of resources but not knowing how and when to use them	Students describe their awareness of resources but may not take advantage of them.	*Despite having access to several sources right here on campus, I rarely took advantage of these. Instead, I often depended on last minute studying followed by strenuous hours of what I call "Youtube tutoring". This is simply where you'd look up a topic, watch, then solve a few practical problems with the hopes that this would be enough to pass the exam.*
Hyper-awareness of their identity within the course	Students describe their place in the course relating to their age and/or background.	*Sometimes people do [judge you]. I guess they don't realize the effect that it can have.*
Challenges with resources due to schedule conflict	Students describe their challenge with attending tutoring services and/or office hours due to a conflict with their schedule.	*My crew like takes up a significant amount of time. And unfortunately, that time is right in time block when every single [tutoring] session is happening. So, it's been hard for me to be able to get like assistance then, because it's just never at the right time for me.*
Mental health creating barriers to utilize resources participating in course, and overall performance	Students mention the difficulties they have with attending tutoring services and/or office hours, doing assignments, and asking questions due to mental health such as anxiety and/or depression.	*So, I do struggle with depression a little bit. So, I find it hard at times to complete homework. And then, like, I get stressed about and having not completed the homework, and then I get stressed about exams because I don't know what I'm doing.*
Challenges with resources due to perceived ineffectiveness	Students describe the challenges they have with resources like tutoring services because they find them ineffective.	*But if you really don't know what you're doing, I don't think [the tutors are] that helpful. Sometimes they actually will confuse you more.*

Code	Definition	Exemplar
Self-Reported Advantages and Disadvantages in Course Performance		
Taking calculus in high school as an advantage in understanding content	Students describe feeling advantage in the class because they've taken calculus and have a good foundation.	*But I thought I was more at advantage because I had just taken calculus in high school. So, I knew most of the information going into the class.*
Having a gap in taking mathematics a disadvantage in preparedness and/or performance	Students describe feeling disadvantaged in having a gap in taking mathematics or never taking calculus such as not feeling as prepared and concerned with not understanding the material.	*But the biggest issue is just that I feel like, unlike a lot of students in this class. The math is not here. A lot of it is way back in high school, and I don't remember a lot of things. So, I feel a little behind. especially now with midterms just finishing, I still feel very underprepared.*
Being in college longer as an advantage in navigating resources and workload	Students describe how their experiences with college contribute to their comfortability and knowledge with navigating the course schedule and workload.	*It's also my second year here at Clemson. so, I'm a lot more comfortable with keeping up with my schoolwork, and I've really adapted to the schedule, the college schedule, the workload of a college schedule.*
Unawareness in accommodations a disadvantage with finishing exams	Students describe feeling disadvantage from running out of time on exams and learning they could have had accommodations.	*Like my last, like 3 exams. I ran out of time and was unable to complete some questions because of that. And I just found out that there are accommodations. You can get to have extra time. But it's too late to like apply that to this exam is just something I could do in the future. So that's been kind of a disadvantage, I guess. Wish I knew about the accommodation sooner.*

Code	Definition	Exemplar
Peer-to-Peer Interactions		
Comfortability working with peers in understanding content	Students mention how peers may help with navigating resources and/or learning the material by working with them.	*I have one friend that every time I'm around them they can say something about the math thing or not, and I'm just doing my math homework, and for some reason around them, I immediately understand what's going on.*
Working with peers outside of class helps with understanding and completing assignments by sharing resources and studying together	Students mention how they study and/or talk with peers outside of class sharing resources like notes and review material.	*Literally the night before. our unit two exam we were discussing how we could solve problems as we were drifting off to sleep like, that's what we were talking about. And then we didn't realize until next morning what we were doing, where we tried that.*
Viewed advantage to friendship among peers	Students describe how friendships help with making math fun and enjoyable and being friends with peers help to motivate.	*It makes it more exciting to come to class, knowing that like my friends are gonna be there, and we're gonna get to like. laugh about something rather than just being there for math.*
Experiences Due to Understanding Content and Material		
Students comparing their experience, effort, and/or performance to their peers	Students describe their experience, effort, and/or performance in the course in relation to peers.	*I never felt like I particularly excelled like I was good at it, but I was always There was always like someone that was much better than me.*
Students' self-reflection on their experience	Students describe their experience in the class such as their ability to understand of the material and enjoyment.	*I've definitely got confused by certain concepts. but I'd say it just takes me like a few questions and a few practice problems to finally like click and get it again.*

Code	Definition	Exemplar
Students' recognition of content's relevance to future	Students mention the importance of class towards major and/or their ability to apply the content to the real world.	*I'm gonna major in mechanical engineering. So, I have to learn this stuff. I know use a lot of math. yeah, hopefully, I can retain everything*
Concern for potential level of difficulty for future content	Students mention their concern with future units and increasing difficulty and how the new material may present a challenge.	*I am most concerned just for the future units. We just finished our unit one exam, so I felt really confident in how I did in just that entire unit. But [I'm] concerned about the upcoming.*
Students concerned that not understanding content and material will impact their performance	Students describe their concern with not understanding math and how that might impact their success.	*I don't think I'll be successful. And I feel like I'm gonna be stuck, cause I'm just not gonna really know what's going on, you know*
Misalignment with effort and expected performance	Students describe a misalignment with effort and expected performance such as performing lower on a test than wanted with respect to the level of studying they did.	*I think it's been going better than I thought it would have gone at first, like I haven't necessarily been putting in the most effort that I could, but I feel like I've still been getting a good result*
Negative math affect due to course performance	Students mention how not performing well leads to them hating math and not enjoying the course.	*It's mostly difficult when you don't understand it, and it's mostly uninteresting when, like you don't understand what you're doing.*
Positive math affect due to course performance	Students mention how performing well leads to them enjoying math and the course.	*I think passing my exam will really make me actually feel like a lot more confident in myself, and like positive about like math.*
Growth in positive affect towards math	Students describe feelings of improving in math such as excitement to get better and learn.	*I feel like my understanding of math has also improved like. II felt like a little bit more confident.*

Code	Definition	Exemplar
Students' Knowledge of Similarities and Differences in Coordination		
Students learn of differences in provided resources and instructional assistance by talking to peers	Students mention knowing peers in other sections and learning about differences in resources and instructors by talking with them.	*When I tried asking a few times, with my friend in the other section, like for help on specific like in-class assignments. We did have different assignments for those.*
Unawareness to potential similarities and differences	Students mention their lack of knowledge of potential similarities and differences between their section and other sections.	*I wouldn't necessarily know because I don't know what other sections are doing.*
Instructor agency within course coordination	Students describe what aspects they believe are in their instructor's control like their teaching style, flexibility and/or communication.	*Teachers have, like some control over their leniency on homework like due dates and stuff.*
Students' Perceptions of Pedagogy Techniques Used by Instructor		
Intentionality by instructor for real-world connections	Students mention their instructors' connecting lessons to the real world.	*I've really how my teacher gives us, like real life situations, or like problems where he had to use the math to prove something. And recently, that's one of the things I've enjoyed about math is finding a way to integrate it into my life.*
Intentionality by instructor for dynamic teaching methods	Students describe the diverse teaching methods used by their instructors such as encouraging questions and keeping class interesting.	*He encourages all questions. It's like because he understands. I guess he understands that some people do take a little longer and if anything that helps me personally more, because then I can see it in a different view as well.*

Code	Definition	Exemplar
Students' Perceptions of Instructor Traits		
Student positive perceptions of instructor's approachability and investment in students	Students describe their positive perceptions of their instructor such as their instructor's approachability and/or investment in them.	*He's someone who's very approachable and is willing to understand, like my difficulties with the course and work with me here.*
Appreciates instructor open communication	Students mention the communication from their instructor such as the reliability, rate, and quality of the communication.	*He gets back as fast as he does. I don't think he's ever like taken long. They've been really helpful.*
Perceived positive personality traits of instructor	Students describe their positive perception of their instructor's personality traits such as their instructor's enthusiasm and/or patience.	*He's patient like, even if I'm struggling with something simple which does make it like it does take the pressure off.*
Students' Relationship with Instructor and Instructors' Impact		
Instructor helped influence view and experience with college, class, and math	Students describe how their instructor has helped with influencing their view and/or experience with college, class, and math.	*[My instructor] gave me more of a positive outlook on like college, and what it can be like. If you get to know the professors, you realize they're humans, not some scary person in a corner who's just there to get you.*
Desired instructor support	Students mention their desires for support from their instructor such as having their instructor reach out to them.	*If a teacher reaches out to student like, Hey, I noticed you've been struggling a bit. It's very reassuring. It could also be the difference between a kid dropping out of the course and saying, I'm going to keep going.*

Code	Definition	Exemplar
Perceived instructional aide support in classroom	Students describe their perceptions of the support in the classroom by the instructors' aides.	*The other aspect I listed was that you have not only your teacher, but you have TAs in the room to help you for questions. I like that easy, quick access. You don't need to really wait for one person to get around to all the questions. There's a lot of people willing and eligible to help you in class.*
Role of Gender in the Course		
The instructor's demographic factors can influence instructional techniques	Students mention the demographic factors of their instructor like age, gender, and/or background and how these factors may influence how they teach.	*So, I think it's really nice to have a female math professor. I don't know. I just think it's like nice to like. Have an introductory course be taught by the female professor. And I feel that because of that, like, she's very understanding and easy going.*
Observations of women in classroom	Students describe their observations of women in the classroom like the representation and spread.	*There were definitely a lot more girls in the course than men.*
Expectations of gender imbalance	Students mention their expectations of gender differences such as the class being male dominated.	*I was coming in expecting to feel like very--being a class very male dominated.*
Student comfort working with women peers	Students describe their comfort with working with women peers in the class for help.	*I feel like I'm trying to think I generally found myself asking the women in the class for more help. I feel like that was just more how comfortable socially I felt with the different people in the course.*

Code	Definition	Exemplar
Relationship with Math		
Outright negative feelings towards math	Students mention their negative feelings towards math such as feeling overwhelmed, hate, and/or even dread.	*This is still a very draining process that's gonna come with a lot of time sacrifice, and maybe even a few tears. Math is not really my thing.*
Maintained Constant Math Relationship	Students describe their relationship with math (positive, negative, or neutral) that is consistent with how they have been describing their math relationship.	*The fact that, like math still isn't my favorite class that really hasn't changed.*
Variable Math Relationship	Students describe their relationship with math that is evolving.	*Right now, it's like a love hate more. It's like a love hate. It's more of a worry right now*
Course influenced improvement in math relationship	Students mention how their mathematics view and relationship has changed because of the course.	*I'd say this course definitely made me think higher of myself, mathematically. So, me saying that I'm middle of the road is a lot better than I probably would have said a few months ago.*
Working towards improvement in math relationship	Students describe their desire to want to improve their relationship with math.	*I was hoping, maybe, like right now, or maybe like by the end of semester, like looking back at those negative feelings and no longer feeling those negative feelings.*
Deeper consideration of math relationship due to participating in dissertation study	Students mention how participating in the study may have changed their perspective in math, reflect on their progress in math, and/or how they feel about math.	*Thank you for allowing me to do this and participate. It also, you know, changed my perspective with math. I guess I don't hate it as much.*

Appendix B Pre- and Post-Math Identity Surveys

Qualtrics Survey to Students: Calculus Experience

Start of Block: Intro

Q1 What mathematics course are you enrolled this semester?

Course (1)

Instructor (2)

Time (3)

Q4 Do you agree with the following statements?

	Disagree (1)	Agree (2)
I enjoy learning math (1)	○	○
Math is interesting (2)	○	○
I look forward to taking math (3)	○	○

Q5 Do the following people see you as a mathematics person?

	No, not at all (1)	(2)	(3)	(4)	Yes, very much (5)
Mathematics instructor (1)	○	○	○	○	○
Parents/relatives (2)	○	○	○	○	○

Other students/friends (3)	○	○	○	○	○
Yourself (4)	○	○	○	○	○

Q6 How would you describe your relationship (i.e. past experiences) with mathematics?

_____

_____

_____

_____

_____

Q7 Would you be willing to participate in a study over the course of the semester? The study would take two hours of time commitment, one hour for an individual interview towards the end of the semester and thirty minutes to an hour dispersed across the semester through video journals and surveys, and you would receive a $50 incentive card.

- ○ Yes (1)
- ○ No (2)

End of Block: Intro

Start of Block: Demographics

Q8 Are you over the age of 18?

- Yes (1)
- No (2)

Q2 Will this course be your last math class?

- Yes (1)
- Maybe (2)
- No (3)

Q10 Do you consider yourself to be (Select all that apply):

- Man (1)
- Transgender (2)
- Gender fluid or Gender diverse (3)
- Woman (4)
- Not listed (please specify) (5)

  _____

- Prefer not to disclose (6)

Q11 Do you consider yourself to be (Select all that apply):

- Alaskan Native or Native American (1)
- Black or African American (2)
- Central Asian (3)
- East Asian (4)
- Hispanic or Latinx (5)
- Middle Eastern or North African (6)
- Native Hawaiian or Pacific Islander (7)
- Southeast Asian (8)
- South Asian (9)
- White (10)
- Not listed (please specify): (11)

  _____

- Prefer not to disclose (12)

Q9 Please provide your preferred email of contact should you be invited to participate in the study.

_____

End of Block: Demographics

Appendix C Flier for Participation Recruitment

Are you a student in MATH 1020 or MATH 1040?

Would you like a chance to receive a $50 incentive card?

Fill out this five-minute Pre-Math Identity Survey

Appendix D Course Coordinator Interview Questions

Background and Introduction

1. What course are you a coordinator for? Do you currently teach the course?
2. How long have you been the coordinator for said course?
3. What are your roles and responsibilities as a coordinator? Who do you oversee (i.e. instructors, TAs, grad students) and what do you view as their responsibilities/roles?
4. What objectives do you hope to accomplish as course coordinator?
5. Do you have a certain philosophy that drives how you coordinate? What does it mean to you to coordinate a course?

Coordination Policies and Implementation

6. How do you maintain consistency among the sections of the course? (Or what policies do you have in place/setup to maintain consistency among the sections of the course?)
7. How often do you communicate with the instructors/TAs teaching these courses? What instructional expectations do you communicate to the instructors of these sections?
8. What information do you tell students how this course is similar across sections?

Equity and Inclusion

9. What does it mean to you for a classroom to be equitable and inclusive?

10. We know women and nonbinary individuals are underrepresented in stem fields, yet looking at the data, women in these classes are performing academically better. To what do you attribute this success in the course?
11. In what ways do you think course coordination impacts an equitable classroom? By an equitable classroom, we are referring to an environment that is both accessible and adaptable to access students where they are at and provide cultivated resources to students to help them towards success.
12. What do you hope for women and gender fluid students to achieve from the policies in place?

Closing

13. For the course you coordinate, is there anything you wish you could do if given the opportunity?

Appendix E Video Journal Prompts

Video Journal Prompt #1

Look at the syllabus for your course. What are your goals and how do these align with the syllabus? Talk me through what you're going to do to meet your goals. What are you most concerned about? What are you most excited about?

What are three key words to describe your relationship with math?

Video Journal Prompt #2

What aspects of the course do you believe are within the instructor's control? List as many as you can think of and what, if any, these aspects may mean for you?

What is your instructor's approach to teaching and what is your relationship to them like? How do you think they might impact how you relate to the material and experience the course? If applicable, share a story or an experience you had with your instructor that resonates with you.

What are three key words to describe your current relationship with math and why?

Video Journal Prompt #3

How do you think your experience may be different from others in your class and why? How do you think your experience may be different from others in other sections of [insert course]? Do you think they will have similar experiences? Why or why not?

What kind of relationship do you have with your peers in your Calculus course? How do your peers help you achieve your goals for the semester both inside and outside the classroom? Share a story or an experience you had with your peers that resonates with you.

What are three key words to describe your current relationship with math and why?

Video Journal Prompt #4

What aspects of the course do you really enjoy? List as many as you can think of. How do you think these aspects might impact how you relate to the course or mathematics? Share a story or an experience that resonates with you.

If there's any aspects you could change, what would they be and why?

What are three key words to describe your relationship with math?

Appendix F Student Interview Questions

Background and Introduction

1. To start us off, could you confirm the pseudonym you would like to be referred to for the study?
2. What pronouns will feel the most affirming to you?

Course Experience

3. How would you describe your experience in your Calculus course this past semester?
4. How would you describe the culture—the social behavior and social norms—of the classroom?
    - Are there ways in which you were disadvantaged or advantaged compared to other students in the course/sections?
    - Is there anything you felt was unfair?
    - Do you feel different resources or supports were provided to ensure success for all students?
    - Are there ways in which you think you didn't have the same opportunity as other sections?
    - We know women and gender fluid individuals are underrepresented in stem fields; in what ways do you feel gender played a role in the course. Do you think it impacted it?

5. Is there a time in the class where you struggled, and the instructor helped? Did the instructors have any influence on how you view math or your experience in the course?
6. Was there a TA for your course?
    - If so, is there a time in the class where you struggled, and the TA helped? Did the TA have any influence on how you view your math experience in the course?
    - If not, do you think having a TA would have any influence on how you view math or your experience in the course?
7. What are your thoughts and experiences with the coordinated exams in the course?

Relationship with Math

8. In your videos, you mentioned the key words to describe your relationship with math. Can you explain how you view yourself mathematically?

Closing

9. If you had the ability to change something in this course, what would it be and why? What did you like about the policies? (i.e. grading, feedback)? What didn't you like about the policies?
10. Do you think participating in this study impacted your experience this semester in mathematics?

Appendix G Instructor Interview Questions

Background and Introduction

1. What course are you an instructor for?
2. How long have you taught said course?
3. Do you have a certain philosophy that drives how you teach? What does it mean to you to teach a course?
4. What do you view as your responsibilities/role?

Coordination Policies and Implementation

5. What are aspects that are coordinated across the sections of the course?
6. Did you have regular instructor communications and/or meetings? What were these like and what did these consist of?
7. How were the course expectations/policies communicated to you and how did you communicate them to students?
8. What information do you tell students how this course is similar across sections?
9. What are things that you have implemented in your course that are unique to the section(s) you teach?
10. In what ways did course coordination support your teaching?
11. In what ways did course coordination help foster relationships with your students?
12. Are you teaching the way you would like to? If no, what's keeping you from teaching the way you would like?

13. In what ways do you think course coordination impacts student experiences with math?

Equity and Inclusion

14. What does it mean to you for a classroom to be equitable and inclusive?
15. We know women and gender fluid individuals are underrepresented in stem fields, yet looking at the data, women in these classes are performing academically better. To what do you attribute this success in the course?
16. In what ways do you think course coordination impacts an equitable classroom? By an equitable classroom, we are referring to an environment that is both accessible and adaptable to access students where they are at and provide cultivated resources to students to help them towards success.
17. What do you hope for women and gender fluid students to achieve from the policies in place?

Closing

18. For the course you teach, is there anything you wish you could do if given the opportunity? What input was elicited to you by the coordinator from the course? Was your voice encouraged by the coordinator?

Appendix H Quality Considerations

As a qualitative study, certain quality considerations are needed. These are: theoretical validity, procedural validity, communicative validity, pragmatic validity, ethical validity, and process reliability (Walther et al., 2013).

Theoretical validity is about how well the alignment of the chosen theory is to the study design. Positioning theory has emerged outside the field of education. However, we are using a version that has been developed for math education researchers and the theoretical framework is being used to examine students' mathematical macro- and micro-identities in coordinated calculus courses. The theoretical framework selected for this study influenced the research questions developed, as well as the interview protocol and video journal developed.

Procedural validity is about the features of the study design we will implement to improve the fit between the theory and social reality. We plan to involve two calculus courses to improve the fit between the theory and social reality. We also plan to craft protocol questions and journal entries with the theoretical framework in mind.

Communicative validity is about presenting to the intended audience an authentic account of the data. With semi-structured interviews, we will ask follow-up questions to ensure we are understanding interviewees' viewpoints. We will also employ the use of discussions between researchers, strict coding protocol, and bracketing.

Pragmatic validity is about how well the study can withstand the exposure to the reality under investigation. The inclusion of multiple courses supports pragmatic validation as the proposed study will allow results to be more generalizable by

accounting for differences among different coordinated systems. Utilizing a phenomenological lens and employing thematic analysis will also support the pragmatic validity since the positions of students in mathematics lessons will be investigated.

Ethical validity is about the integrity and transparency throughout data collection, cleaning, and analysis in the study. At the start of the study, participants will be asked to select a pseudonym. This pseudonym will then be used throughout the study and any identifiable information will be scrubbed from interviews.

Process reliability is about ensuring a mitigation of random influences on the study. We plan to follow a semi-structured interview protocol to help establish consistency across interviews. We also plan for the prompt's student participants receive for their video journals to be consistent among all participants. The selection criteria for participants are pre-defined. In addition, other researchers will be called upon during the analysis of interviews and video journals for the development of codes and/or themes.

Research Decision	**Quality Considerations**
Examining Calculus I Courses	Supports Procedural and Theoretical Validation
Justification: Examining coordinated undergraduate calculus courses will help focus on the main objective of the study as we are interested in how coordinated and uncoordinated aspects may influence student experiences in these entry level math courses. This supports both theoretical and procedural validity.	
Research Decision	**Quality Considerations**
Including two courses in the study	Supports Procedural, Theoretical, and Pragmatic Validation. Threatens Process Reliability.
Justification: Including two courses can threaten process reliability by introducing more elements into the study that cannot be controlled. Including these two specific courses also threatens process reliability as the majors of students enrolled in these courses are more likely to be non-STEM majors or those who needed additional math support than those taking Calculus 1 in one semester We may miss certain majors and math identities by not including other courses. However, the inclusion of multiple courses also merits itself to supporting pragmatic validity as the study is exposed to	

more than just one design of course coordination. Including multiple courses also allows for more features of course coordination to be investigated and how these features may position students, lending to support both theoretical and procedural validity.	
Research Decision	**Quality Considerations**
Conducting study as a multiple exploratory case study	Supports Procedural and Pragmatic Validation as well as Process Reliability
Justification: To help mitigate the study happening due to random chance and to be able to contextualize the results found, the study will be conducted using multiple cases supporting process reliability. These cases will be individual students in the courses who experienced the coordinated and uncoordinated aspects throughout the semester and will be purposefully picked based off information such as gender and math identity. This feature of the study will also improve the fit between theory and social reality by providing more data to analyze supporting procedural validity and pragmatic validity.	
Research Decision	**Quality Considerations**
Utilizing positioning theory as theoretical framework	Supports Theoretical Validation
Justification: Positioning theory as a theoretical framework is the main guiding force of the study in terms of research questions, interview protocol, and journal entries prompts. The theory also influences how the data will be analyzed. Because of this, the theory supports theoretical validation.	
Research Decision	**Quality Considerations**
Semi-structured interviews with course coordinators and instructors	Supports Theoretical, Procedural, and Communicative Validation as well as Process Reliability.
Justification: Each prompt will focus on an objective and/or provide context for an objective such as how course policies are communicated to students. Interview data from instructors and coordinators will not be analyzed but used to help situate the context of coordinated and uncoordinated aspects and classroom environment described by enrolled students supporting communicative validity, procedural validity, theoretical validity, and pragmatic reliability.	
Research Decision	**Quality Considerations**
Surveying students at the start and end of the semester	Supports Ethical Validation
Justification: The survey to students will be used to select ten participants based on their math identities and demographic information such as gender and will include necessary disclosure information of what would be needed from them in the study such as time commitment and asking for their consent. The survey will also include incentive information for participating by submitting video journals and participating in an interview. This supports ethical validity.	
Research Decision	**Quality Considerations**

Having students complete journal entries during the semester	Supports Theoretical and Procedural Validation as well as Process Reliability.
Justification: Prompts in the journal entries to participants will be structured to focus on an objective from the positioning theoretical framework and the system of course coordination such as asking students to describe what aspects of the course they know are the same across sections and asking students to describe interactions with their peers supporting both theoretical and procedural validity. By having the prompts focused on the theoretical framework this will also support process reliability.	
Research Decision	**Quality Considerations**
Having a team of researchers to code data	Supports Commutative Validity and Process Reliability.
Justification: Enlisting a team of researchers to develop codes and themes for the stages of thematic analysis will support process reliability. Having a team of researchers to also aid in constructing meanings from the constructed codes will also support communicative validity.	
Research Decision	**Quality Considerations**
Conducting individual interviews with students	Supports Theoretical, Procedural, and Communicative Validation as well as Process Reliability.
Justification: Each prompt will focus on an objective and/or provide context for an objective related to the positioning theoretical framework, coordinated and uncoordinated course aspects, and/or math identity such as do you feel like different resources were provided to support all students supporting communicative validity, procedural validity, theoretical validity, and process reliability.	
Research Decision	**Quality Considerations**
Executing a study with a phenomenological lens	Supports Pragmatic Validity.
Justification: Taking a phenomenological approach will support the pragmatic validity since the positions of students in mathematics lessons will be investigated.	
Research Decision	**Quality Considerations**
Utilizing thematic analysis for the data	Supports Pragmatic Validity.
Justification: Employing thematic analysis will support the pragmatic validity since the positions of students in mathematics lessons will be investigated.	
Research Decision	**Quality Considerations**
Participants will select a pseudonym at the beginning of the study which will be used throughout	Supports Ethical Validity.
Justification: Removing identifiable information will protect participant's privacy and support ethical validity.	
Research Decision	**Quality Considerations**
Selecting women or gender fluid students as participants	Supports Theoretical and Procedural Validity.

<table>
<tr><td colspan="2">Justification: Selecting women or gender fluid students as participants will help focus on the main objective of the study which is to centered student voices, a missing gap in course coordination literature, and specifically marginalized voices of women and gender fluid students in STEM spaces usually dominated by cisgender white men and support both theoretical and procedural validity.</td></tr>
<tr><th>Research Decision</th><th>Quality Considerations</th></tr>
<tr><td>Collecting syllabi and calendars from course coordinators</td><td>Supports Theoretical and Procedural Validity as well as process reliability.
Threatens Procedural Validity.</td></tr>
<tr><td colspan="2">Justification: Collecting artifacts such as syllabi and calendars from course coordinators at the beginning of the study supports both theoretical and procedural validity and will also support process reliability. However, by only collecting syllabi and calendars from course coordinators this threatens procedural validity by not collecting other potentially informative material such as student assignments, instructor reviews, and course announcements.</td></tr>
<tr><th>Research Decision</th><th>Quality Considerations</th></tr>
<tr><td>Researcher’s level of training in qualitative methods</td><td>Threatens Theoretical and Procedural Validity</td></tr>
<tr><td colspan="2">Justification: The researcher did not have much experience or training in qualitative methods at the beginning of the study and as such is a threat to both theoretical and procedural validity.</td></tr>
</table>

Appendix I Bracketing Journal

Before moving on to the data portion of a study, it is important for researchers to bracket out their own experiences. *Bracketing* is done by the researcher setting aside their own preconceived experiences and judgments to allow for a fresh perspective toward the phenomenon being investigated (Husserl, 1970; Moustakas, 1994). Throughout the research process, I have made continual use of a researcher journal to describe my own experiences with course coordination (Tufford & Newman, 2012). In this journal, I listed out assumptions about what I expected to see in the data so that I explicitly recorded my positions, viewpoints, and particular biases (Tufford & Newman, 2012). With this research journal, I was able to refer to it during the analysis portion, 'bracketing' time and attention to what I had recorded to make sure what I had written was not overtly influencing analysis.

This research journal describes my own experiences with course coordination. In this journal, I will also list out assumptions about what I expect to see in the data, explicitly recording my positions, viewpoints, and particular biases.

Personal Experiences:

My personal experiences with course coordination are from the instructor's perspective. As a first-time instructor, I appreciated the structure and organization of the course. Having provided resources, such as lesson plans, assignments, and teaching materials offered tremendous support for teaching. Along with these resources, I was exposed to a common schedule, common exams, and common grading. With these common elements, I was restricted in the agency I had as an instructor. I could not offer

extensions. I could not award partial credit not allowed by the course coordinator. And I could not easily allow exam make-ups without approval from the course coordinator. With the course I taught, the organization established through course coordination was helpful with securing fairness for every student enrolled. However, in the effort to procure and maintain this equality, equity was sacrificed. I believe course coordination can achieve both equality and equity and should strive for this balance.

Positions, Viewpoints, and Biases:

From my personal experience, I view my position as one that is for course coordination. It is my viewpoint that course coordination does implicitly benefit students through its organization and cultivation of resources. I view course coordination as an idea that can do a lot of good when executed correctly which is where my biases come in. My exposure to coordinated systems is for my current institution. A bias I have from what I've seen is that I view some coordinated systems as focusing entirely too much on uniformity and communicating the idea of fairness. I do believe that uniformity is needed, but I am positioned that a humanity aspect is lost which I believe attendance to equity can help mitigate.

Assumptions:

The assumptions I expect to see in the data are storylines referring to the instructor's impact. Instructors are the one thing that can't be uniform for large multi-section courses. The personality and teaching philosophy of an instructor are dynamics that I have seen in the pilot as having a high influence on students. I expect this storyline to continue.

The storyline of math as intimidating and/or not good at math is also something I expect to see in the data. This is a common sentiment to hear from students with their math identity. A part of this storyline that I did not see in the pilot that I will assume I see in the data is math as intimidating as related to exams. Common tests are a huge part of students' grade. Success on tests is usually associated with being good at math. So, I expect to see more references to exams with this storyline.

A storyline that I saw in the pilot that I think will continue is how helpful the organization of the course was for students. What I assume I might also see in the data is how limiting the strict structure can also be such as for strict due dates and limited partial credit.

<u>After Interviewing Course Coordinators:</u>

Preliminary thoughts on interviewing course coordinators are that the two coordinators have widely different approaches to coordination. The choice architect for business calculus stressed fairness throughout the interview and expressed a Resource-Managerial Orientation with their approach. She was focused on consistency. The choice architect for long calculus stressed fostering an enjoyable experience for students and a community for instructors to suggest ideas and learn from each other, expressing a Humanistic-Growth Orientation with her approach.

With two different primary orientations between the two coordinated systems, I do expect to see differences in the data when it comes to student experiences in the course and what instructors report in their interviews. I am assuming that students in long calculus may report a more enjoyable experience than students in business calculus. I

must keep this bias in mind when analyzing the data and ensure that I have other researchers to look over the data as well.

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