

THE INTENDED AND ENACTED CURRICULUM IN A NEW DEVELOPMENTAL
MATHEMATICS COURSE: A STUDY OF COMMUNITY COLLEGE STUDENTS'
PARTICIPATION AND ATTITUDES

BY

MARTHA BETH MAKOWSKI

DISSERTATION

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Doctoral Committee:

Professor Sarah Lubienski, Chair
Associate Professor Gloriana González Rivera
Professor Michelle Perry
Professor Debra Bragg

ABSTRACT

Serving approximately 80% of the one million college students taking pre-college-level mathematics classes, community colleges perform an important function in providing access to advanced coursework and degrees. Low success rates in these classes has led mathematics educators to consider alternative forms of curriculum and instruction for these often required, but non-credit bearing pre-college, or *developmental*, classes. One emerging reform has pushed for the inclusion of more real-world problem solving and group work in these classes, mirroring reform efforts in K-12 mathematics education (National Council of Teachers of Mathematics, 1989, 2000). Success rates of students in early implementations of this developmental mathematics reform show promising results. However, these studies provided little information about the actual enactment of the curriculum or how developmental students, who have dramatically different demographics and mathematical histories than the K-12 population, experience these classes.

Sitting at the intersection of research on K-12 mathematics education reform and research on developmental mathematics in the community college context, this dissertation sets out to examine how a problem-centered, group-intensive form of instruction plays out with developmental mathematics students at a single community college. Classroom observation data, classroom audio, and both instructor and student interviews were collected in a focus classroom. In addition, survey responses from students in seven *Mathematical Literacy* classrooms are used to examine the impact of the implementation on students. More specifically, this mixed-methods study: (a) describes what *Mathematical Literacy* looks like at the classroom level, examining the students' and instructor's patterns of engagement with the curriculum over time using an innovative, visual representation of the classroom, (b) examines students' persistence and

affective outcomes using statistical methods, including hierarchical linear modeling, and (c) examines students' perceptions of the class and how these differ among students and compare with the instructor's intentions, using open coding and the mixed-method analysis technique of matrices.

Results show that students in the focus classroom had ample opportunity to work within their groups while the instructor operated in a facilitator role. Contrary to many of the reform models implemented at the K-12 level, whole-class discussion was minimal. Instead, students spent the vast majority of class time working collaboratively in their assigned groups, engaging in a comparatively small amount of off-task talk. Those who persisted in the class experienced some positive changes in their attitudes towards mathematics, but benefits were unevenly distributed among this diverse group of students. Differences in the perceptions of the students with positive, neutral, or negative experiences in the class were at least partially rooted in the challenges of having very mathematically diverse students required to work together in groups. although the developmental students' focused goals and desire for efficiency were strengths in the classroom, they also led to tensions between some of the more and less advanced students within groups.

This study illuminates critical challenges of productively implementing instruction centered around problem solving and group work in developmental mathematics courses. To improve implementation, instructors may need to (a) help students better understand each other's needs and motivations, (b) support students as they mediate large differences in mathematical backgrounds, and (c) leverage students' backgrounds and goals when grouping students. More research is needed to uncover productive ways to address these implementation challenges, as well as the academic benefits that can be obtained when doing so.

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION.....	1
CHAPTER 2: REVIEW OF RELEVANT RESEARCH.....	6
CHAPTER 3: PROBLEM SOLVING AND GROUP WORK IN A COMMUNITY COLLEGE CLASSROOM: ENACTING A NEW FORM OF DEVELOPMENTAL MATHEMATICS INSTRUCTION.....	43
CHAPTER 4: EXPLORING CONVERGENT AND DIVERGENT STUDENT EXPERIENCES IN <i>MATHEMATICAL LITERACY</i>	88
CHAPTER 5: DISCUSSION AND CONCLUSIONS.....	140
REFERENCES.....	155
APPENDIX A: POST-OBSERVATION PROTOCOL AND SURVEY INSTRUMENTS.....	174
APPENDIX B: SURVEY SAMPLE AND DATA CLEANING DETAILS.....	181
APPENDIX C: ANNOTATED STATA SYNTAX FOR THE CREATION OF GROUP-LEVEL DIAGRAMS.....	193
APPENDIX D: EXAMPLE UNIT INDEX FROM TEXTBOOK.....	204
APPENDIX E: TEXTBOOK ANALYSIS SAMPLING, CODING, AND SUMMARY STATISTICS.....	205
APPENDIX F: FULL INSTRUCTOR AND STUDENT INTERVIEW PROTOCOLS.....	208
APPENDIX G: FULL CODING RUBRICS FOR STUDENT INTERVIEWS.....	213
APPENDIX H: INSTITUTIONAL REVIEW BOARD APPROVAL.....	223

CHAPTER 1:

INTRODUCTION

Community colleges, with their open enrollment policies and mission to provide educational access for all students, are perhaps the most democratic postsecondary schools in the United States today. Students at community colleges are more racially diverse and have a larger range of life stages and ages than more selective enrollment colleges and universities (Cohen, Brawer, & Kisker, 2013). Ranging from traditionally aged college students to adult learners returning to school after many years in the workforce, the community college population, while an incredible asset, also poses a great challenge to those seeking to meet their educational needs.

To offer students appropriate educational experiences, community colleges employ a variety of services and supports to promote students' academic success. At the institutional level, policies such as placement testing sort students into the classes that will best prepare them for their intended degree. At the student services level, students receive counseling into programs and classes that fit with their interests and academic backgrounds. At the classroom level, teachers strive to deliver curriculum and instruction that align with various programs while keeping students engaged. In these, and many other ways, the individuals working at community colleges are charged with meeting the complexity of their student population.

The processes and decisions employed by community colleges to meet the needs of diverse students sometimes, paradoxically, restrict access to higher education (Clark, 1960). Placement into pre-college level classes increases students' time to degree and uses up students' financial resources, while academic advising may divert students from more prestigious degrees. During class, instructors may struggle to provide the help students require in the time allotted, unintentionally conveying the message that struggling students do not have what it takes to

succeed. The issues of placement, academic preparedness, and teaching all come to a head in the classes offered at the pre-college level. These remedial, or *developmental*, classes serve the most academically vulnerable population at community colleges: those enrolled in academic tracks that require advanced coursework, but not deemed knowledgeable enough to take college-level, credit-bearing classes. The fact that developmental courses are populated disproportionately with students from low socio-economic backgrounds (Hagedorn, Siadat, Fogel, Nora, & Pascarella, 1999) and from minority racial and ethnic groups (Attewell, Lavin, Domina, & Levey, 2006) makes examination of developmental education even more critical.

Within developmental education, mathematics enrolls the most students (Parsad, Lewis, & Greene, 2003), with classes aiming to prepare students for college-level mathematics. Thus, developmental mathematics serves a gatekeeping function, making it a critical component of a student's education. However, a large percentage of students who start developmental classes never finish (Bailey, 2009; Bailey, Jeong, & Cho, 2010). Student attrition from developmental classes stems from diverse causes, including individual circumstances (e.g., jobs or change of family role) or changes in degree plans. For these students, the question becomes one of how the curriculum and instruction can better meet their needs so success rates can increase.

Successfully meeting student needs is the great challenge of all instruction, from kindergarten through college. In addition to the diversity of demographic and life stages discussed earlier, developmental students also have great diversity in their mathematical experiences. K-12 tracking practices and a lack of standard curricula between states and school districts means that some students have never had the opportunity to take the prerequisite classes for college-level work. Other students have taken the classes (Hoyt & Sorensen, 2001), but either delayed enrollment in college, thus requiring refreshment of their knowledge before taking

advanced classes (Cohen et al., 2013) or struggled to learn the material sufficiently to place out of the subject (Bahr, 2010a).

Community college instructors must negotiate vast differences in preparation while also attending to the unique circumstances of college students. The K-12 curriculum has been designed to prepare minors to be college ready by the end of high school (National Governors Association Center for Best Practices, 2010), so they can have the freedom to pursue any career they choose. Developmental students, however, are adults with enough knowledge and experience to make educational choices that restrict their career options. Adult students, particularly at the community college, value knowing how the things they are asked to study connect to their specific career goals (Cox, 2009; Merriam & Bierema, 2014) and are highly goal oriented (Mesa, 2012). Unlike reading and writing, which connects broadly to all college majors, the link between the developmental mathematics curriculum and the rest of their coursework is often less explicit. Traditional mathematics instruction in the developmental curriculum emphasizes procedural skills (Grubb et al., 1999; Mesa, Celis & Lande, 2014), with minimal real-world context, compounding the isolation of the mathematics curriculum from students' experiences and goals.

A recent curriculum movement called *Mathematical Literacy* sets out to change developmental mathematics to better reach students. The intention of *Mathematical Literacy* classes is to (a) make the mathematics content more relevant to the academic needs of the developmental students, and (b) highlight for students how mathematics informs their daily lives. Statway and Quantway, developed by the Carnegie Foundation (hereafter referred to as the Carnegie Pathways; Cullinane & Treisman, 2010; Hoang, Huang, Sulcer, & Yesilyurt, 2017), are the most well known and widely implemented of these classes. Many of those involved in the

Mathematical Literacy reforms further hope to reduce the cycle of failure by structuring the class to cover required remedial algebra content in as little as one semester (e.g., Cullinane & Treisman, 2010; Hoang et al., 2017). To meet these goals, the curriculum of these classes has centered around real-world problem solving facilitated through group work.

In many ways, the *Mathematical Literacy* movement echoes the National Council of Teachers of Mathematics' (NCTM; 1989, 2000) push for more problem-centered instruction in the K-12 curriculum, which may raise the question of what a study of *Mathematical Literacy* can add to the already rich body of knowledge about group work and problem-centered mathematics classrooms. In short, although similar in intent, *Mathematical Literacy* is tailored to meet the needs of the developmental population, who, as previously described, create a unique, diverse classroom full of self-selecting, but often skeptical students.

Fields Community College (FCC; all names are pseudonyms), a large community college in a small Midwestern city, has recently become involved in the *Mathematical Literacy* movement. *Mathematical Literacy* at FCC uses a curriculum centered around real-world problem solving, combined with group work, to promote mathematical success for developmental students. Moreover, although the *Mathematical Literacy* curriculum at FCC has roots in a national curriculum movement, the case of FCC is worthy of individual study for reasons beyond the intent of the curriculum. FCC's demographics reflect the average developmental population, with a large enough program to provide depth in the population of study. Moreover, faculty teaching the new curriculum at FCC were professionally active in adapting the general *Mathematical Literacy* framework and curriculum to meet state articulation standards, making FCC a valuable site for studying the implementation of the curriculum and its impact on the diverse developmental population.

In particular, I focus on how FCC's implementation of *Mathematical Literacy* meets the challenges of serving diverse adult learners in the developmental mathematics classroom. Given the real-world focus of the curriculum and fact that community college students value course materials that seem personally relevant (Cox, 2009), significant promise exists for the implementation. In addition, similar initiatives in the K-12 curriculum have shown that students can adapt and even thrive in classrooms emphasizing group work (e.g., Riordan & Noyce, 2001; Boaler, 2002), but the shorter, one-semester time frame of the implementation and differences in student goals and life circumstances lead to questions about whether *Mathematical Literacy* will serve developmental students as intended. To explore this question, I examine the intended and enacted curriculum at both the classroom and individual level. At the classroom level, I examine what the implementation of *Mathematical Literacy* looks like and then explore persistence and affective outcomes associated with the course. At the individual level, I investigate how diverse students experience the class, focusing on how their perceptions of the classroom practices and group work vary depending on whether they had an overall positive, neutral, or negative experience in the class. These are then contrasted with the instructor's intentions with respect to the class.

By providing these two lenses on *Mathematical Literacy*, I shed light on the consequences of asking diverse students to work with and learn from each other and from a curriculum centered around real-world problems. The results can be used to better meet the needs of students, as well as to open the door to other ways of thinking about college mathematics classrooms and the ways students can be reached.

CHAPTER 2:

REVIEW OF RELEVANT RESEARCH

Community colleges, although initially conceptualized as a place to prepare students for advanced study, now serve an incredible range of missions and students (Dougherty & Townsend, 2006). Students enter these schools at dramatically different stages of life, ranging from recent high school graduates with plans to earn a PhD, to adults returning to school after many years in the workforce or at home raising families (Cohen, Brawer, & Kisker, 2013). Today's community colleges are faced with the challenge of meeting the needs and supporting the goals of this demographically rich and complex population.

For many community college students, achieving their educational plans requires completing a mathematics class at the pre-college level (Blair, Kirkman, & Maxwell, 2013). These pre-college, or *developmental*, classes are intended to provide the knowledge and skills necessary for success in credit-bearing college-level classes. However, despite these intentions, developmental courses often play a gate-keeping function, preventing students from accessing higher education. In recent years, developmental mathematics educators have moved to address the high failure rates by implementing mathematics curricula that use real-world problems and group work to help students more effectively engage with the material, mirroring reform efforts from the 1980s and 1990s in K-12 mathematics (National Council of Teachers of Mathematics [NCTM], 1989, 2000).

Sitting at the intersection of the literatures on K-12 mathematics education reform and developmental mathematics, my dissertation explores an early implementation of a developmental mathematics class that uses real-world problems and group work as a regular part of instruction. For the duration of this chapter, I call these classes *reform-oriented developmental*

mathematics classes (or reform-oriented for short), as an acknowledgement of lineage (NCTM, 1989, 2000) of the rationale for including real-world problem solving and group work in the developmental mathematics curriculum.

In this chapter, I first introduce a curriculum model to help contextualize the larger guiding framework of this project. I then summarize and explore the literature related to: (a) the developmental mathematics landscape, (b) the curriculum and instruction of developmental mathematics, and (c) mathematics education at the K-12 level, focusing on themes that relate to the enactment of reform-oriented instructional strategies around problem solving and group work. I argue that the unique demographics, mathematical histories, and institutional context of the developmental population creates circumstances unexplored at the classroom level in the reform-oriented mathematics education literature. Thus, reform-oriented developmental classes like the one examined in this dissertation, can contribute greatly to our knowledge about the curriculum and instruction of mathematics education reforms at the developmental level. I close with a discussion of my guiding research questions and a brief overview of the remainder of this work.

A Framework for Considering Curriculum and Instruction

Developmental mathematics has routinely been examined in education policy literature, most of which looks at outcomes such as course success or degree attainment (e.g., Bahr, 2010a; Bettinger & Long, 2009; Calcagno and Long, 2008; Clotfelter, Ladd, Muschkin, & Vigdor, 2015). These studies shed light on the observable patterns between the studied outcomes and the individuals involved, but, given the complexity of the instructional environment, reveal comparatively little information about the developmental classrooms themselves. Thus, understanding the developmental mathematics classroom becomes a pressing issue.

Although classrooms can be observed using any number of frameworks and lenses, the classroom under study in this dissertation centers around a novel curriculum, implemented with methods of instruction not typically seen in developmental mathematics. I thus choose the framework of the planned and enacted curriculum. The *planned curriculum* (Gehrke, Knapp, & Sirotnik, 1992) represents the body of knowledge, ideas, and processes the course designers intend for students to learn and experience in the class. Often called the intended curriculum (Stein, Remillard, & Smith, 2007), the planned curriculum is not always reflected in the actual implementation. The experienced (Gehrke et al., 1992) or *enacted curriculum* (Stein et al., 2007), describes the collection of experiences that actually occur in the classroom. Given that the instructor and students have agency in how curriculum materials are implemented, Stein, Grover, and Henningsen (1996) identify three stages in the enacted curriculum: (1) the task from the curriculum materials, (2) the task as the instructor presents it to the students, and (3) the task as implemented and engaged with by the students.

To contextualize the setting of the curriculum explored in this study of a reform-oriented developmental mathematics class, I now turn to a survey of the educational literature on developmental and mathematics education.

Situating Developmental Mathematics

Offered at almost all public two-year colleges (Parsad, Lewis & Greene, 2003), the developmental curriculum covers content deemed to be below college level. The developmental curriculum has a long history, with a primary goal of preparing students for college-level work (Merisotis & Phipps, 2000). By giving students the option to remediate in content they either never learned or have forgotten but considered necessary for postsecondary work (Phipps, 1998), the developmental curriculum serves an important role in creating access to higher education by

providing *all* students with the chance to become *college ready* (McCabe, 2000). However, although intended to support students' educational goals, developmental classes rarely count for degree credit (Parsad et al., 2003), and thus prolong time to degree and use up financial resources.

In this dissertation, I focus on *developmental mathematics curriculum and instruction*, the learning materials and instruction in the academic content classes students take to prepare for college-level work in mathematics. The developmental (or remedial) curriculum covers much of the same material as K-12 schooling. Although the primary function of developmental instruction is preparing students for college-level work, there is no national agreement on what constitutes “college-level” (Merisotis & Phipps, 2000; Oudenhoven, 2002; Phipps, 1998), and definitions may even vary among schools in the same state (Perin, 2006; Bailey, 2009). On average, community colleges offer three or four levels of developmental mathematics (Bailey, Jeong, & Cho, 2010), ranging from Arithmetic through Intermediate Algebra. The *Common Core State Standards for Mathematics* (CCSSM; National Governors Association Center for Best Practices [NGACBP], 2010) represents an effort to standardize the meaning of “college ready” at the K-12 level, but colleges have no obligation to adopt the benchmarks. Given that postsecondary schools have diverse missions, informed by the selectivity, location, and type of school, colleges will probably continue to set standards that reflect the values and goals of the specific institutions. Thus, in the near term, the meaning of “college ready” will probably continue to vary among schools.

The terms “developmental” and “remedial” tend to be used interchangeably to describe the services and classes that prepare students for college-level work. That said, some use “remedial” to mean “re-teach” (Breneman & Haarlow, 1998, p. 3). In contrast, the use of

“developmental” refers to “a comprehensive process focusing on the intellectual, social and emotional growth and development of all learners” (Casazza, 1999, p. 13), although some have argued the use of “developmental” disguises the nature of these classes (Breneman & Haarlow, 1998; Deil-Amen & Rosenbaum, 2002). Still, researchers who have examined developmental instruction have noted the existence of instructors who make student support a primary goal of their teaching in these classes (Grubb et al., 1999), suggesting that at least some teachers embrace supporting students’ development as they transition into college-level work. Thus, although the definition may vary, the label means less than the actual practice of the instructors involved in teaching developmental and remedial classes.

The Location and Scope of Developmental Education

Regardless of the intentions and interests of developmental instructors or how students experience developmental instruction, remediation serves an important function in helping students access the college curriculum. Although some four-year schools have chosen to remove developmental education from their curriculum (Merisotis & Phipps, 2000; Oudenhoven, 2002), developmental coursework occurs at both two- and four-year schools (Blair, Kirkman, & Maxwell, 2013). In terms of raw numbers, two-year schools have and continue to bear the brunt of developmental education. In 1995, four-year schools enrolled approximately 222,000 students in developmental mathematics, while two-year schools enrolled about 800,000, or 78%, of the remedial mathematics enrollments for the year. In 2010, the share of remedial mathematics students at two-year schools increased to approximately 85% of the 1.36 million developmental mathematics enrollments (Blair et al., 2013). From these numbers, it is clear both that a great need for remediation exists and that community colleges play a huge part in meeting that demand.

A substantial portion of first-year undergraduates take developmental classes across all subjects and school types, ranging from 28% in 1995 (Parsad et al., 2003) to about 20% in 2008 (Sparks & Malkus, 2013). Developmental mathematics has the highest enrollments (Blair et al., 2013), with upwards of 28% of all entering students, and 45% of entering community colleges students, taking at least one developmental mathematics class in 2000 (Parsad et al., 2003). However, these estimates rely on self-reported data from students' first year of college and do not factor in the tendency of students to underreport remedial enrollment (Adelman, 2006). In an examination of longitudinal data using student transcripts, Attewell, Lavin, Domina, and Levey (2006) found that around 60% of the community college students in their sample took at least one developmental class. Bailey et al. (2010) produced similar numbers using different longitudinal data sets and observed that this number was probably an underestimate of the need for remediation in mathematics, as they also found that many students referred to developmental coursework never take these classes. Lastly, instructors of non-developmental classes often engage in "hidden remediation" (Grubb et al., 1999) of topics not officially in their curriculum, but necessary to teach for student success.

The Developmental Population

As the previous section highlighted, the demand for developmental education is large. The reasons students require remediation vary widely, but some students in developmental mathematics simply have not had the opportunity to take advanced mathematics coursework. Many U.S. schools sort students of different perceived abilities into different mathematics classes (Cogan, Schmidt, & Wiley, 2001), despite the equity challenges inherent in doing so (e.g., Oakes, 1990). Researchers have shown that prior coursework is the strongest predictor of college placement (Adelman, 2004; Bettinger & Long, 2009), suggesting that the need for

developmental mathematics may primarily be a function of prior educational opportunity. The widely adopted CCSSM (NGACBP, 2010) sets out to create a curriculum that *all* students take, but given that many schools still use sorting practices that expose different students to content at different rates, it is unclear whether all students will actually have the chance to complete a Common Core-aligned curriculum as intended. This question is beyond the scope of this review, but has serious implications for the future developmental population.

The current developmental population tends to be older and disproportionately enrolls students of color and students from academically vulnerable populations (Cohen et al., 2013). For example, African American students are almost twice as likely as White students to enroll in developmental classes (Attewell et al., 2006). In addition, students taking classes at the remedial level tend to come from lower-socio-economic status (SES) backgrounds and have parents with lower average levels of education than students taking non-developmental classes (Hagedorn, Siadat, Fogel, Nora, & Pascarella, 1999). Students from lower-SES backgrounds and students of color often have, by the time they reach college, faced racial discrimination during schooling or been underserved by their K-12 schools (Davis & Palmer, 2010), meaning that ensuring that developmental education actually *serves* the enrolled students, rather than creating additional *barriers* to their success, becomes critical.

Prior mathematics background explains much of the observed difference in the developmental success rates between White students and students from underrepresented racial and ethnic backgrounds (Bahr, 2010b). Nonetheless, some have suggested that developmental education may impact underrepresented students in different and unintended ways. For example, some have found that students of color feel that developmental placement ostracizes them, particularly when they take the classes at two-year schools (Parker & Richardson, 2005), fosters

a sense of powerlessness (Callahan & Chumney, 2009), and obscures their educational status (Deil-Amen & Rosenbaum, 2002). Given these findings, studies of developmental instruction should be particularly sensitive to how new curriculum initiatives impact students of color and lower-SES students.

The Effectiveness and Impact of Developmental Mathematics

Those who study developmental education often lament the relative lack of information on the effectiveness of developmental classes at promoting student success (Bahr, 2008; Breneman & Haarlow, 1998; Grubb, 2001). Much of the work that does exist from before 2000 has serious methodological flaws (Bahr, 2008; Boylan & Saxon, 1999), so reliable conclusions from these studies cannot be drawn. Direct comparisons of developmental and non-developmental students are difficult: students who need remediation have different educational backgrounds, demographics, and educational aspirations than those who do not (Cohen et al., 2013). As a result, to measure the effectiveness of developmental education reliably, researchers must consider the context of the students within the analysis, not just make simple comparisons of educational outcomes such as success in college-level classes.

Raw descriptive statistics on students who finish developmental classes are grim. Attewell et al. (2006) found that only 30% of those placing into developmental mathematics pass all of their required pre-college-level mathematics classes. Bailey (2009) performed a similar analysis with a different data set and found that 31% of those placing into developmental mathematics finished their sequence, which was 44% of those who actually enrolled in developmental classes after placement. However, the lower a student places, the lower their chances of completing remediation. For example, Bailey et al. (2010a) found that only 17% of students who started three levels below college ready in mathematics finish their developmental

mathematics classes, compared to 45% who finish if they only need to take one developmental mathematics class.

Remediation impacts who has access to four-year schools. When a large urban university removed remediation from its curriculum, enrollments of students of color decreased (Parker & Richardson, 2005), suggesting that remediation helped students who otherwise might not have had the opportunity to reach college-level work. Students who finish remediation pass college-level mathematics classes, earn certificates and degrees, and transfer to four-year schools at the same rate as those who were able to enter college-level classes immediately (Attewell et al., 2006; Bahr, 2008, 2010a).

Most of the studies discussed in the preceding paragraphs either compared developmental completers to non-developmental students (Bahr, 2008, 2010a) or looked at the relative success rates of the developmental students (Attewell et al., 2006; Bailey, 2009) but did not compare remediated students to those who should have remediated but did not. Bailey et al. (2010) compared students who placed into and took developmental mathematics with those who placed into but avoided remediation, but within their analysis did not control for unobserved differences between these groups such as mathematical background or preparation. To fill this methodological gap, Bettinger and Long (2005) took advantage of the fact that Ohio schools do not all use the same developmental cut-off scores. Using a regression analysis, they compared community college students who placed into and took developmental classes with students having similar educational and demographic backgrounds who placed out of remediation at different schools. The students who took developmental classes earned more credit hours and were more likely to transfer to a four-year school than students who did not. However, in a methodologically similar analysis using data from North Carolina, Clotfelter et al. (2015) found

that developmental education had a somewhat negative effect on college persistence for students recently graduated from high school. Still, among full-time students intending to earn a bachelor degree, Bettinger and Long (2009) found that students who remediated persisted in college at higher rates than those who had no such prerequisites.

An alternative way to attempt to measure the impact of developmental education is to take advantage of the fact that most community colleges place students into developmental classes using a placement exam, which allows for a powerful statistical method known as regression discontinuity to be applied. Regression discontinuity takes advantage of the fact that students scoring close to the cut score of a placement exam are probably similar in terms of actual ability, regardless of which side of the cut score they place into. Calcagno and Long (2008) used regression discontinuity to compare students who narrowly passed their placement exam (and did not take developmental coursework), to students who just missed passing the exam (and took remedial classes). They found that the students who took remediation had better rates of persistence into the second year of college compared to those who narrowly placed out of developmental courses. They did not find a difference in degree completion or the total credits earned in college between the two groups. Martorell and McFarlin (2011) performed a similar comparison with two- and four-year students in Texas who intended to earn a degree in college. They found no difference in educational outcomes for the two groups.

Taken together, the results discussed in this section suggest that for students who place just under the developmental cut-off score, remedial education does not negatively impact their long-term educational outcomes, but does not seem to produce clear benefits either (Calcagno & Long, 2008; Martorell & McFarlin, 2011), which raises the question as to whether students really gain anything from developmental education. Conversely, Bettinger and Long's work (2005,

2009) and the findings related to removing remedial education from the curriculum (Parker & Richardson, 2005) suggest that remediation does help students achieve more with their education, although the curriculum goals and age of the students may influence these results (Clotfelter et al., 2015). The different findings may be a consequence of the populations each group examined and the methods employed. Those who found no effect used regression discontinuities, comparing students who just barely needed remediation to those who needed no remediation. The researchers who found more positive effects examined students placing into *all* levels of developmental mathematics. Thus, remediation seems to help students who enter college significantly below college ready, but may not offer much benefit to those who only need a small amount or who are recently out of high school. That said, greater amounts of required remediation correlates with lower completion rates (Bailey, 2009; Bailey et al., 2010), raising questions about whether the time and costs of remediation are worth it, even for those with low initial placements. Thus, although developmental mathematics may be effective in helping students learn, it is unclear how large that impact is or who is best served by the current system. That said, emerging research related to developmental redesigns, discussed later in this review (e.g., Sowers & Yamada, 2015; Yamada, Bohannon, & Grunow, 2016; Yamada & Bryk, 2016; Norman, 2017), suggest that perhaps the patterns observed in this literature are a function of the developmental curriculum structure, rather than the purpose or intent of developmental education.

The Price of Developmental Education

The large need for developmental instruction and the low completion rates have led some to question whether developmental education costs too much for the return on investment. Developmental classes cover the same content as K-12 schools, leading to the question of why

the public pays to teach individuals the same material twice (Boylan, 1999; Hoyt & Sorensen, 2001). The other side of the argument notes that developmental education serves a democratic function, allowing all students access to higher level material, especially those who did not take a college preparatory program in high school or have returned to school after a long break (McCabe, 2000).

Estimating what society pays for remediation is tricky; the lack of agreement on what constitutes pre-college level and the diversity of services housed under the name developmental education complicates the calculation. Almost two decades ago, Breneman and Haarlow (1998) estimated the national cost of remediation to be between 1 and 2 billion dollars, which at the time was around 2% of the total spent on higher education. More recent estimates at the national (Strong American Schools, 2008) and state levels (Florida Office of Program Policy Analysis and Government Accountability, 2006; Ohio Board of Regents, 2006) suggest the proportion of the higher education budget going to remediation has grown slightly, but the overall value remains a small proportion of the overall budget. These estimates seem like a reasonable investment from a state and national perspective, given that individuals with at least some college-level education tend to have lower crime rates, are more productive, and pay more taxes (Phipps, 1998).

Although the national cost of developmental education may seem reasonable, individual costs also matter. When required to take developmental coursework in college, students must consider both the financial and opportunity cost of attendance. Opportunity cost, in particular, may play a large role in the cost calculations for community colleges students who come from lower-SES backgrounds or have family obligations. For such students, time in school or doing homework means time away from jobs and children, which may be higher priorities (Cohen et

al., 2013). Melguizo, Hagedorn, and Cypers (2008) used data from the Los Angeles area to estimate the financial and opportunity costs of remedial education for local students. They found that generally, the financial cost to students over two years was low because many of these students received grants and worked part-time, which reduced their opportunity cost, but doing so increased their time to degree dramatically, a cost of remediation that has been noted by other researchers (i.e., Attewell et al., 2006). The increased time to degree and accrued costs may also have the effect of causing students to divert their educational aspirations to less prestigious, but less time consuming, certificates or degrees (Brint & Karabel, 1989), a phenomenon sometimes called “cooling out” (Clark, 1960).

Developmental Mathematics Placement

Open enrollment policies at community colleges mean that students enter with diverse educational backgrounds, which can make advising students about course choices complicated. The use of placement exams allows for efficient sorting of students into different ability bands, streamlining course selection processes. But, as with standards for “college ready,” placement practices vary between schools (Bettinger & Long, 2005, 2009), and the tests tend to focus on procedural, rather than conceptual knowledge (Gordon, 2006). Thus, even with a “neutral” sorting mechanism, students may enter the classroom with diverse levels of conceptual understanding of mathematics, which has complex implications for instruction.

Summing Up Developmental Education

The literature discussed in this section describes many of the issues and challenges facing the developmental mathematics population, as well as the effectiveness of developmental education in promoting student success. One consequence of the various dimensions of the developmental system is that students from all walks of life and with different levels of

conceptual understanding of mathematics end up in pre-college level classes together. The question then becomes whether and how these students, who might need very different things from a mathematics class, can all have their needs met by the curriculum and instruction implemented in a developmental mathematics classroom.

In the next section I explore findings related to the curriculum and instruction of developmental mathematics at the classroom level. Because literature specifically focused on developmental classrooms is somewhat limited, I include studies examining college mathematics classrooms when the results pertain to either group work or real-world problem solving, as these components inform a large part of the curriculum and instruction of the classroom studied for this dissertation.

The Curriculum and Instruction of Developmental Mathematics

In her comprehensive survey of mathematics education literature related to the community college population between 1970 through 2014, Mesa (in press) identifies a dramatic uptick in the amount of scholarship produced since 2005. She notes, however, within this body of literature, across the decades spanning her review, much of the existing work makes assumptions that explicitly or implicitly apply a deficit lens to the community college population (e.g., focusing on ways to “fix” the knowledge deficits of students through instructional intervention), rather than examining students’ ways of thinking or their educational experiences within the greater context of their life stage, prior educational experiences, and motivations for enrollment in a particular class. Given that students enrolled in the developmental sequence are there because they have been identified as *not ready* for college-level work, her point is particularly salient and should be attended to in mathematics education work with the community college population.

Classroom-level research on developmental curriculum and instruction is limited, although surveys of the research that end with calls for more high-quality investigations are fairly common (e.g., Bragg, 2011; Condelli et al., 2006; Mesa, in press; Mesa, Wladis & Watkins, 2014; Speer, Smith, & Horvath, 2010). Of those that do exist, most focus on what instructional methods the teachers are using, rather than focusing on the interplay between the curriculum, students, and instruction (Mesa, in press). One recent exception to this trend examined the experiences of African American students in a remedial mathematics class, noting the ways institutionalized structures contributed to negative experiences in the class (Larnell, 2016). Perhaps the best-known investigation into teacher practices at community colleges was conducted by Grubb et al. (1999). Their work documented that most of the developmental teachers studied, including those in mathematics, used traditional methods emphasizing skill acquisition rather than instructional techniques that focused on meaning-building between the different concepts under study.

Traditional lecture and drill practices are not inherently bad; students value teachers who present the knowledge to be learned in a clear, organized format so they can easily identify what they need to know to pass the class (Cox, 2009). However, many of the students enrolled in developmental education may benefit from teaching that uses different approaches, given that many have taken and failed to learn the material before (Hoyt & Sorensen, 2001). Few community college teachers are trained in educational theory or methods, meaning that instructors who wish to change their teaching must rely on trial and error or their own research (Grubb et al., 1999), although calls for professional development targeting the needs of community college faculty, especially in mathematics and science are beginning to emerge (Dowd, 2011).

Although traditional methods are employed heavily by community college instructors, evidence suggests these teachers are interested in supporting students in understanding the material. Grubb et al. (1999) distinguishes between traditional pedagogies and meaning-making pedagogies, which echo NCTM's (1989, 2000) distinction between traditional, behaviorist-oriented techniques and reform-oriented pedagogies. Mesa, Celis and Lande's (2014) investigation into community college mathematics classrooms found that although about one-third of their sample exclusively used traditional methods with little to no meaning making, almost all the remaining teachers combined traditional with meaning-making instructional methods. Cox (2015) also described differences between developmental mathematics classrooms where instructors, in their lectures, tended towards procedural questioning versus a focus on conceptual questioning, finding that instructors' use of conceptual questions seemed to correlate with their ideas about the nature of mathematics learning. Although they may not receive training in developmental mathematics teaching, these results suggest that many instructors may see value in taking a risk with different instructional strategies because it appeals to how they think students should learn mathematics.

Mathematics Communities in College Classrooms

Several researchers have examined whether collaborative learning communities support student success in college classrooms. Perhaps most famously, Treisman (1992) described a project in which African American college students learned Calculus through group work and problem solving. He found that these students, who had historically performed poorly in the class, started outperforming their peers. Using a meta-analysis, Springer, Stanne, and Donovan (1998) found that when group work was used in mathematics-related class settings and implemented well, it produced positive results for students. Although both studies provide

encouraging findings with respect to the use of group work with college students, the findings should be interpreted with caution for the developmental population. Treisman's (1992) study took place at Berkley in the Calculus sequence. Many developmental students are students of color, but African American students in Calculus at Berkley are fundamentally different than developmental mathematics students, who usually have lower self-efficacy (Hall & Ponton, 2005) and greater mathematics anxiety (Sprute & Beilock, 2016) than more advanced students, which may contribute to how well students do in a group work context.

Hagedorn, Sagher & Siadat (2000) found that in a developmental mathematics class where students engaged in peer tutoring, students had higher retention rates, although not higher grades, than students in a class with similar instructional practices but no peer tutoring. The instructor in Hagedorn et al.'s study used group work routinely, though only when the students demonstrated a need for re-teaching of a concept already covered in lecture. The preponderance of instruction in the class followed the more traditional lecture format.

Lastly, alternative instructional methods like flipped classrooms have gained growing attention. In flipped classroom models, students consume the classroom lecture outside of the class, through video provided by the instructor. During class, the students engage in applying ideas from the lectures to problems that would have traditionally been covered in their homework. Early studies of these instructional methods have mixed to neutral results for student learning, but optimistic support from instructors (e.g., McGivney-Burelle & Xue, 2013; Ziegelmeier & Topaz, 2015).

Attitudes Towards Mathematics and the Developmental Population

The relationship between affective variables, such as mathematics anxiety and mathematical performance, is a thriving field of mathematics education research, with many

researchers examining how mathematics anxiety, self-efficacy, enjoyment, motivation to study, and beliefs regarding the utility value of mathematics influence or correlate with student outcomes.

Broadly, *mathematics anxiety* encompasses test anxiety and a sense of dread related to doing mathematics, but some describe it as “the general lack of comfort that someone might experience when required to perform mathematically” (Wood, 1988, p. 11). A high negative correlation between mathematics anxiety and mathematics performance exists, with increased anxiety associated with decreased mathematics performance, including at the college level (Hembree, 1990; Sprute & Beilock, 2016). High mathematics anxiety tends to result in mathematics avoidance (Ashcraft, 2002). Given that developmental students experience higher mathematics anxiety than students in more advanced classes (Sprute & Beilock, 2016) and the fact that community college students have some choice regarding when in their program they take their mathematics classes, finding ways to reduce their anxiety becomes an important goal of mathematics instruction at the developmental level.

Higher self-efficacy, which measures the degree to which a person believes they can successfully navigate and perform in mathematical situations (Bandura, 1997), often correlates with lower mathematics anxiety (Betz & Hackett, 1983; Hackett, 1985; Lent, Lopez, & Bieschke, 1991). College students with high self-efficacy are more likely to be able to solve mathematics problems (Pajares & Miller, 1994), but developmental students usually have lower self-efficacy than students enrolled in transfer-level mathematics classes (Hall & Ponton, 2005). In addition, older students have lower self-efficacy and higher mathematics anxiety than their younger classmates (Jameson & Fusco, 2014).

Having an academic goal seems to correlate with higher success rates on measures of mathematics ability (Cleary & Chen, 2009; Singh, Granville, & Dika, 2002) and some research suggests that motivation to study mathematics is malleable (Forbes & Schmader, 2010; Jansen & Middleton, 2011). Qualitative work suggests that motivation helps college students negotiate and persist through barriers to their success in mathematics classes (i.e., Martin, 2006) and that creating a supportive environment in which students feel valued (e.g., Ryan & Patrick, 2001; Treisman, 1992) also increases student motivation.

Students who enjoy doing mathematics tend to do better in university-level mathematics classes (Villavicencio & Bernardo, 2013), and a negative correlation seems to exist between enjoyment of mathematics and mathematics anxiety for college students (Hembree, 1990).

Although many mathematics educators clearly see the importance of learning mathematics, it often seems that students do not value the mathematics they learn in school. Some have found that connecting mathematical principles to real-world applications positively impacts college students' perceptions of the utility of mathematics (Shechter, Durik, Miyamoto, & Harachkiewicz, 2011). Additionally, *mathematical utility value* (Eccles et al., 1983) seems to correlate with career choices made in late high school and college (e.g., Lopez & Lent, 1992; Stage et al., 1985; Watt, 2006).

Developmental mathematics classes offer a critically important opportunity to improve students' perceptions of mathematics and of themselves as doers of mathematics. The results in this section suggest that well-structured and supportive learning environments might improve students' mathematics-related attitudes, as many of these attitudes appear to be malleable under the right conditions. In particular, structuring classes so students can engage with the mathematics might increase mathematics enjoyment. Deliberately connecting the mathematical

concepts to scenarios the students can relate to might also increase the value a student places on learning mathematics.

Summing up Curriculum and Instruction in Developmental Mathematics

The literature examined in this section points to a relative lack of classroom-level studies examining the curriculum and instruction of developmental classes. Although there is some research on college mathematics classrooms, the results most relevant to the curriculum and instructional methods used in reform-oriented developmental classes apply to dramatically different populations. The few developmental classroom studies that do exist have primarily examined courses taught with more traditional methods of instruction, rather than using the reform-oriented methods.

That said, many of the instructors in these classrooms demonstrated interest in promoting mathematical sense making, suggesting that alternative methods of instruction might appeal to them, given appropriate curriculum materials and supports. Evidence examining collaborative learning environments also suggests learning opportunities that create communities may benefit developmental students. To further explore existing research that could shed light on how real-world problem solving and group work might impact the developmental population, the next section turns to K-12 literature related to reform-oriented mathematics instruction.

Group Work and Problem Solving in the K-12 Mathematics Classroom

Although comparatively little work has explicitly examined the curriculum and instruction of developmental mathematics classrooms, particularly related to using group work and real-world problems, research at the K-12 level has examined related questions for many years. The two populations differ in many important ways, including life stage, age, mathematics background, and motivation for enrollment, but lessons from what works with the general K-12

population can still provide a useful starting point for understanding how similar instructional strategies might impact developmental students.

I focus this review on literature related to: (a) models for implementing a problem-solving-based curriculum, with a particular focus on group work, (b) student outcomes from classrooms taught using reform-oriented curriculum and instruction, and (c) how instructor enactment matches with intentions, and the implications of various levels of enactment on student outcomes.

Models for K-12 Reform-Oriented Instruction

For at least thirty years, NCTM, the largest professional organization of mathematics teachers in the country, has influenced the visions for mathematics curriculum and instruction (NCTM, 1989, 2000). For example, the commonly adopted CCSSM (NGACBP, 2010) reflect many ideas that the NCTM articulated, including its emphasis on mathematical reasoning and problem solving. Much of the work related to reform-oriented instruction describes mathematics curriculum and instruction that engages students using rich problems, which many believe will promote opportunities for students to develop their understanding of important mathematical ideas (Hiebert & Wearne, 2003).

NCTM's focus on engaging students in deeper mathematical learning has resulted in many documents articulating how the enactment of these principles would look in the classroom (e.g., NCTM, 1991, 2007, 2014). Several researchers, in their examinations of how reform-oriented curriculum and instruction impact student outcomes, describe the reform-oriented instruction in the classrooms they studied as occurring in three stages (e.g., Lampert, 1990; Lubienski, 2000; Tarr, Grouws, Chávez, & Soria, 2013). In the first stage, the instructor launches the task, introducing and motivating the problem. In the second stage, students engage in small

group work, exploring the assigned problem(s). During the last stage, students engage in whole-class discussion, during which the instructor helps the class highlight and better understand the intended mathematical ideas of the lesson. Van DeWalle, Karp, and Bay-Williams (2015) in their widely used elementary and middle school pedagogy textbook, explicitly articulate this process as the “Three-Phase Lesson” format. Thus, in a reform-oriented class at the developmental level, we might expect to see a period when the instructor launches students’ investigation of a problem, a time during which the students engage in group work on the problem, and then a final whole-class discussion.

Literature with respect to the teacher’s “launch” of a problem is rare, but research pertaining to problem-centered group work and whole-class discussion of mathematics are covered briefly in the following sections.

K-12 group work. A large focus of reform-oriented mathematics instruction is on decentralizing the role of the instructor while students engage in individual and small group problem solving. In their widely cited book on designing small group instructional practice, Cohen and Lotan (2014) say that prior to engaging in group work, instructors should work to establish good cooperative norms within the classroom, in addition to making sure the group roles, composition, and assignments are clear to students. Once students are working, the instructor should enforce norms while providing space for students to engage in the work independently, intervening primarily when the group is hopelessly off-task or does not seem to be making progress because they are stuck, engaged in interpersonal conflict, or unorganized. Other reviews of effective strategies for collaborative group work make fairly similar recommendations (Cohen, 1994; Webb, 2009).

The decentralization of the instructor role in classrooms emphasizing group work leads to questions about the influence of the instructor on the mathematical learning and behavior of students within their groups. To evaluate the effectiveness of teacher interventions with ninth graders engaged in mathematics problem solving during small-group work, Chiu (2004) tracked group behavior before and after teacher intervention. Chiu found that teacher interventions were usually teacher-initiated, and occurred when the students were off-task. Moreover, the teachers touched base with all of the groups, regardless of the group's progress. Other studies examining the role and impact of the teacher on small group work in mathematics classrooms has examined the influence of instructor questioning on within-group student questioning (Webb, Nemer, & Ing, 2006; Webb et al., 2009) and on students' relational thinking (Lin et al., 2015). The results from these studies suggest the instructor does influence students' mathematical conversations and thinking in small group work, although not always in the ways intended.

As previously mentioned, Cohen and Lotan (2014) recommend instructors intervene with hopelessly off-task groups, and Chiu (2004) found that the teachers in his study often intervened while groups were off-task. Although off-task behavior is often mentioned in studies of group work, the actual amount of off-task behavior is rarely explored. Wood and Kalinec (2012) offer one of the few looks at a group's entire process in working on a mathematics problem and found that approximately 50% of the fourth graders' time was spent in off-task conversation. Given that developmental students have high achievement goal orientations (Mesa, 2012) and value efficiency in their educational experiences (Cox, 2009), it may be that their patterns of off-task behavior differ from those observed in K-12 classrooms, especially given that adult students have been shown to have highly productive group work sessions in non-mathematical contexts (Barkaoui, So, & Suzuki, 2008). On the other hand, developmental students might be more likely

to engage in off-task behavior given that the high mathematics anxiety of developmental students (Sprute & Beilock, 2016) might lead to avoidance of the mathematical tasks before them (Ashcraft, 2002).

A fair amount of group work research in mathematics classrooms has examined the power dynamics at play within the conversations, and the resulting implications for mathematical learning. Baxter, Woodward, and Olson (2001) found that students identified as low achievers in a reform-oriented mathematics classroom rarely participated in their groups. When they did contribute, it tended to be in the form of short, one- to two-word answers. By performing textual analysis of the students within their groups, Esmonde and Langer-Osuna (2013) demonstrated that students thought to have less knowledge can still employ social power to maintain their status within the group, which students also seem to recognize (Esmonde, Brodie, Dookie, & Takeuchi, 2009). In a related study, Langer-Osuna (2016) described how the power relationships influenced which mathematical ideas were taken up within the group, a result noted by other researchers (Wood, 2013). Research suggests, however, that status within groups is malleable (Cohen & Lotan, 1995), suggesting these power relationships are not fixed within groups. Given that a single developmental mathematics classroom might contain students who have never seen the material before, along with students who are reviewing the material and might have taken even more advanced mathematics classes, power struggles within groups related to social status and knowledge levels (Cohen & Lotan, 2014) may come into conflict within groups.

Whole-class discussion. Emphasizing communication at the group and classroom level comes with perils, but also shows promising results in the type of mathematics the students can learn (Lampert & Cobb, 2003). NCTM, in its *Professional Standards for Teaching Mathematics* (1991), identifies “orchestrating classroom discourse” as one of its six standards. A great deal of

research has examined classroom level discourse, far more than is possible to cover in this review. Importantly, the scope of the literature includes practitioner discussion about their learning process while attempting to implement classroom discourse (e.g., Heaton, 2000; Herbel-Eisenmann & Cirillo, 2009), understanding how linguistic tools can be combined to understand the greater mathematical argument (e.g., González & Herbst, 2013) and the relationship between instructor actions and student participation (e.g., Jackson, Garrison, Wilson, Gibbons, & Shahan, 2013; Moschkovich, 1999; White, 2003). In short, classroom-level discourse has been a large focus of the discussion around reform-oriented mathematics curriculum and instruction, and, by extension, an important attribute to look for in a reform-oriented developmental mathematics classroom.

Reform-Oriented Curriculum and the Developmental Population

Given the conversational load intended in any enactment of group work and the fact that many real-world problems come in the form of word problems, oral and written communication makes up a big component of reform-oriented instruction, and has a fundamentally different style than traditionally taught mathematics classrooms (Cazden, 2001). Community colleges are typically open enrollment, with the result that community college students (and by extension, developmental students) tend to be more diverse in terms of race and age, are more likely to speak English as a second language, generally have lower levels of academic preparation, and come from lower-SES backgrounds than students at selective enrollment schools (Cohen et al., 2013). As a result, how reform-oriented instruction impacts students from these backgrounds becomes particularly important to tease out.

Research examining the effect of reform-oriented instruction on different populations has demonstrated generally positive results. For example, Moschkovich (1999) found that English-

language-learning students, who we might expect to struggle in a language-intensive classroom, can be successful in reform-oriented classes when the teacher is attentive to their language needs and willing to support and value the students' contributions.

Research has also documented that students from working-class backgrounds enter school with different communication patterns than middle-class students (Lareau, 1987), which could impact their ways of interacting within groups and with the instructor. Lubienski's (2000) observation that many of her lower-SES students viewed class discussions as a place where ideas were evaluated for correctness rather than as a place to discuss mathematical ideas raises such questions. She concluded that low-SES students may need additional teacher supports to thrive in new problem-centered, discourse-intensive pedagogies as intended. Several researchers have examined the impact of reform-oriented instructional methods with students with low-SES backgrounds. Most found that these students did as well as students with high-SES backgrounds (Boaler, 2002; Hickey, Moore, & Pellegrino, 2001; Knapp, Shields, & Turnbull, 1995; Silver, Smith & Nelson, 1995). Ginsbury-Block and Fantuzzo (1998) found that low-SES students did best when they learned through problem solving, and also showed positive gains when given the opportunity to collaborate during class. However, importantly for the low-SES population, low levels of compliance with reform-based pedagogies corresponded with larger learning gaps between low- and high-SES students (Schoenfeld, 2002).

The results presented above are encouraging. Students who are likely to enroll in developmental mathematics might gain from reform-oriented instruction in similar ways as students who are less likely to need remediation. However, for these students, the level of implementation and the responsiveness of the teacher to the student as an individual seems to matter a great deal, which has important implications for the enacted curriculum in a reform-

oriented, developmental mathematics class. The teacher cannot expect that students will understand the intent of the curriculum; she needs to help the students understand the content and make sure they get the support they need both within their groups and with respect to larger class goals.

Student Outcomes and the Enactment of Reform-Oriented Mathematics Curriculums

The curriculum of many reform-oriented developmental mathematics classes is intended to meet the needs of students planning to enter Statistics or general education mathematics classes (c.f., Sowers & Yamada, 2015). However, research has shown that the planned (Gehrke et al., 1992) or intended curriculum rarely matches the enacted curriculum in K-12 classrooms (Stein et al., 2007). Indeed, many have noted the complexity in implementing K-12 reform-oriented curricula as intended (c.f., Cohen, 1990; Drake & Sherin, 2006; Heaton, 2000). Some research has shown that giving teachers information about the intent and purpose of various curricular elements seems to impact how a teacher implements a curriculum that uses group work and problem solving pedagogies (Carpenter, Fennema, Peterson, Chiang, & Loef, 1989). Hence, we might expect that teachers who are more knowledgeable about a reform-oriented curriculum and its intentions, whether at the K-12 or community college level, would enact the curriculum more reliably as intended.

Several K-12 studies have examined how fidelity in enactment of the intended curriculum impacts student learning. Hickey et al. (2001) found that the students in classrooms where the teacher complied with recommended reform-oriented pedagogies scored better on measures of problem-solving ability than students in classrooms with teachers who used the reform materials with more traditional pedagogies. Tarr et al. (2008) investigated whether having a textbook that presents material in reform-consistent ways impacted student learning. They found that when

teachers implemented the text and adjusted their instruction to support using such materials as intended, students did better on assessments of problem solving ability than students who used the same textbook but were taught in more traditional ways. Both groups of students performed equally well on traditional assessments. When teachers did not use reform-recommended pedagogies, students using traditional and reform curriculums did equally well.

The interplay of how the instructor introduces and enacts the curriculum also matters. Boaler (2002) compared two schools over several years and noted that the way reform teachers approached teaching the students about the *purpose* of the reform-oriented curriculum and pedagogies impacted how the students responded to the methods. In a related vein, Murrell (1994) noted that instructors need to be mindful of how students respond to and enact their roles in the reform pedagogies—it is possible for students to act involved but miss the learning opportunities the instructional methods are meant to provide. Lubienski (2000) made a similar point in her work with a seventh-grade, mixed-SES classroom. Thus, implementation of the reform-oriented pedagogies needs to include instructor attention to how the students engage with the materials.

The amount of time students spend using a reform curriculum also seems to matter in K-12 schooling. Riordan and Noyce (2001) found that the longer a school used reform-oriented materials, the better students did. Boaler (2002a) found similar results in her comparison of two schools implementing different curricula, noting that the longer that students worked with the reform curriculum, the better students did relative to students using traditional materials. Reys, Reys, Lapan, Holliday, and Wasman (2003) performed a similar analysis to Riordan and Noyce, but only examined schools that had used the reform curriculum for a short period. They showed some positive results towards the reform curriculum, but had few significant comparisons. These

results suggest that teachers and students at the K-12 level may require a period of adjustment before significant results can be found, although alternative explanations might exist.

The results discussed above demonstrate that implementing the standards *as intended* is an important component to producing improved results for the students (Hickey et al., 2001; Tarr et al., 2008). Thus, in reform-oriented developmental mathematics classrooms, the nature of the instructional enactment may matter a great deal.

Summary of Reform-Oriented K-12 Mathematics Instruction

The literature featured in this section highlights the great interest in, and complexity of, implementing a reform-oriented mathematics curriculum at the K-12 level. From the task implementation through the ending whole-class discussion, teaching to the intentions of a reform-oriented curriculum requires a great deal from the instructor, including establishing new classroom norms, skillful facilitation of students' problem explorations and discussions, and attending to students' engagement with the curriculum. Evidence suggests that teachers often fall short of reformers' intentions, but that teachers who understand the curriculum and its intentions have more success. Finally, in K-12 classrooms where reform-oriented curricula are implemented as intended, students learn at least as much traditional material as other students, and they become better at mathematical problem solving. Taken together, this work suggests that college-level, developmental students might benefit from instruction centered around real-world problem solving and group work. However, it is not clear how such instruction would play out in developmental classrooms.

Mathematical Literacy

Up until this point, this chapter has discussed issues related to developmental mathematics, identifying comparatively little classroom-level research on these educational

spaces. Studies of K-12 mathematics classrooms suggest that reform-oriented instruction might provide an avenue for promoting student success in developmental classes, which have historically been plagued by low success rates (Attewell et al., 2006; Bailey et al., 2010). However, developmental mathematics serves adult students, many with busy lives, multiple obligations, and drastically different levels of prior experience in mathematics. Because of the unique population and context that places students in developmental classes, it is unclear whether K-12 implementation strategies will impact these adult students in similar ways.

A national developmental mathematics curriculum called *Mathematical Literacy* was created to align with reform-oriented practices such as real-world problem solving and group work. The *Mathematical Literacy* movement responds to a call from the American Mathematical Association of Two-Year Colleges (AMATYC) in its standards documents *Crossroads in Mathematics* (Cohen, 1995) and *Beyond Crossroads* (Blair, 2006). With roots in the NCTM *Standards* (1989, 2000), these documents call for more relevant and engaging developmental mathematics classes that fit the needs of community college students.

Quantway and Statway (Carnegie, n.d.a, n.d.b) are perhaps the best known of the various implementations within the *Mathematical Literacy* movement. These classes are designed to replace developmental algebra in a way that targets the mathematics needs of students who plan to take Statistics and General Education Mathematics classes at the college level. As such, *Mathematical Literacy* omits algebraic content that students do not need to be successful in these college-level classes and adds content that supports later success in quantitatively focused classes (for example, data organization and analysis is a more useful skill for a student going into Statistics than being able to solve, by hand, a system of three equations with three unknowns). *Mathematical Literacy* curricula also are designed to take a student who traditionally would have

been required to take two semesters of developmental algebra through their required mathematics content in a single semester, reflecting AMATYC’s recommendation that the mathematics curriculum “help students progress through their chosen curriculum as quickly as possible” (Blair, 2006, p. 41). Figure 2.1 illustrates the traditional developmental sequence and timeline and Figure 2.2 provides an illustration of the Carnegie Pathways curriculum redesign, adapted from descriptions of their curriculum (Carnegie, n.d.a., n.d.b; Yamada, Bohannon, & Grunow, 2016).

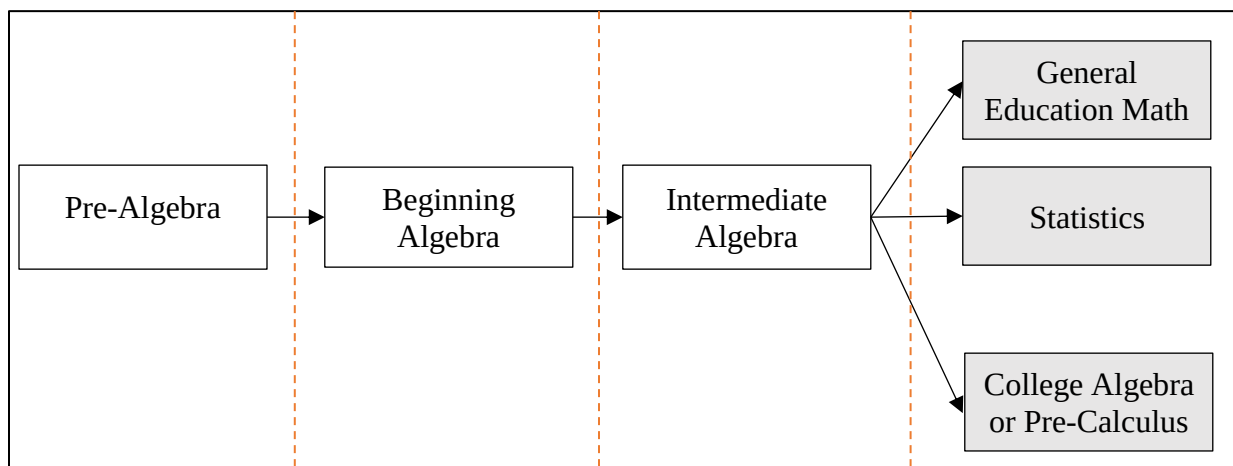


Figure 2.1. Traditional Developmental Mathematics Sequence. Adapted from Cullinane and Treisman (2010). The vertical dashed lines indicate a single semester. Grey boxes indicate a credit-bearing class.

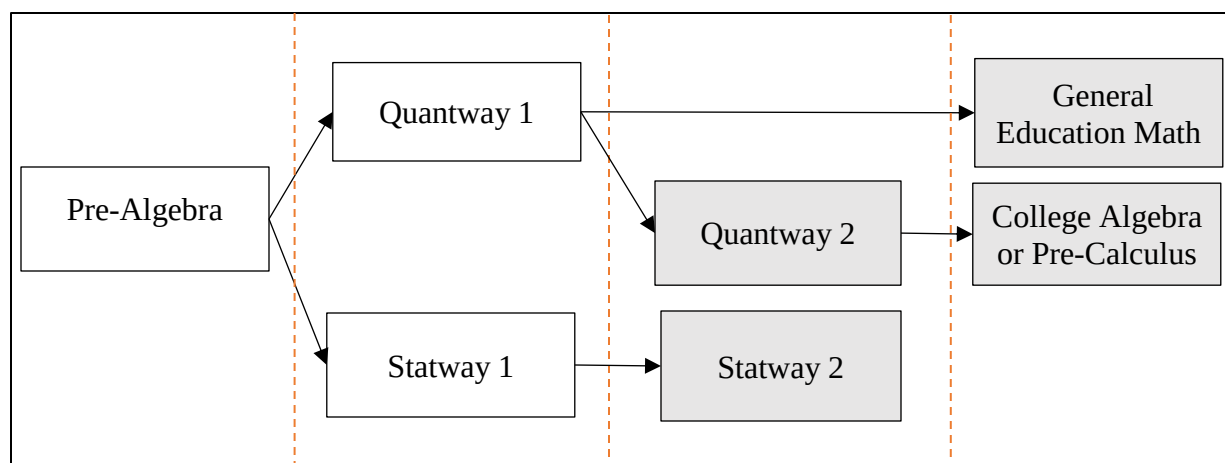


Figure 2.2. Carnegie Pathways Developmental Mathematics Redesign. Adapted from published Carnegie Pathways descriptions (Carnegie, n.d.a., n.d.b; Yamada, Bohannon, & Grunow, 2016). The vertical dashed lines indicate a single semester. Grey boxes indicate a credit-bearing class.

As previously discussed, research on developmental mathematics classrooms is relatively rare, especially related to reform-oriented curriculum and instruction. However, some degree of work has been done to examine student success outcomes in such classes. Since the inception of the Carnegie Pathways, the Carnegie Foundation has routinely published statistical reports, comparing results from students in traditional sequences to students who took one of the two Carnegie Pathways (e.g., Sowers & Yamada, 2015; Norman, 2017). These reports have primarily used descriptive quantitative methods, which can limit the generalizability of the results,¹ but a recently published article used a more sophisticated analysis and found similar findings (Yamada & Bryk, 2016). These results are promising, but they do not provide a detailed discussion of the *classroom* experiences of students or the enactment of the curriculum, leaving questions about what actually occurred in these classrooms, and which aspects of the curriculum redesign impacted the students the most.

¹ See my discussion earlier related to determining the effectiveness of developmental education (pp. 13-16) for a full discussion of the problems with simple descriptive comparisons.

Starting in 2013, Fields Community College (FCC; all names are pseudonyms), a large community college in a small Midwestern city, started implementing a *Mathematical Literacy* curriculum. Prior to this implementation, FCC had a traditional developmental sequence. *Mathematical Literacy* at FCC shares many common features of the Carnegie Pathways (Sowers & Yamada, 2015; Yamada, Bohannon, & Grunow, 2016; Yamada & Bryk, 2016; Norman, 2017), including the fact that students planning to take College Algebra or higher still require a full year in the developmental algebra sequence. However, the FCC courses differ from the Carnegie Pathways in several important ways: (a) each Carnegie Pathway only prepares students for one college-level class on the reduced time frame, while *Mathematical Literacy* at FCC prepares students for both Statistics and General Education Mathematics, and (b) *Mathematical Literacy* at FCC includes more content than the single semester classes so as to meet state articulation standards. See Figure 2.3 for a diagram of the FCC’s implementation of *Mathematical Literacy*.

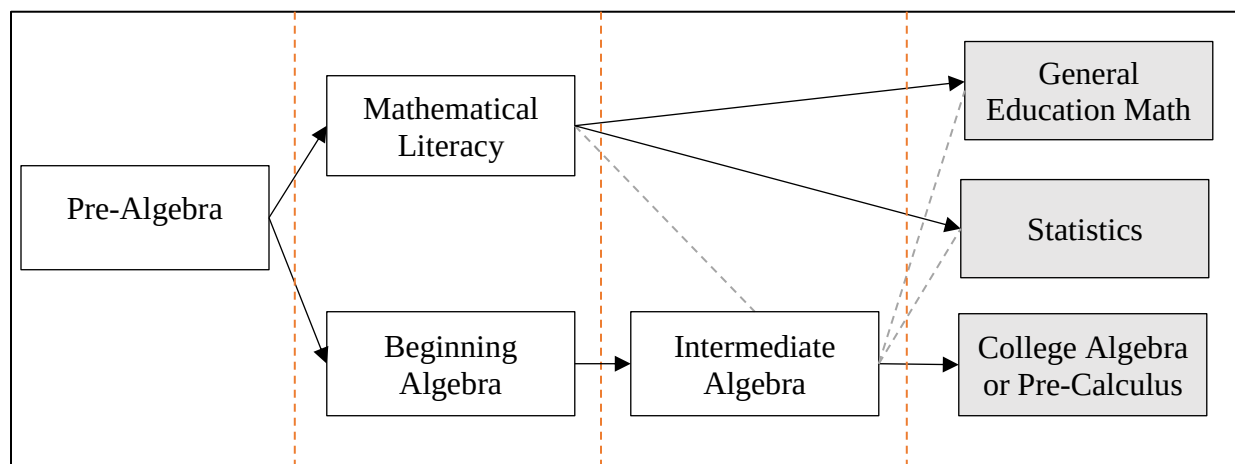


Figure 2.3. *Mathematical Literacy* and the Developmental Mathematics Curriculum at FCC. The vertical dashed lines indicate a single semester. The light grey dashed lines indicate alternative, but rarely taken, developmental sequence pathways. Grey boxes indicate a credit-bearing class.

The fact that *Mathematical Literacy* at FCC does not separate students preparing for General Education Mathematics from those preparing for Statistics gives students more latitude

than the Carnegie Pathways to change their minds about their goals after course enrollment. In the Carnegie Pathways, students choose a path (Statistics or General Education Mathematics) and have the chance to complete both their remediation and a college-level class in one year. However, if they change their mind about which transfer-level class they want to take, they must start at the beginning of the other sequence. In contrast, *Mathematical Literacy* at FCC lets students narrow their curriculum focus without becoming too specialized. That said, given that both curriculum redesigns are still comparatively new, the long-term implications of more or less flexibility in curriculum choice remains an open question.

That *Mathematical Literacy* at FCC takes one semester to fulfill the state articulation standards for developmental algebra also has important implications. The state in which FCC resides requires more algebraic and geometric content than the Quantway 1 class includes, which is part of the reason FCC cannot implement the Carnegie Pathways. Thus, *Mathematical Literacy* might impact students differently, given that more is expected of the students and instructors in the same timeframe.

In summary, *Mathematical Literacy* at FCC represents a unique effort to address both the content and structural needs of developmental mathematics students while working within the constraints imposed by state educational guidelines. The refocusing of the curriculum on real-world problem solving and more alignment with content in the college-level classes that developmental students are most likely to take makes *Mathematical Literacy* more relevant to students than traditionally taught classes. Because the students can complete remediation in a single semester, students can experience a reduction in the amount of time spent in developmental mathematics. Further, the emphasis on the use of group work challenges students to engage in mathematics as a social rather than individual endeavor. These decisions have the

potential to impact students, both in terms of traditional outcomes, such as student persistence, and in how they see themselves as doers of mathematics.

Guiding Questions

Mathematical Literacy, through its focus on real-world problems and use of group work, has the potential to engage students in a relevant and mathematically rich curriculum. However, lessons from reform-oriented implementations in K-12 mathematics classrooms demonstrate that teachers often struggle to enact the reforms to the degree intended (e.g., Cohen, 1990; Drake & Sherin, 2006; Heaton, 2000). Even if enacted as intended, the differences between the developmental population and K-12 students raises questions about what an enactment of reform-oriented developmental mathematics will look like and how it may impact students.

Many of the students who require developmental mathematics have had weak mathematical preparation (Bahr, 2010a) and many, perhaps as a result of the poor quality of their preparation, have high anxiety towards mathematics (Sprute & Beilock, 2016) and low self-efficacy (Hall & Ponton, 2005). Towards this end, it becomes important to investigate student persistence and affective outcomes associated with the class in addition to the experiences of students in the enactment. Towards this end, I ask:

1. What does *Mathematical Literacy* look like in practice?
 - a. What are the various components of *Mathematical Literacy*, and how does the instructor allocate time to these components during instruction?
 - b. Given *Mathematical Literacy's* emphasis on group problem solving, how do student groups move through the assigned problems in a typical class period, and what are their patterns of interaction with each other and the instructor as they work?

2. Who persists in *Mathematical Literacy* and what are the effects, if any, of the course on students' affective outcomes?
3. Do students experience *Mathematical Literacy* as intended?
 - a. How do perspectives on specific aspects of the course differ among students who have a positive, neutral, or negative reaction to the course?
 - b. How do students' experiences with the course compare with the intentions of the course instructor/developer?

As the first part of this chapter highlights, the need for an examination of developmental mathematics from a mathematics education lens is sorely needed. The two chapters that follow represent related, but different, lenses on the curriculum and instruction of a developmental mathematics class taught using novel methods. The majority of this project will focus on elements of the three states of the enacted curriculum (Stein et al., 1996), describing what a reform-oriented developmental class looks like and some of the student outcomes from the enactment. The students' experiences of the enactment are contrasted with the instructor's intended curriculum goals for the class.

Chapter 3 addresses the first and second research questions, which focus on examining the classroom from more of a bird's-eye perspective. In particular, the chapter examines the intentions and enactment of the curriculum at the classroom level, demonstrating the prevalence of various curriculum elements and how the instructor and student groups move through the curriculum. This chapter closes with an examination of students' affective and persistence outcomes, demonstrating that although many students persist in *Mathematical Literacy*, some students experience more success than others, warranting a closer examination of student experiences to understand divergent outcomes.

Chapter 4, in answering the third research question, builds on the work of Chapter 3 by providing a more personal look at how individual students experience *Mathematical Literacy*. This chapter contrasts the instructor's intentions with respect to the course with student perspectives on the class, organized by whether the students had a positive, neutral, or negative experience. This classification of student experiences allows for convergent and divergent patterns of student perspectives to emerge.

Within Chapters 3 and 4, I present the sample, data sources, and methods used to obtain the results for each chapter. This structure, although less traditional for a dissertation, allows for a clear link between the methods and results for each research question. These chapters also contain short discussions highlighting the main findings of the work presented, with a larger discussion covering the broader implications of the findings of this dissertation presented in Chapter 5.

CHAPTER 3:

PROBLEM SOLVING AND GROUP WORK IN A COMMUNITY COLLEGE CLASSROOM: ENACTING A NEW FORM OF DEVELOPMENTAL MATHEMATICS INSTRUCTION

The students, teacher, curriculum used, and the instructional strategies employed all contribute to the lived experience of the mathematics classroom. Stein, Grover, and Henningsen (1996) suggest that within a classroom, the enacted curriculum has three distinct phases: the *written task*, such as the problems published in the texts used in the class, the *task as set up by the instructor*, relating to how the instructor introduces and frames the work of the day, and the *task as implemented*, represented by what the students and teachers actually use from the task and how they engage with it. Learning, the product of these stages of curriculum, represents what students retain from the task and its implementation.

At the K-12 level, where problem-solving and group-work-based instructional methods have been widely studied, some researchers have examined the link between the intended and enacted curriculum of reform-oriented instruction. These studies have shown that teachers, although willing to work towards decentralizing their role, can struggle to actually do so to the degree intended by mathematics education reformers (e.g., Cohen, 1990; Drake & Sherin, 2006; Heaton, 2000). As argued in Chapter 2, the developmental population poses unique challenges to instruction, raising questions about whether *Mathematical Literacy* instructors and students can effectively adapt to the new mode of teaching, especially given that they are faced with the task of covering, in 16 weeks, the same material high schools often cover in a year or more. The pressure to cover content and the difficulties of pushing students towards the unfamiliar both mathematically and instructionally might mean that the enacted instruction falls short of intentions, particularly in terms of decentralizing the instructor's role. Even if the teacher

achieves decentralization, the students may choose not to work together or otherwise resist the instructional choices made.

More broadly, developmental students generally have lower mathematics self-efficacy (Hall & Ponton, 2005) and higher anxiety in mathematics (Sprute & Beilock, 2016) than other college students, so a shift in the instruction of mathematics may impact them in unintended ways. As such, it becomes important to understand student affective outcomes in the class, which go beyond their successful completion of the course.

This chapter examines the intended and enacted curriculum of *Mathematical Literacy*, focusing on the enactment of the curriculum materials at the classroom and group levels. I then examine persistence and affective outcomes associated with the class to help understand how the enactment impacts the developmental population. These questions draw from the first and second research questions of this dissertation:

1. What does *Mathematical Literacy* look like in practice?
 - a. What are the various components of *Mathematical Literacy*, and how does the instructor allocate time to these components during instruction?
 - b. Given *Mathematical Literacy's* emphasis on group problem solving, how do student groups move through the assigned problems in a typical class period, and what are their patterns of interaction with each other and the instructor as they work?
2. Who persists² in *Mathematical Literacy* and what are the effects, if any, of the course on students' affective outcomes?

² Examining the characteristics of persistent students is problematic in the sense that such studies can open the door to discussions about whether students with attributes correlating with lack of persistence inherently do not have what it takes to succeed. My intent in examining persistent

Methods

All the data for this study come from FCC, which implemented a *Mathematical Literacy* curriculum over the 2014-2015 school year. The majority of the data were collected in the spring of 2015 in a single-focus classroom taught by an instructor who had participated in the course development at FCC. Data were also collected from six other *Mathematical Literacy* classrooms at FCC during the same academic year.

Sample

The focus classroom started with 24 students, which adjusted to 22 students (6 men and 16 women) within the first week of the semester due to student schedule changes. Of those, 14 were White, 6 were Black, 2 were from Asian backgrounds, and 1 was Hispanic. Nineteen of the 22 students agreed to be audio recorded in their groups. Groups shifted throughout the semester, and to record a group, everyone in the group needed to assent, so at most 14 students were in audio-recorded groups during any given observation period.

In addition, 131 *Mathematical Literacy* students from seven course sections, including the observed classroom, took a survey at the beginning of the semester. At the end of the semester, the students still pursuing the course and present on the day of the researcher's visit were surveyed a second time³ resulting in 82 completed post-surveys.

students is rather to help identify and understand those who *Mathematical Literacy* does not reach. Doing so allows future studies to focus on questions that examine the classroom experiences of students who are less likely to be persistent, so future iterations of the class can better empower such students and provide more access to the content.

³ One additional section of *Mathematical Literacy* was surveyed in Fall 2014, but due to a scheduling conflict I was unable to administer the post-survey. These data are omitted from the analysis throughout this chapter.

Data Collection

To answer the first research question, I draw on field notes and classroom audio from the focus classroom, collected during classroom observations. I also draw briefly from an interview with the author of the textbook to describe the intended implementation of the materials. To answer the second, I draw from student surveys given to seven sections of *Mathematical Literacy*. Appendix A contains the complete survey instruments and post-observation protocol.

Classroom observations. For this chapter, I focus on the observation and audio data from a single classroom. I observed this focus classroom for four weeks with an eye towards choosing weeks that (a) collectively spanned the entire semester, (b) included two weeks in each half of the semester, and (c) the instructor identified as “typical” of the curriculum. This resulted in the first, seventh, thirteenth and fifteenth weeks being observed. Class met three times a week for 110 minutes. During all but one observation day, I was present the entire class period.⁴

On observation days, I collected three forms of data. First, the instructor was audio recorded using a microphone. Recording started when she entered the classroom and ended after the last student left.⁵ Second, student groups were audio recorded using table microphones. Recording started when the class transitioned to small-group work and generally stopped after the groups were gone, although occasionally the students ended recording after completing their work for the day. Third, during observations, I took field notes about the climate of the room, the location of the instructor, and the behaviors of targeted groups and individuals using software

⁴ On the third day of the first week I surveyed another section of *Mathematical Literacy* during the observation time and was therefore out of the observation classroom for approximately 20 minutes. Audio recording took place as normal in the observation classroom.

⁵ On one day during the third week of observations the instructor’s audio recorder failed approximately 80 minutes into the lesson. The majority of her audio past this point could be reconstructed from the recordings of her visits with individually recorded groups.

designed to take timestamped location data and notes. I started taking fields notes before class started and ended when students were dismissed. Additional notes were written up following the lesson using the post-observation protocol.

Surveys. A pre- and post-survey were given the first and last weeks of the semester. Conversations with *Mathematical Literacy* instructors at FCC indicated that although they used the same assessments and materials, they had different philosophies towards lecture, pacing, and the grouping of students. This suggests that instructor effects should be accounted for within an examination of student change. Thus, I administered the survey to seven sections of *Mathematical Literacy* at FCC, taught by multiple instructors, to minimize bias introduced by any single instructor's implementation.

The surveys contained affective scales and individual items designed to measure student attitudes towards mathematics, their views on the nature of mathematics, learning preferences, the preponderance of group work, and their general opinions about the class.

To measure change in attitudes towards mathematics I used the Attitudes Toward Mathematics Inventory (ATMI; Tapia & Marsh, 1996) on both the pre- and post-survey. The ATMI measures attitudes towards mathematics along four dimensions: self-confidence, enjoyment, motivation, and value. The original instrument alpha coefficients for these factors are .95, .88, .89, and .86, respectively (Tapia & Marsh, 1996), and the self-confidence scale includes items related to both mathematics anxiety and self-efficacy. Table 3.1 contains example items from the scales.⁶ Although originally designed to measure the attitudes of middle and high

⁶ The items of some of the scales, although loading on four distinct factors during the confirmatory factor analysis, still appeared to contain elements that overlap. To gain a sense of the overlap of the different attitude scales for my sample, I ran pairwise correlations between the four scales. In general, correlations were moderately strong ($<.65$), but the correlation between motivation and enjoyment was high (.86). These scales were not run together in any models, and

school students, the four factors of the ATMI were verified to hold for college students (Tapia, 2002).

Table 3.1

Example Items Used on Surveys

Construct	Example items
<i>ATMI</i>	
Self-confidence (15 items)	1. Mathematics is one of my most dreaded subjects. (R) 8. Mathematics does not scare me at all.
Enjoyment (8 items)	1. I get a great deal of satisfaction out of solving a mathematics problem. 6. Mathematics is a very interesting subject.
Motivation (9 items)	5. I am willing to take more than the required amount of mathematics. 6. I plan to take as much mathematics as I can during my education.
Value (8 items)	5. Mathematics is one of the most important subjects for people to study. 7. I can think of many ways that I use math outside of school.
<i>Single items</i>	
Nature of mathematics ^a	1. Learning mathematics is mostly memorizing facts. 2. There is only one way to solve a mathematics problem. 3. The math I learn in school rarely helps me when I use math in my daily life.
Learning preferences ^b	1. I enjoy working in small groups in math class. 2. I learn mathematics best when I get to work in a group. 3. I learn mathematics best when I work by myself.

^aOccurred on pre- and post-survey. The first two were taken from the National Assessment of Educational Progress. The last was researcher written.

^bOccurred on both the pre- and post-survey. These were researcher written.

For the community college population, I slightly modified the ATMI to include the instructions at the top of the survey and adjusted individual items to reflect the classroom context. For example, I changed item 7 from “High school mathematics courses would be very

so this high correlation does not dilute regression results reported here. Appendix C reports the full pairwise correlation matrix.

helpful no matter what I decide to study” to “This mathematics course will be very helpful no matter what I decide to study.” Students answered items using a 5-point Likert scale.

The pre- and post-surveys also included single 5-point Likert scale items. Six items related to the nature of mathematics and students’ learning preferences were included on both the pre- and post-survey. Table 3.1 includes these items and their sources. In addition to the Likert scale items, both surveys contained free response or multiple-choice items asking about students’ mathematics backgrounds (pre-survey), demographics (pre-survey), educational plans (pre-survey), and their expected grades (post-survey).

Analysis

To answer the first research question, which relates to the intended and enacted curriculum at the classroom level, I draw on field notes and both instructor and student audio from a single class. To address the second research question, which examines persistence and affective outcomes, I conduct a statistical analysis using survey results from multiple sections of *Mathematical Literacy*. I discuss the methods of analysis for each question in more detail in this section.

The intended and enacted curriculum in a *Mathematical Literacy* classroom. The first research question of this chapter examines the intended curriculum elements of *Mathematical Literacy* and how these are enacted at the classroom level. The curriculum of *Mathematical Literacy* was written to teach students using real-world contexts with the instructor in a decentralized role, mirroring the K-12 mathematics educational reforms of past decades (NCTM, 1989, 2000). Although the implementation of these reforms can take many different forms, NCTM has argued for the importance of teachers facilitating class discussion of important mathematical ideas (NCTM, 1989, 2000, 2007, 2014).

One popular lesson model, advocated by the NSF-funded *Connected Mathematics Project* and *Core Plus* curricula, involves the teacher “launching” a problem, students working on the problem in small groups, and then the teacher engaging the whole class in a discussion of the intended mathematical ideas (e.g., Lampert, 1990; Lubienski, 2000; Tarr, Grouws, Chávez, & Soria, 2013). Van DeWalle, Karp, and Bay-Williams (2013), in their commonly used mathematics pedagogy textbook, formalize this Three-Phase Lesson format by discussing expectations of the teacher and students (See Table 3.2). This “Before, During and After” model offers one concrete framework for translating reform-based instructional ideals, inspired by NCTM, into the classroom. As such, it offers a useful framework for examining reform-oriented lessons.

Table 3.2

Teacher and Student Roles in Three-Phase Lessons

Lesson Phase	Expected Actions
Before	• Activate student knowledge that will be relevant to the task of the day • Motivate the problem • Set learning expectations and help students fully understand the task
During	• Walk around, let students engage in productive struggle • Monitor student progress • Provide support to students as appropriate, without removing opportunities for learning
After	• Bring class together and orchestrate classroom-level discourse about mathematical issues and ideas raised • Listen to student ideas without evaluation • Summarize the main mathematical ideas

Note. Adapted from Van DeWalle et al.’s (2013) discussion of the Three-Phase Lesson format.

In this model, each phase of the lesson serves a particular purpose, with the instructor’s and students’ roles changing between phases. In the first stage of the lesson (*Before*), the instructor introduces the topic for the day, helping students activate ideas or prior learning that

will facilitate the problem solving they will do that day. This phase also usually includes the instructor motivating the content, making sure students understand the problem(s), and setting expectations for the work. In the *During* phase, the instructor lets the students work freely, paying attention to student thinking about the problems and providing help as needed. In the *After* phase, the instructor pulls the class together and engages students in a discussion about the important ideas of the lesson. This Before-During-After framework is used to classify the different stages of the lessons observed in this study.

Many have documented the difficulty of orchestrating such reform-oriented instruction to the degree intended (e.g., Cohen, 1990; Drake & Sherin, 2006; Heaton, 2000). As discussed in Chapter 2, classroom discourse, which is central to the *After* phase of the lesson, has been an area of intense study in previous mathematics education research. The intention of this last phase is for the instructor to support the students, at the classroom level, to come to a shared understanding of the intended mathematical ideas. As part of this, we might expect the instructor to address common misconceptions and to contrast different problem solutions using information gathered and work generated by students in the *During* phase of the lesson. In this phase, the instructor also usually engages in active listening without evaluating ideas, helping students critically consider their peers' ideas and to ultimately summarize the big ideas of the lesson.

Using an analytic lens informed by the Before-During-After framework, I examine the observed *Mathematical Literacy* classroom using two different descriptive representations of the classroom, drawing from multiple data sources. To generate these representations, I use:

1. Field notes and audio recordings of a single classroom to identify the elements of the written tasks and typical enactment of these elements. With these I create a verbal description of the class, supplemented by descriptive statistics on classroom activities.

2. Audio recordings of the students in their groups in a single classroom to:
 - a. Provide descriptive statistics on participation patterns and the time students spend working on different parts of the curriculum.
 - b. Present visual representations created from coded and timestamped transcripts of the classroom to show curriculum enactment within student groups and instructor movement throughout the room.

In the following two sections, I explain the details of the translation of these data sources into the different classroom representations.

Curriculum elements and their enactment at the classroom level. To create a description of a typical *Mathematical Literacy* classroom, I drew from both my field notes and instructor audio recordings. The field notes were used to create an outline of the typical day with typical class activities (e.g., quiz, group work, Lecture about technology assignment). To enrich and validate the outline, I used the instructor audio. As noted earlier, I audio recorded the instructor from the time she entered the classroom until after the last student left. Using the list of regular class activities built from the observation notes, I partitioned the instructor audio using time-stamps. A new partition started when the class activity in which the instructor and class was engaged changed. Activities that were captured in these partitions included: beginning of class, quiz, quiz review, lecture (topic documented), group work time, and other. These data were used to compute the average time spent on typical class activities.

The observation data and instructor audio were combined to create a description of a typical day in the observed *Mathematical Literacy* classroom. This description primarily serves as an opportunity to introduce the curriculum to the reader and provide a general outline of the curriculum elements and the enactment of those elements during a typical day.

Curriculum elements enacted at the group level. To supplement the descriptive picture of the intended and enacted curriculum, I used the student audio to create quantitatively generated diagrams of the classroom that documents both how student groups moved through the curriculum and how the instructor moved through the classroom in a single graphic. An example of these diagrams occurs in Figure 3.4 in the results section (page 70).

To create these diagrams, I first transcribed all group audio for selected days in full, identifying individual speakers. Turns were time-stamped and started when a new person started talking or if there was an extended gap in students' conversation.⁷ Transcripts were further coded in two ways:

1. Whether the instructor was present for each speaker turn.
2. The activity of the students in their groups.

I validated the instructor presence using the instructor audio recording. Exchanges related to group activity could be as little as two turns. Generally, discussion related to a group activity contained multiple turns among individuals. Coding of the group activity occurred at the group level, with isolated comments included in the dominant activity code (e.g., if a student greeted a non-table student while the rest of her group worked on a problem, and no other conversation took place related to the greeting, the greeting was coded as the problem the rest of the group was completing). This decision reflects the fact that I am interested in group behavior, not individual. There is no reason to expect this choice biases the results one way or the other: situations where a student tried to get their group on-task with isolated comments while everyone else gossiped also occurred. At times, separate conversations clearly occurred simultaneously. In

⁷ Generally, a long gap was identified as more than 10 seconds, but was partially group dependent as some groups had longer intervals between speaker turns than others.

such instances, each turn was coded separately for the topic, and an indicator identifying that two conversations were occurring was added to the transcript.

Group activities were assigned one of four categories:

1. Problems from the workbook, coded at the problem level.
2. Homework assignments, coded at the assignment level.
3. Class-related activities not directly related to a graded assignment (e.g., helping other groups, planning).
4. Off-task talk.

Table 3.3 contains examples and elaborations of these categories. When a student visited a recorded group, and the non-group student provided help, the problem number they were working on was coded, just as it would have been if the non-group student were not there. When the recorded group helped a non-group student with a problem, the code assigned was “Helping Other Groups.”

Note that the Planning and Other Class-Related Talk code includes both times when students discussed their plans for completing assignments and discussions related to mathematical *issues* not tied to assigned work. For example, on one day a student named Dave engaged in a conversation with the instructor about whether it was possible to do something that did not require mathematics. This instance and others like it were coded as Planning and Other Class-Related Talk because the discussion relates to the curricular goal of helping students see the utility of mathematics. Discussions not directly related to group activities or mathematics were coded as off-task. A typical instance of this occurred with a problem related to finding the cheaper of two pre-paid cell phone plans under different conditions. While working on this problem, it was common for students to discuss their own cell phone plans for a few moments.

Such conversational diversions, although rooted in a mathematics problem, were coded as off-task because the focus of their talk was not about mathematical issues or a group activity.

Table 3.3

Group Activity Sub-codes

Code	Description	Example	
Problem From Workbook	Students work towards a solution on a problem from the workbook. These were coded at the individual problem level.	<i>Henry:</i> <i>Jen:</i> <i>Henry:</i> <i>Gabby:</i> <i>Henry:</i> <i>Jen:</i> <i>Henry:</i> <i>Jen:</i> <i>Henry:</i>	So it would be 360 feet for the yards. Yeah. And that's going to be 160 feet. The 120 yards? Yeah, and then the other one is already in feet, so we are good on that. And then mower is -- 30 divide by 12; two and a half feet. 2.5 feet. And then the four miles is -- 23,280 feet. Damn. (150223, Group C, 247-255, 2-7 Group Problem 2)
Homework Assignment	Students work on one of the two group homework assignments. These are coded at the assignment level (review or project).	<i>Henry:</i> <i>Jen:</i> <i>Henry:</i> <i>Jen:</i>	"Write a sentence or two using the terms independent and dependent to describe the relationship between the miles flown and the gas remaining." The dependent changes based on the independent, so the dependent is miles flown and the independent is gallons of fuel. The dependent changes, what? Based on the independent. (150225, Group C, 580-583, Review assignment)
Helping Other Groups	When students from other groups visited the recorded table and engaged in discussion with one or more group members about a problem the table had already solved.	<i>Non-table student:</i> <i>Carrie:</i> <i>Non-table student:</i> <i>Carrie:</i> <i>Non-table student:</i> <i>Carrie:</i>	All right, and then so if you drive more than 1.5 miles-- do I have to write all that down? Yes, because they're asking for each side. For here? No. For the next part. If you— --drive more than 1.5 miles, the inequality is true. (150227, Group B, 517-522)

Table 3.3 (cont.)

Code	Description	Example	
Planning and Other Class-Related Talk	Negotiations about which assignment they should work on, group roles, times they could meet outside of class, check-ins to see if anyone needed help, organization talk as they transition to a new assignment, or discussions about mathematics not directly related to their work for the day. Classroom related discussions not related to completing the workbook problems or group homework assignments.	<i>Craig:</i> <i>Helen:</i> <i>Craig:</i> <i>Helen:</i> <i>Carley:</i> <i>Craig:</i> <i>Fiona:</i> <i>Craig:</i>	Yes. That's the shit. Who's is this? I took two. I'm copying it. You got one? Everyone has one. Did you get one? There has to be one to turn in. Yeah. Did you get one, Fiona? No, I did not. Not yet. Because I took two. (150225, Group D, 731-738)
Off-task	Students talking about non-mathematical issues that did not directly contribute to their classroom assignments or the nature of mathematics.	<i>Dave:</i> <i>Sarah:</i> <i>Dave:</i> <i>Sarah:</i>	Where's the farthest you've ever been? Well, I've travelled. The farthest I've ever been is England. England? [inaudible] People to People? No. I went with my church when I was growing up. I went to Wales when I was 14 and England when I was 17. (150225, Group A, 629-632)

Computation of times. After the coding was completed, I computed the total time spent on each activity within groups using time-stamps to find the length of each turn and then adding turn times for each activity together. Sometimes turns ended with a lengthy break in all group speech. My method of time calculation assumes that the group activity during these periods of silence remained the same until the next utterance. Although this may not always be accurate, there is no reason to expect the method is biased in favor of any particular activity, likely making the slight error negligible.

Group- and classroom-level diagrams. Diagrams of the classroom-level enactment of the various classroom activities were created from time-stamped and coded transcripts. All diagrams plot time against classroom or group activities and use colored regions to indicate different classroom-level activities (e.g., group work time, lecture). Group-level diagrams have two additional layers of information:

1. The y-axis lists the curriculum-level activities described in Table 3.3. The ordering of these activities mirror the general structure of the curriculum in ascending order, with on-task activities lower and off-task group activities higher in the diagram.
2. Markers in the diagrams are linked to individuals to keep track of people through time as they move between group activities.

Markers indicate the start time of an individual's speaking turn, corresponding to the curriculum activity of the group at that time. Each color represents a unique speaker, allowing the reader to immediately see how individuals contributed to the discussion of each problem.

To help visualize the whole class, showing both group and instructor patterns, I created diagrams that included multiple groups on a single plot (see Figure 3.5 on page 80 below for an

example). To minimize the overall complexity, three main modifications were made from the group-level diagrams:

1. Markers no longer correspond to different individuals. Instead, individuals within the same group are assigned the same color. This modification allows the patterns of the group's progress to be observed without the complexity of keeping track of approximately 15 individuals in a single diagram.
2. The instructor is tracked by her presence at the table, rather than by her individual contributions, using a larger, black marker throughout the diagram regardless of which group she visited or who was talking. This adaptation allows visualization of how the instructor moves between groups while maintaining continuity in the presentation of group problem solving behavior.
3. Problem numbers are not explicitly labeled in the diagrams. Items are ordered the same way as the group-level diagrams, with off-task utterances being the highest row for each group. To separate on- and off-task utterances, a dashed line cuts through the region for each group represented on the diagram. This modification allows the reader to keep track of on- and off-task utterances within each group without cluttering the y-axis.

The diagrams I present are in some ways similar to the Chronologically Ordered Representations of Discourse and Features Used (CORDFU) diagrams that Luckin (2003) proposed and Hmelo-Silver, Jordan, Liu, and Chernobilsky (2011) argue should be more frequently used in studies of collaboration. Like my diagrams, CORDFU diagrams use time as an organizing dimension to help display the distribution of events in a learning environment and do so with individual markers. However, despite being proposed as an analytic framework for over ten years with several calls to use them, the number of individuals using CORDFU diagrams to

help guide textual analysis remains small.⁸ My diagrams improve on CORDFU diagrams by using color strategically to separate individuals from each other, organizing the y-axis strategically, and clumping individuals around group activities to allow easy comparison of individuals.

Survey Data. To address the second research question about the affective and persistence outcomes for students in *Mathematical Literacy*, I examine the pre- and post-survey data for:

1. Differences on attitude scales between those who persist through *Mathematical Literacy* and those who did not.
2. Relationships between attitude changes towards mathematics and both demographic and background information.

I also conduct a pre-post analysis of individual items asking about classroom structures, the nature of mathematics, and learning preferences.

To determine who persists in *Mathematical Literacy* I compared the descriptive statistics of students who took only the pre-survey with those who took both the pre- and post-survey (for brevity, I call this second group the persistent sample).⁹ To compare the demographics of the

⁸ This may be because, although CORDFU diagrams, as proposed, offer an opportunity to visually identify patterns, individual speakers are separated from the codes associated with their utterances. For example, in a simple system with two individuals engaged in paired problem solving, a researcher might keep track of when questions are asked and which individual is speaking. This simple coding of the transcript would result in three codes: Speaker 1, Speaker 2, and Question. The CORDFU diagram, then, for this scenario, would be a scatterplot with time on the x-axis and the three codes as separate lines on the y-axis (imagine three rows of dots: one for when Speaker 1 talks, one for when Speaker 2 talks, and one for when a question is asked). This results in codes for a dialogue element of interest separated from the individual speaking. These constraints are partially imposed by the fact that Excel is the recommended program for constructing CORDFU diagrams. The diagrams I created used Stata, a statistical program known for having flexible and complex graphing capabilities. See the Appendix C for an annotated discussion of the Stata syntax created to generate these diagrams.

⁹ Comparing these two samples assumes some relationship between presence in class during the post-survey and persistence. Some differences between the post-survey sample and the true

pre-survey-only sample to the persistent sample, I used Fisher's exact test, which assumes the persistence rate should be the same for each sub-sample, regardless of their demographic categories and is appropriate for samples where the expected cell size is less than five.

Prior to the main analysis using the ATMI scales, I explored the attitude scales (confidence, enjoyment, motivation, and value) for missing data, skew, and fit. A full report on the fit statistics for the four scales for both the pre- and post-survey attitude data is included in Appendix B. Although Cronbach's alpha for the four scales was very high for the original scales with the pre-survey sample that had complete data on each scale (.95, .88, .87, and .83 respectively), fit statistics suggested a confirmatory factor analysis (CFA) was needed.¹⁰

The sample also contained item-level missing data on the ATMI for approximately 25% of the individuals, impacting the sample size for the different attitude scales. To determine whether values could be imputed, I ran detailed summary statistics on the distribution of each attitude scale and found the distributions for all four pre-survey scales to be fairly symmetrical and close to normal for the students with no missing data. As such, I imputed values for students with at most one missing value on each scale using means. Appendix B contains the details of CFA and other scale analyses.

Using the ATMI scales and single item pre-post measures, I performed paired sample *t*-tests to determine if students changed their attitudes towards mathematics over the 16-week

persistent population may exist due to student absence, but informal conversations with the instructors and my own observations suggest this bias is small. Due to limitations of the study design, I do not have additional success data for the class. However, on the post-survey, the students indicated their expected grade for the course, and all students taking the post-survey said they expected to pass.

¹⁰ All analyses were run using both the CFA and original scales. Results for the original scales are included in Appendix B.

class. I also used independent sample *t*-tests to look for possible attitude differences between the persistent sample and those who only took the pre-survey.

To examine the relationship between the changes in attitudes and students' background characteristics, I performed two-level Hierarchical Linear Modeling (HLM) in Stata/SE 14 using instructors as a level-two variable and students as level one. Some instructors taught multiple sections. I clustered on instructors because instructor interviews indicated that they might have varied in their level of implementation of the intended *Mathematical Literacy* elements. Only those with complete data for all the included outcome and covariate variables were included ($n=63$).¹¹ For the HLM models, maximum likelihood estimation was used, with independent residuals. Four models were run: one for each of the four attitudes with the post-survey attitude score serving as the dependent outcome variable, which allows for measuring which factors predict post-survey scores. Independent variables were students' pre-survey attitude score for the outcome attitude variable, gender, race, age, anticipated course grade, whether they had taken prior developmental mathematics, and the highest degree they intended to earn.¹²

Results

To answer the first research question about the intended and enacted curriculum at the classroom level, I start with a brief discussion of the implemented text and a verbal description of a typical class. This description includes excerpts of the written curriculum and audio

¹¹ Data were collected in two waves with slightly different versions of the surveys given, which means race data was not collected in Fall 2014. A full discussion of the samples and ways the surveys varied between the two waves is included in Appendix B.

¹² Appendix B includes details about the data sources, coding, and variable entry into the final models for the independent variables.

transcripts from a single day¹³ to illustrate typical exchanges related to the class activities. I next present group- and classroom-level diagrams that represent the classroom visually while presenting information about how student groups worked through the curriculum and how the instructor moved through the classroom. The verbal, quantitative, and visual representations are then analyzed in terms of the Before-During-After format for problem-centered lessons. The last set of results examines questions about the persistence and attitudinal changes for students who took the course using survey results from multiple sections of the class.

A Brief Note on the Curriculum

The text for this course (Sobecki & Mercer, 2015) came packaged as a workbook: pages were loose leaf with space after each problem for students to complete the tasks. Although a fair amount of commentary surrounded the various problems, it was generally motivating the topic or directing students to think about connections among problems. The text provided few “model problems” the students could examine for hints or problem-solving ideas. There were four units in the text, each expected to take four weeks to complete, covering a range of algebraic and data analytic topics including discussions related to the fundamentals of probability and statistics, compound interest, and exponential growth and decay. Units were partitioned into *lessons*, which were usually six to ten pages. In the observed classroom, the switch to a new unit was marked by a summative exam and rotation of the groups.

The text was designed to facilitate group work. In the first lesson of each four-week unit, the text included space and a prompt suggesting that the students collect the contact information of their group (Sobecki & Mercer, 2015, pp. 7, 87, 170, 233). In an interview with one of the

¹³ This day took place during the seventh week of instruction, at which point classroom norms were fairly well established. Students had been in their current group for just over two weeks at the time of recording.

authors of the text, he linked using the text to having students working in groups for the majority of the class time, noting that instructors using the text in a *Mathematical Literacy* context needed to “be willing to let go of a certain amount of control and be willing to be flexible and adaptable and ready to take things one way or take things another way depending on how the group conversation goes.”

The text was also heavily focused on real-world problems. A brief examination of the problems revealed that almost all of them were presented as word problems, with most rooted in real-world contexts.¹⁴ Specifically, approximately 85% of the surveyed problems were framed within an everyday application. In addition, over 20% of the surveyed problems required students to collect or use data from articles or reports. An example of a unit organizing index is included in Appendix D.

A Typical Class

The instructor, Ms. Ann, generally entered the classroom right as the period started and spent a few minutes circulating the room, talking to students, setting up the computer, and returning assignments. Most students used this beginning of class time to talk to each other, look at their phone, or organize their materials. The curriculum for the course was packaged as a workbook in a binder, so a handful of students used the time to start work on the section they anticipated they would cover that day.

After finishing her check-ins, Ms. Ann asked students to put away any work so they could take their “homework check”; a one- to two-problem, individually graded quiz. Homework

¹⁴ Using a random sample of 33 of the 279 NOUN (problems?) (13.8%) the workbook pages related to mathematical problem solving (I don’t follow). Other pages in the text helped organize units and were omitted from the random sampling. On each selected page, I coded problems for their use of data and real world contexts. See Appendix E for a full description of this work.

check problems usually mirrored those completed during the previous class period. These assessments went quickly: for the 12 days I observed, the longest quiz lasted just shy of ten minutes. After collecting the quizzes, Ms. Ann usually gave a solution for the problems, noting common errors and strategies that she had seen while picking up their work. These were not interactive sessions. Instead, she usually covered the problem quickly, answering students' questions at the end of her explanation. For example, on one such day, for the first part of a two-part problem, she said:

So for (a), how fast am I usually driving on average? Well 15 miles in 20 minutes. And then some of you were doing some creative things with scaling down and up to figure out, like, multiplying that up by three to get to 60 minutes. I saw some interesting things like that. The other way you can do it is to say 60 minutes in an hour and kind of do it like a conversion. And so 15 times 60 divided by 20, for that drive, I'm going about 45 miles per hour, average. Faster on the country roads, slower in town. But it averages about 45 miles per hour.

On that day, as on most of the others observed, Ms. Ann then transitioned into the day's lesson, introducing the topic, making note of things she wanted the students to be attentive to while working, and linking ideas to previously discussed topics. On the same day as above, for example, she opened by commenting "The theme of the day is making decisions." She then went on to introduce an article they had been asked to read prior to class. The article had been published by a rental car company that argued, using data, that renting a car for road trips was cheaper than taking a personal vehicle. She described the purpose of part of their work that day as "analyzing whether [the article's authors] were completely accurate in their interpretation of the information." On all days, including the one with the car rental article, in addition to

introducing the topic of the day, Ms. Ann used her brief lecture to give hints or indicate which problems and ideas she thought might prove difficult. These lectures were short, averaging approximately two minutes.

About 20 minutes into the class session, Ms. Ann opened the class up for group work. Groups typically started working quickly. Lessons from the textbook usually took a single class period to cover and contained both individual and group problems. However, some groups did everything together while others worked quietly for a while before engaging in more regular conversations about the material. Each section had three types of assignments: Group Problems, Applications, and Reflections. Group Problems were completed first and were intended to prepare students to work on the similar, but harder Applications. Reflection questions usually asked students to summarize and reflect on important ideas from the section. Reflections and Applications were collected during the following class period for group grading, while Group Problems received individual completion grades. Each section had additional individual homework assignments (Technology, Connect) that were due electronically by the beginning of the next class period. Example Group Problems, Applications, and Reflection problems for the rental car lesson are included in Figures 3.1, 3.2, and 3.3 respectively.

Next, the article claims that the deal becomes even better if the customer pays an additional \$10 per day fee for unlimited miles, rather than being limited to the 300 mile max. Factoring in that \$10 per day charge, plus 15% in extra fees, the total cost for the 3-day weekend rental in a full-sized car is \$103.47. Add the \$0.39 per mile you still pay in spite of not using your own car, and we can find a formula with input the number of miles (m) and output the total cost of renting (C).

6. Write the formula for the total cost of renting a full-sized car when the unlimited mileage charge is added.

7. At \$0.63 per mile, the cost of driving your own car for m miles remains _____ dollars.

Distance driven (mi)	Full-size rental: Total cost	Driving own car: Total cost	Full-size rental: Average cost per mile	Driving own car: Average cost per mile
0	\$103.47	\$0.00	N/A	N/A
100				
200				
300				
400				
500				
600				
700				

8. Find all the total costs and write them in the table using the table feature on a graphing calculator.

9. Is there a number of miles for which the total costs for renting and driving your own car are the same? If so, find the number of miles. You'll have to experiment with some settings on your calculator.

10. Based on your answer to Question 9, explain when it would be cheaper to drive your own car, and when it would be cheaper to rent a full-sized car.

Figure 3.1. Example Group Problem from Workbook (Sobecki & Mercer, 2015, p. 149).

The two tables below display the charges for two taxi services based on the number of miles driven. Yellowish Taxi has an initial charge of \$2.30 plus \$0.15 for each quarter mile; Calloway Cab has an initial charge of \$2.00 plus \$0.20 for each quarter mile.

Yellowish Taxi		Calloway Cab	
Distance (mi)	Cost (\$)	Distance (mi)	Cost (\$)
0.0		0.0	
0.5		0.5	
1.0		1.0	
1.5		1.5	
2.0		2.0	
2.5		2.5	
3.0		3.0	

6. The cost to ride with Yellowish Taxi for m miles is _____ dollars.

7. The cost to ride with Calloway Cab for m miles is _____ dollars.

8. Use your answers to Questions 6 and 7 to fill in the table.

9. When would the two cabs cost the same?

10. When would you choose Yellowish Taxi? When would you choose Calloway Cab?

Figure 3.2. Example Application Problem from Workbook (Sobecki & Mercer, 2015, p. 152).

Reflections

Type a short answer to each question.

1. ☐ Why did you choose the life decisions you did in Question 2 of the class activity?
2. ☐ How does the work we did in analyzing the rental car article connect to making decisions in your life? What do you think the point of this lesson is?
3. ☐ Take another look at your answer to Question 0 at the beginning of this lesson. Would you change your answer now that you've completed the lesson? How would you summarize the topic of this lesson now?
4. ☐ What questions do you have about this lesson?

Figure 3.3. Example Reflections Prompts from Workbook (Sobecki & Mercer, 2015, p. 151).

As was typical, from the time that Ms. Ann opened the class up for group work through the end of the class period, students spent most of the remaining time working in their groups. During the rental car lesson, she ended her introductory lecture with the comment “I’ll walk around and see how you’re doing it. I’m going to let you work with that from there.”

During the group work time, Ms. Ann walked around the room, checking in with each group, examining their work and progress. She spoke with each group regularly throughout the time, offering hints, VERB additional ways of thinking about the problems, and summarizing the purpose of some of the problems or lessons. For example, Ms. Ann stopped by one group to check whether they determined the point at which renting a car became cheaper than taking their own, using the values presented in the article.

Ms. Ann: So mathematically how are you guys doing?

Tyrone: What?

Ms. Ann: So we talked about the 54 cents.

Tyrone: Right. So what I’m saying, like, if I did -- I don’t even know what I’m doing.

Ms. Ann: So they are saying look back at this chart. And the article tells you it’s 54 cents a mile, but, where is the only place that’s true?

Dave: After 700 miles.

Tyrone: Right here.

Ms. Ann: Yeah. Not until we get to 700. If you round that you get 54 cents. That’s when it finally gets down to 54 cents a mile. So they are trying to tell you that it’s always that cheap, and it’s not.

Tyrone: Right. So it’s never.

Ms. Ann: It’s sometimes. Because once you get to 700, it’s true.

Tyrone: Okay.

Ms. Ann: Yes. So we should all storm Enterprise Rentals and say “This is not true!”

Dave: We could sue them--

Ms. Ann: The poor guy working in there is going to be like “I didn’t write the article!”
(150225, Group A, 731-744)

At some point after most groups had completed the Group Problems, Ms. Ann usually assigned each table a problem to write on the board for the class. These solutions were not presented orally by the students. Instead, students tended to use the solutions to check their work, although Ms. Ann occasionally called the class together to point out solutions to selected problems. Very rarely, she halted the groups to engage in a mini-lecture about a single problem or idea.

The class period ran continuously for 110 minutes. Ms. Ann encouraged students to take a ten-minute break at the halfway point of the period and usually provided a reminder. Some groups appeared to never take a break, while others visibly stopped working or left the room. On all observation days, Ms. Ann never left the classroom for a break or stopped talking to students.

Usually with about ten minutes remaining, Ms. Ann called the class together to demonstrate the Excel functions needed for their Technology homework assignment. She used this lecture to demonstrate how to use Excel, not to have a whole-class discussion about the content for the day or the content of the assignment. For example, on the day with the rental car article, Ms. Ann started her Technology lecture by opening the Excel template for the assignment and explaining the organization of the spreadsheet:

When you open the template it looks like it’s got all this stuff going on. The stuff on the left, you don’t need to do anything with the stuff on the left. They are what you already did in class on paper.

She then explained “Over here, what they want you to do is do it again for a compact car. Everything we did in class is for a full-sized car” and went on to demonstrate entering the formula into Excel and dragging formula cells down to fill in the tables. During this lecture, she

solicited student input through questioning such as “What am I going to tell [Excel]?” and “What did we do to find average cost?” She then turned to a couple of highlighted cells, saying:

Let me help you figure out what the neon yellow ones here mean. So it says “use trial and error to plug some different things in.” Now that you’ve got the chart, you can type different things in here and try to figure it out, like you did on your calculator, where they are the same.

She closed the lecture by asking if there were any questions about the assignment and then reminded students of other assignments due the next week, closing with “I’ll come help you with those as well.”

After these brief Technology lectures, groups often started packing up or socializing, but a few typically continued working until Ms. Ann dismissed class at the time the class period was over. She stayed in the room talking and working with students until everyone left.

A quantitative look. The description above illustrates typical elements of the curriculum and the enactment of those elements. Notably, the class period almost always included time at the beginning for checking in, several short lectures on different topics, and lots of group time. Table 3.4 supplements the above description with summary statistics associated with the average length of time spent on each of the general class activities over the 12 observed periods. Notably, the general flow of the observed class periods allocated very little time for lecture (less than 12 minutes on average), while over 84 minutes were spent on group work.

Table 3.4

Average Time Spent on Class Activities

Class activity	Days	Time spent (min)		
		Mean (SD)	Minimum	Maximum
Beginning of class	11	5.28 (1.93)	1.47	7.67
Quiz	10	6.45 (1.38)	4.82	9.23
Quiz review	8	0.93 (0.61)	0.45	1.93
Teacher introduces section	9	1.94 (2.43)	0.27	8.07
Group work time	12	84.12 (12.27)	62.65	99.27
Teacher led content lecture	8	5.36 (5.65)	0.57	18.22
Teacher introduces technology assignment	11	4.30 (2.81)	2.53	12.6
Other	4	10.84 (10.30)	0.78	21.32

Mapping to Before-During-After. In considering the use of class time and the Before-During-After model of problem centered instruction, both the Before and During phases were observable in the description above. The Before phase, during which the instructor introduced the lesson for the day and motivated the problems, occurred on 75% of the observation periods, although it was short, lasting an average of two minutes. The During phase, where students worked in groups while the instructor moved around the room supporting students in their work, occurred in every observed period and lasted an average of 84 of the 110-minute session. In contrast, the After phase, where we would expect to observe a whole-class discussion about the material for the day, did not occur at the classroom level in any of the observed periods. That said, the Reflections questions are phrased in a way to open up a discussion of the big ideas of the section. It might be that these discussions are taking place within the groups, rather than at the classroom level. To understand this level of enactment, a finer grain of analysis is needed.

The results above suggest that the curriculum, as enacted in this classroom, did provide ample time for students to work with their groups. Given the length of the During phase though,

and the fact that during this time the students actively engaged with the curriculum materials and the instructor, closer examination is warranted. To examine this aspect of the enacted curriculum, I rely on audio transcripts from the groups in the classroom, discussed in the next section.

Visualizing the Enactment of *Mathematical Literacy*

The descriptive statistics and narrative in the previous section provide an overview of the typical elements of the enacted curriculum, but give only a brief overview of a very complex space with many participating actors. To understand more deeply how groups engaged with the curriculum, I first used the time-stamped group audio from a single week to look at student participation within their groups and how much time each group spent on the different group activities. Table 3.5 presents, by group, average speaker turns and time spent talking. Table 3.6 presents the average time, per group, spent on different group activities, both with and without the instructor. Note that the average number of turns per individual suggests active, sustained conversations over the class periods, although individual participation varied greatly, raising questions about what each individual contributed or talked about. Emilia, in Group B, spoke only an average of 38 times each day (or about 3.4 minutes), while Craig, in Group D, spoke an average of 424 times a day (or about 45 minutes). At the group level, groups spent an average of about 15 minutes off-task, which, considering they were asked to take a 10-minute break at their discretion during their group time, does not seem unreasonable. Note that these results only speak to off-task *talk*. During my classroom observations, I did routinely see students on their phones, and students occasionally discussed texts they sent each other during class. However, these results focus on group behaviors, and when students were talking within their groups, which was often and regularly, they were usually talking about class-related issues.

Table 3.5

Average Number of Turns and Length of Group Contributions by Individual per Day

Table	Individual	Days present	Average number turns (SD)	Total time (min) speaking (SD)
A	Dave	3	199(41)	12.2(2.4)
	Felicia	3	140(29)	9.3(2.9)
	Sarah	3	231(36)	21.1(7.1)
	Tyrone	3	371(71)	30.4(8.0)
B	Beth	3	260(38)	40.5(13.8)
	Carrie	3	240(18)	30.5(11.3)
	Emilia	3	38(22)	3.4(2.3)
C	Henry	3	189(21)	17.4(3.3)
	Gabby	3	116(22)	9.3(3.2)
	Jen	3	253(11)	44.3(7.0)
D	Carley	3	231(82)	15.4(15.4)
	Craig	3	424(33)	45.3(2.6)
	Fiona	2	223(35)	15.1(3.5)
	Helen	2	206(131)	14.3(9.1)
Total ^a	14		223(96)	22(13.8)

^a This row reports the average contribution for each student, weighting each student equally (so, an average of the averages).

Table 3.6

Average Time Spent Within Groups on Different Group Activities

Activity	Average ^a time (SD)		
	Total	Without instructor	With instructor
Workbook	49.5 (5.9)	41.8 (4.5)	7.7 (1.5)
Reflections	2.2 (1.9)	2.9 (1.5)	0.6 (0.6)
Group homework	15.5 (13.7)	11.9 (7.8)	0.4 (0.3)
Planning and other class-related talk	7.9 (2.4)	6.0 (1.9)	1.7 (0.6)
Helping	1.9 (3.4)	2.5 (3.0)	0.0 (0.1)
Off-task	15.8 (7.6)	13.9 (6.8)	1.9 (1.7)

^a Time was measured in minutes and averages were calculated by first computing the average time spent on each activity by group over the three days for which I have detailed records. I then averaged over the four groups.

To further investigate the enactment of *Mathematical Literacy*, I created visualizations of the classroom by transforming the transcripts of the group and teacher audio from each class period into diagrams. Figure 3.4 below shows one of these diagrams for a single group during the same day discussed earlier in the results. In the diagram, the colored rectangular background regions indicate the overall classroom activity within the given time interval. For example, in Figure 3.4 light blue regions indicate when the instructor was checking in with students at the beginning of class, light grey regions show when the students engaged in individual assessment, and light orange regions identify when the instructor lectured. The x-axis represents time from the beginning of class until the end of the period.

These group-level diagrams show individual patterns of participation, which descriptive statistics at the group level mask. For example, in Figure 3.4, Craig talks a great deal, which the descriptive statistics in Table 3.5 demonstrated, but the diagram shows that his participation level was consistent, regardless of the group activity. In contrast, Carley's contributions increased markedly during off-task discussion. The instructor (always represented by a black marker) talks to the group about three of the four main problems of the day, with usually one visit per problem.

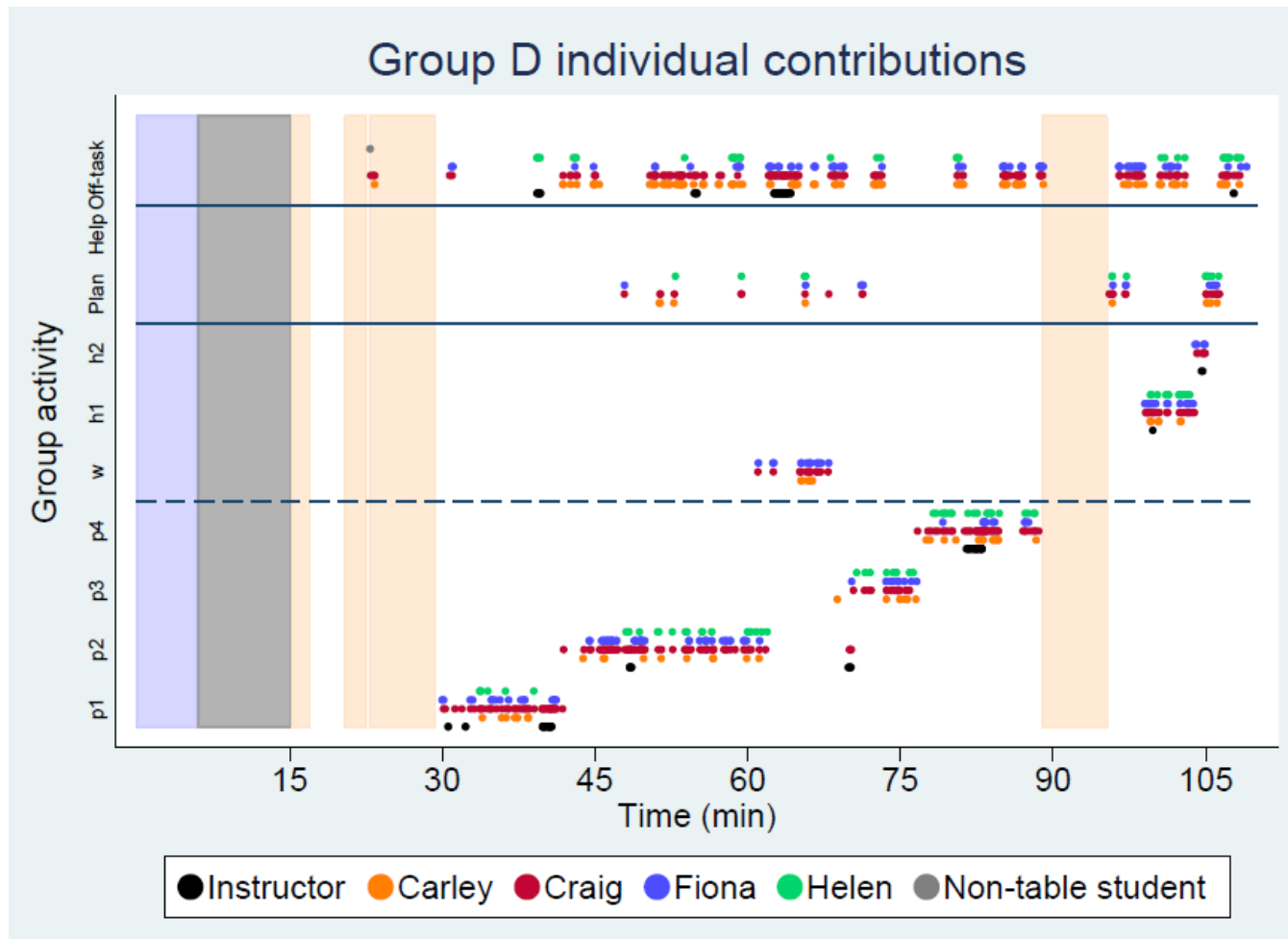


Figure 3.4. Individual Contributions Through Group Activities for Group D. Each dot indicates when an individual started a new speaking turn. Recording of individuals started when the instructor opened the classroom up for group work (here, at minute 22). The light blue regions in the plot area indicate when the instructor was returning assignments and checking in with students. The grey regions are when the students were engaged in a quiz or an activity related to the study. The light orange regions are when the instructor was lecturing to students and white regions are when the class was expected to be working in groups. The Group activity codes mean, in ascending order: problem 1 through 4 in the workbook, written reflection task (w), group homework assignments (h1 and h2), group planning and class-related talk, helping other groups, and off-task discussion.

The classroom-level diagrams demonstrate many of the same features of the classroom as the group-level diagrams, but lose the ability to visualize an individual's contributions during class. However, the classroom-level diagrams allow for easier comparisons of groups within a single day and more clearly show the instructor patterns as she moves between groups. Figure 3.5 presents an example of a diagram for the same day as in Figure 3.4 using similar conventions.¹⁵ Figure 3.5 shows that, on the day presented, the groups tended to move through the material in a similar fashion, although Groups B and C finished their work early in the class period and then worked on group homework assignments, while Groups A and D took the entire period to complete the work. Groups A and D, however, also spent far more time off-task than Groups B and C, suggesting different working dynamics. The classroom perspective also shows that Group A sometimes talked about two problems at the same time, suggesting a division in the group that might warrant further attention in later analysis. Figure 3.5 also shows the instructor spending time with each group, stopping at each group several times over the course of the period, although she spends markedly more time with Group A than the other groups. For the most part, her visits occur while groups are in the middle of solving a problem, not at the end.

¹⁵ See the Methods section for a detailed account for how classroom-level diagrams differ from group-level diagrams.

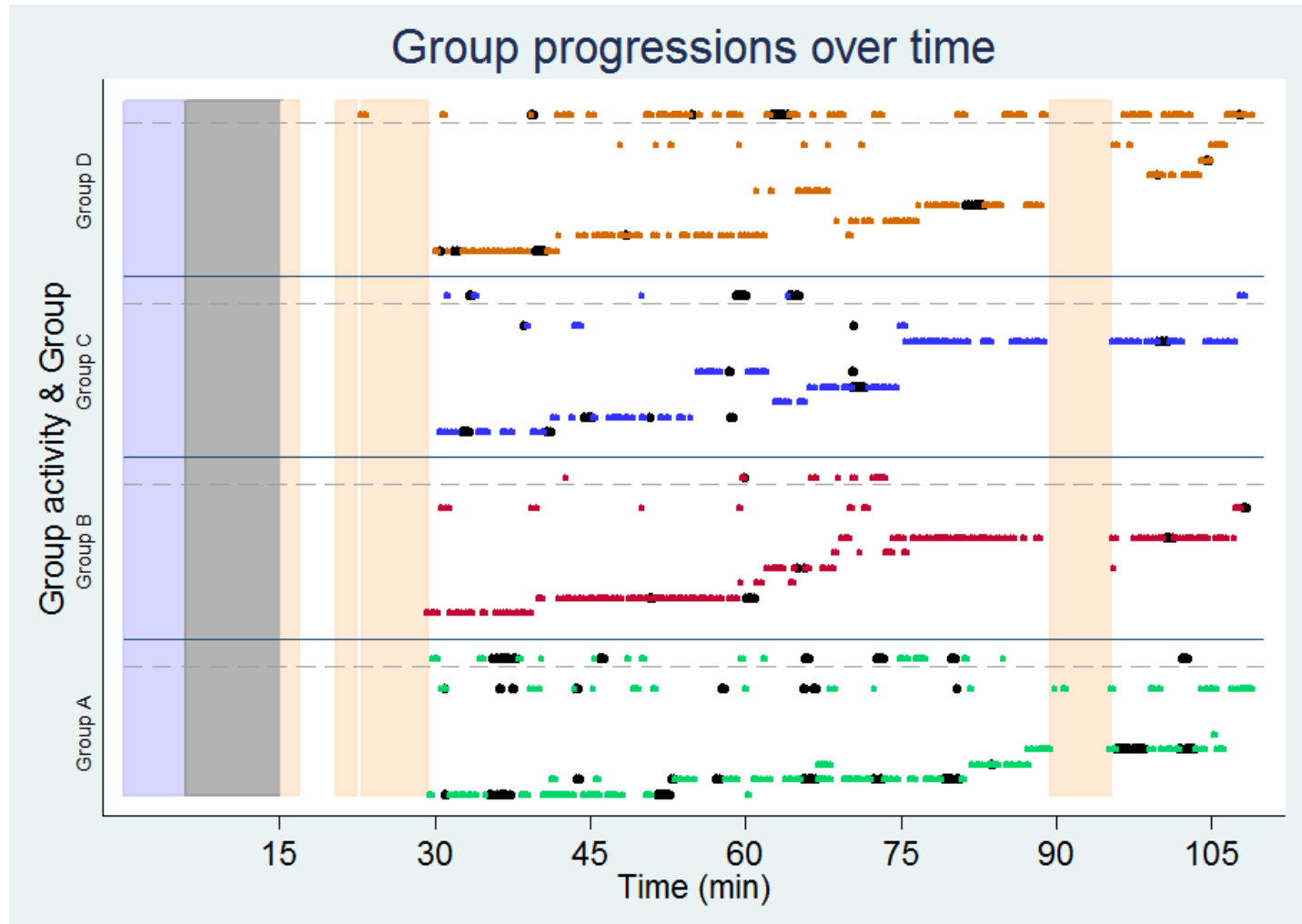


Figure 3.5. Progression through Group and Classroom Activities. See note for Figure 3.4 for an explanation of the shaded regions. Markers indicate that an individual started speaking at that time with respect to a particular classroom activity. Differently colored markers indicate different groups. The larger, black markers always indicate the presence of the instructor at the table, regardless of who spoke. Classroom activities are separated as they are in Figure 3.4; the dashed lines indicate the location of the off-task line for each group.

These diagrams demonstrate several things about the enactment of the curriculum at both the classroom and group level. At the classroom level, the diagrams reinforce the findings of the previous section that students have a large amount of opportunity to work within and with their groups. The instructor clearly moves around the room and talks to students almost constantly at the group level, and almost never lectures at the classroom level about the content. Thus, on the surface, she has clearly shifted towards a facilitating rather than lecturer role. The diagrams provide a more nuanced picture of what occurred within groups while in the During phase of the lesson. Within their groups, students generally worked together through the material. The diagrams show students talking about the mathematics problems regularly and consistently. Some groups regularly went off-task but these groups appeared to rarely need direct teacher intervention to get back on track. This is not to say that all groups always spent most of their time engaged in curriculum-related discussion, but students in these classrooms are capable of such patterns of behavior and of staying engaged for a long period of time with their groups.

Persistence in *Mathematical Literacy*

The second research question of this chapter focuses on student outcomes, including the rate of persistence and the affective impact of the class. To do this, I examine a larger sample that draws from multiple sections of *Mathematical Literacy* at FCC.

Descriptive statistics for the entire survey population, participants who took only the pre-survey, and the persistent sample (those present to take the post-survey at the end of the course) are summarized in Table 3.7. Notably, the whole survey sample is more female than male and majority White, which is consistent with the developmental population at FCC. The percentage of the pre-survey students who persisted to take the post-survey was 63.3%. The “pre-survey only” sample was younger, contained more men, and contained significantly more Black

students than the persistent sample. Prior developmental coursework did not have an overall disproportionate relationship to student persistence in *Mathematical Literacy*.

Table 3.7

Demographics of Survey Samples

	Whole sample		Pre-survey only sample		Persistent sample	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
<i>Gender</i>						
Male	56	44.09	25	44.64	31	55.36
Female	71	55.91	20	28.57	51	71.83
<i>Race</i>						
White	52	55.91	8	15.38	44	84.62
Black	30	32.26	21	70.00	9	30.00
Hispanic	5	5.38	1	20.00	4	80.00
Asian	5	5.38	0	0.00	5	100.00
Other	1	1.08	0	0.00	1	100.00
Taken prior developmental	48	37.50	17	35.42	31	64.58
No prior developmental	80	62.50	31	38.75	49	61.25
Age (years)	131	22.9(7.7)	47	21.5(6.5)	81	23.7(8.3)

Note. Age reports the mean age of the participants in years followed by the sample standard deviation. Percentages in pre-survey only column and persistent sample columns are of the sample sizes for each category in the whole sample column.

Changing Student Attitudes in *Mathematical Literacy*

To understand the relationships between students' attitudes towards mathematics and course persistence, I completed independent tests of means between the students who took only the pre-survey ($n=49$) and the students who persisted ($n=82$). I found no significant differences between students in these two groups in their pre-survey attitudes towards mathematics (self-confidence, motivation, enjoyment, and value) suggesting that attitudes towards mathematics do not seem to have any relationship with who persists in *Mathematical Literacy*.

Students who persisted had a significant, positive shift in their enjoyment of mathematics.¹⁶ This increase corresponds to just over a tenth of a point increase on a 5-point

¹⁶ Applying a Bonferroni correction to these values results in the result for enjoyment no longer being significant. As a result, these findings should be interpreted with caution.

scale, or a small effect size using guidelines for Cohen's d (Cohen, 1988). The students also had non-significant, positive gains on the remaining three attitude scales (self-confidence, motivation, and value). Even with minimal gains and not highly significant results, these trends are important to note. The relatively small sample size limits the statistical power of the analysis, while the 16-week semester did not provide a long period of time to undo years of more negative attitudes towards mathematics. Also, although not significant, it should be noted that students' average pre-value score $\bar{x}_{pre-value} = 3.69$ (about 0.30 points lower than "Agree" on a 5-point scale) was higher than the other attitudes scales, suggesting that the students did value the subject, despite not being particularly mathematically confident or motivated. Table 3.8 presents the results and test statistics for these analyses. This is also not a random sample, so the results here are more about identifying relationships that can be used to inform future work, than about making causal claims about the effect of the class on students' affective change.

The only significant result for single items relating to the nature of mathematics and learning preferences was that students were less likely to agree with the statement "there is only one way to solve a mathematics problem" at the end of the semester¹⁷ (Table 3.9). The magnitude of this change amounts to approximately three-tenths of one point on a 5-point scale and a small effect size. However, the research question under consideration focuses on looking for patterns of change that warrant closer and deeper examination in future work, rather than definitively evaluating *Mathematical Literacy*. Although small in value, the shifts presented suggest *Mathematical Literacy* does have the potential to impact students.

¹⁷ Applying a Bonferroni correction to these values results in the result no longer be significant. As a result, this result should be interpreted with caution.

Table 3.8

Attitude Change Results for Persistent Students

Attitude	N	Mean score		Pooled SD	p-value	t-statistic
		Pre-survey	Post-survey			
Self-confidence	78	2.82	2.96	0.87	0.167	1.395
Enjoyment	78	2.93	3.06	0.58	0.047	2.019*
Motivation	78	2.67	2.77	0.66	0.166	1.399
Value	82	3.69	3.71	0.56	0.702	0.385

*p<0.05

Note. Attitude scores were scaled to be on a 5-point scale with 5 corresponding to “Strongly agree” and 1 corresponding to “Strongly disagree.” The reported test statistics and their significance are for the individual tests. Applying a Bonferroni results in the Enjoyment coefficient no longer being significant. The number of individuals for each scale varies due to missing data for some individuals on some scales.

Table 3.9

Attitudes Shifts towards Mathematics and Classroom Structures

Item statement	N	Mean post-pre difference	SD
Learning mathematics is mostly memorizing facts.	77	-0.04	1.03
There is only one way to solve a mathematics problem.	80	-0.29*	1.17
I enjoy working in small groups in mathematics class.	78	-0.08	1.07
I learn mathematics best when I get to work in a group.	81	-0.19	1.25
I learn mathematics best when I work by myself.	81	0.19	1.21
The mathematics I learn in school rarely helps me when I use mathematics in my daily life.	78	-0.12	1.03

*p<0.05

Note. Items were scored on a 5 point Likert scale, with 5 corresponding to “Strongly agree” and 1 corresponding to “Strongly disagree.” Sample size varies between items because of missing data.

The Relationship between Attitude Change and Background Characteristics

The above analysis demonstrates few clear differences in attitudes between persistent students and those who do not complete *Mathematical Literacy*. The results, however, leave open the question of whether there may be demographic patterns in the persistent students’

attitude changes. In this section I turn to these questions using an HLM analysis.¹⁸ As described in the Methods section above, the HLM models predict students' post-survey attitude scores, conditioning on their pre-attitude scores and various demographic and mathematics background data. The models have two levels: students nested within instructors. These results are reported in Table 3.10.

For each of the measured attitudes, the biggest significant predictor of their post-survey attitudes was their pre-survey attitude score. The instructor effect was statistically significant for enjoyment and value of mathematics, suggesting that under the right conditions the instructor can impact student attitudes.

Other predictors of change in affective outcomes followed patterns that might be anticipated: expecting to earn a grade of A had a positive effect on mathematics self-confidence, enjoyment, and motivation post-scores.¹⁹ Notably, only post-score-value of mathematics was not positively predicted by expecting to earn an A, and although the coefficient was not significant, it was negative, suggesting higher performing students may have valued mathematics less after the class was over. The results reflecting expected patterns suggest that the analysis is sensitive

¹⁸ Logit models using student persistence indicators at the outcome variable and students' pre-survey attitude scores as the dependent variables to identify the effect, if any, of pre-attitude scores on student persistence in the class, but the models were not significant.

¹⁹ This result might lead to asking whether students who started with higher pre-attitudes gained more in their attitudes than those who started lower on the scales. That is, did the "rich get richer?" A supplementary analysis using the same predictors as the analytic models in Table 3.9, but predicting attitude growth (post-pre) rather than post-score revealed that the pre-scores for self-confidence, enjoyment, and motivation were significant and *negative*, while the coefficient for pre-value was insignificant. These results suggest that those who started lower on most of the pre-attitude scales gained more than those who scored higher. Statistically, the rich did not get richer. Basic descriptive statistics on those who had high pre-attitude scores (4 or above) showed that approximately 10% of the sample was in this range on the scales of self-confidence, enjoyment, and motivation. About 25% of the sample was above this threshold for pre-value scores. A table documenting this analysis is included in Appendix B.

enough to identify predictive factors, meaning that the general lack of other patterns related to prior developmental enrollment and gender implies that the effects of the class are fairly evenly distributed across these groups. Other weakly significant effects were also present: being male had a significant positive effect on end-of-class enjoyment of mathematics, as did being older than the average student in the sample. A race of Asian or Other significantly predicted a post-score attitude, but the sample sizes for those racial categories were not sufficiently large to warrant interest in these results. See table note for additional information related to the racial categories.

Table 3.10

HLM Coefficients for Models Predicting Post-Survey Attitude Scores

	Self-Confidence	Enjoyment	Motivation	Value
Fixed effects^a				
Pre-attitude scores	0.619*** (0.104)	0.510*** (0.085)	0.657*** (0.087)	0.782*** (0.141)
Male	0.317+ (0.189)	0.289* (0.129)	0.226 (0.151)	0.060 (0.149)
<i>Race/Ethnicity</i>				
Black (n=9)	-0.130 (0.252)	0.220 (0.183)	0.259 (0.198)	-0.024 (0.204)
Hispanic ^b (n=4)	0.446 (0.337)	0.169 (0.233)	0.101 (0.279)	-0.454 (0.292)
Asian/Other ^b (n=5)	-0.003 (0.295)	0.260 (0.200)	-0.085 (0.240)	0.540* (0.242)
Age (years)	0.013 (0.012)	0.021* (0.009)	0.017+ (0.010)	-0.004 (0.011)
Prior developmental (n=27)	0.233 (0.182)	-0.047 (0.125)	0.023 (0.146)	-0.271+ (0.142)
<i>Expected grade</i>				
A (n=20)	0.787** (0.275)	0.471** (0.172)	0.554** (0.207)	-0.197 (0.211)
B (n=31)	0.449+ (0.236)	0.071 (0.161)	0.061 (0.188)	-0.148 (0.186)
<i>Anticipated degree</i>				
Bachelors (n=28)	-0.052 (0.263)	-0.215 (0.180)	0.053 (0.214)	0.106 (0.211)
Masters or higher (n=21)	0.182 (0.281)	-0.081 (0.196)	0.143 (0.231)	0.223 (0.232)
Unknown (n=2)	0.095 (0.499)	0.469 (0.345)	0.593 (0.407)	0.400 (0.409)
Constant	0.607 (0.384)	1.337*** (0.329)	0.595+ (0.317)	0.925+ (0.513)
Random effects				
Teacher	0.000	0.127**	0.026	0.144**
Residual	0.598***	0.403***	0.491***	0.477***
<i>N</i>	57	58	60	60

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

^a The sample sizes reported for the independent variable categories are not necessarily reflective of the sample for every model. Each analysis was run on the sample of students with complete data on all items included in the model, with a maximum possible sample of 63 individuals. Actual sample sizes for each model ranged from 57 to 60.

^b Sample sizes for race categories are smaller than desirable for this type of analysis. However, given that the coefficients for Hispanic and Asian students have opposite signs, and combining them into “Other” would erase this nuance, I leave them separated. However, results and relationships by race should be interpreted with caution. The sample size of 5 for Asian/Other breaks down into 4 Asian students and 1 student from a mixed-racial/ethnic background.

Discussion

This chapter explored the elements of *Mathematical Literacy*, focusing on the enactment of the curriculum at the classroom level. The persistence and affective outcomes of the course for students were also examined.

As previously discussed, community college students value course work that seems relevant to their needs and goals (Cox, 2009). The *Mathematical Literacy* curriculum used at FCC was structured to provide students with multiple opportunities to engage in real-world problem solving and the enactment of this curriculum at the classroom-level showed that the instructor provided ample time for students to engage with the problems while she monitored and supported their progress. The instructor's dramatic move away from lecture, the instructional method that dominates many developmental classrooms (Grubb et al., 2009; Mesa, Celis, & Lande, 2014), demonstrates that such an instructional shift is possible within developmental mathematics. Moreover, the students, although often having had many years of negative experiences in mathematics and only a short time frame to acclimate to group work and problem solving, can and do engage for sustained periods of time with mathematics problems in their assigned groups.

At the classroom level, the enacted curriculum varied from the model of problem-centered instruction as advocated by the K-12 mathematics reform documents (NCTM, 1991, 2000). Most notably, the lack of a whole-class discussion summarizing the main mathematical ideas of the day, or the "After" phase of the lesson, deviates greatly from the K-12 reform principles, which suggest that "whole-class discussions...build on student thinking and guide the learning of the class in a productive disciplinary direction" (NCTM, 2014, p. 35). The analysis presented here does not suggest deep mathematical conversations do not occur, only that these

conversations do not happen at the classroom level. The Reflections assignment for each section in the textbook may have offered one such opportunity. For these assignments, the students often wrote about the big ideas of the lesson for the day. However, the average amount of time spent on this task was just over two minutes, suggesting that Reflections-related discussions were not extensive. Alternatively, the instructor could have engaged in individual group-level summary discussions during her individual visits to groups. However, examination of the classroom-level diagrams show that she usually talked to students while they were in the middle of working on the problem, not towards the end of their discussion, when we might expect summary discussions to occur.

In investigating the second research question, the descriptive statistics presented indicate that White students were more likely to persist than Black students. However, examining the affective differences between persistent students and those who only took the pre-survey show no differences in pre-attitude scores. Although the race-related patterns in persistence are concerning, the samples are relatively small, and these patterns are not necessarily due to the instructional approach of the *Mathematical Literacy* class. Developmental mathematics students often have life circumstances that divert their attention from class and school. For this reason and others, developmental mathematics generally has low completion rates (Bailey, 2009; Bailey et al., 2010), and White students do traditionally have higher success rates, with mathematics background explaining much, but not all, of this difference (Bahr, 2010b). The data discussed in this chapter do not *explain* differences in persistence. In combination, these results suggest that a more nuanced examination of the classroom experiences of students is warranted to better understand the ways the classroom environment may be impacting students differently. Those

who are not persistent may be not be able to access the curriculum materials and content in the same ways, suggesting instructional interventions or modifications may be necessary.

For those who did persist in *Mathematical Literacy*, the results suggest that students' enjoyment increased overall after one semester in this reform-oriented environment. Additionally, results suggest that individual teachers have the opportunity to affect students' enjoyment and value of mathematics. However, the fact that those expecting to earn a higher grade experienced more growth in many of their attitudes leaves questions about how individuals experienced the curriculum, particularly those students who struggled in the course. A closer look at individual experiences in the classroom can help shed additional light on these findings.

CHAPTER 4:
EXPLORING CONVERGENT AND DIVERGENT STUDENT
EXPERIENCES IN *MATHEMATICAL LITERACY*

Community colleges, like most schools across the United States, serve students with a rich variety of backgrounds and needs. However, these schools, more than any other type of educational institution, contain students with great diversity in terms of age, life stage, and mathematical history. While the previous chapter revealed that many students in a new, group-work centered *Mathematical Literacy* course at a community college experienced positive changes in their attitudes towards mathematics and that students had many opportunities to interact with and learn from the other students, it is less clear how these diverse students experienced the class.

In particular, the work explored in Chapter 3 demonstrates that not all students persisted in the course. However, few significant affective patterns emerged from the survey data, either between the students who did not persist and those who did, or in terms of determining who benefited the most from the class. This chapter looks beyond basic demographics, mathematical coursework, and survey data on attitudes towards mathematics, and instead focuses on understanding individual experiences with the *Mathematical Literacy* course. Many factors contribute to a student's success in a mathematics class, including the values and goals of the student, the instructor and classroom environment, and students' connection to the curriculum. In this novel community college course, it is important to understand both what the individual instructor intended for students and how students perceived specific classroom events and structures, including how perceptions differed between students who had a generally positive, neutral, or negative reaction to the class.

With this in mind, I explore the third research question examined in this dissertation, which focused on the guiding question of:

Do students experience *Mathematical Literacy* as intended?

- a. How do perspectives on specific aspects of the course differ among students who have a positive, neutral, or negative reaction to the course?
- b. How do students' experiences with the course compare with the intentions of the course instructor/developer?

Methods

All data were collected from a single *Mathematical Literacy* classroom at FCC, taught by an instructor who had participated in the development of the course. Data drew upon student and instructor interviews, as well as classroom audio recordings of the interviewed students' groups during the Spring 2015 semester. All names are pseudonyms.

Sample

The observed class had an initial enrollment of 24 students, which adjusted to 22 (6 men, 16 women) students within the first week of the semester due to schedule changes. Of the retained students, 14 were White, 6 were Black, and the remaining three came from different racial or ethnic groups. Nineteen of the 22 students agreed to be audio-recorded in their groups. Groups shifted throughout the semester and the audio recording of a group required that all group members assent to recording. This resulted in a maximum of 14 students in up to four groups recorded on any individual observation day.

Eight of the 22 enrolled students participated in a single interview outside of class. All students in the observed classroom were invited to take part in the interviews, and everyone who

indicated interest was interviewed. Table 4.1 provides basic demographics and the mathematics backgrounds of these students.

Table 4.1

Interviewee Demographics, Mathematics Backgrounds, and Class Outcomes

Name	Demographics	Mathematics background	Expected grade
Bea ^a	Hispanic female 22 years old	First developmental class Calculus in high school	C
Carley	White female 19 years old	Started developmental at lowest level; Trigonometry in high school	C
Carrie	Asian female 20 years old	First developmental class AP statistics in high school	A
Craig	White male 25 years old	First developmental class Trigonometry in high school	A
Dave	White male 20 years old	First developmental class Statistics in high school	A
Emilia	Black female 19 years old	First developmental class Trigonometry in high school	Did not complete class ^b
Tyrone	Black male 48 years old	Started developmental at lowest level; GED	Did not complete class ^b
Vince	White male 21 years old	First developmental class Homeschooled	B

^aParticipated in an interview but not in group audio recording.

^bData from this column comes from the post-survey given the last day of class. Students were asked to indicate their anticipated grade. Emilia and Tyrone had stopped pursuing or withdrawn from the class on the post-survey date.

Of these interviewed students, all but Bea agreed to be audio recorded in their groups. Vince assented to being recorded in his group, but for almost 70% of the observation periods he was placed in groups that were not recorded. As later stages of analysis depend on data taken from group audio transcripts, I omit Bea's and Vince's contributions from the main analysis.

The instructor, Ms. Ann, was also interviewed for this study. She holds a Masters in mathematics and a Ph.D. in education, making her a mathematics content expert with deep knowledge of research on mathematics curriculum and instruction. Moreover, she participated in

the initial implementation of *Mathematical Literacy* at FCC, making her intimate with the goals, rationales, and methods of the course.

Data Collection

I focus primarily on the student interview data, which I supplement with classroom audio. I also draw upon demographic and mathematics background information from a pre-survey given the first week of class and a post-survey given the last day of class. The complete interview protocols are included in Appendix F.

Student interviews. Students were invited to interview during the seventh week of class and most interviews occurred during the eighth or ninth week of the semester. Interviews took place outside of class and used a semi-structured format. All participants were asked key questions related to their experiences in the class and their perceptions of the various class structures (e.g., group work, problem solving). Within this format, I tailored interviews to pursue topics of interest that each student raised (Fielding, 1993) and adjusted the order of the questions to keep the flow of the conversation natural. Interviews lasted between 30 and 45 minutes.

Recorded student group work sessions. During classroom observations, I audio recorded every group composed entirely of students who agreed to be audio recorded (this ranged from two to four groups). Audio recording started when the instructor opened the class up for group work and continued until the class period ended or the students shut off the recorder. In addition, the instructor was audio recorded for the entire class period. Her audio was used to supplement the student audio.

Classroom data were collected the first, seventh, thirteenth and fifteenth weeks. I focus on the data collected in week seven. Focusing on this subset of classroom data provides a degree of alignment between the observation data and the experiences students shared during their

interviews. Week seven also occurred early enough in the semester that all 22 students were still actively attending class, meaning the class contained its full range of diversity, both in terms of mathematical background and demographically. This allows for observation of the behaviors and interactions necessitated by a mathematically diverse student population within the classroom. Data from the first week of class also had a full roster of students, but did not allow students much time to adjust to the class structure, making the classroom audio less pertinent to the research questions. By week 13 several students, including one of those interviewed, had either withdrawn or stopped attending class, resulting in a smaller sample from which to draw.

Instructor interview. Ms. Ann, the instructor of the observed class, was interviewed for approximately two hours during the last week of instruction. Her interview covered, among other topics, discussions about individuals in the class and her perceptions of their trajectories, conversations about her instructional decisions and intentions for *Mathematical Literacy*, experiences implementing the course at FCC, and reflections on the observed semester. The interview was audio recorded.

Analysis: Student Interviews

The guiding research question for this project examines the similarities and differences in students' perceptions of *Mathematical Literacy*, depending on the type of experience they had in the class. To address this question, three main stages of analysis took place.

- **Stage 1:** Students' experiences were classified as positive, neutral, or negative.
- **Stage 2:** Interviews were coded for emerging themes related to their perceptions of the class and classroom phenomena using open coding (Creswell, 2014; Emerson, Fretz, & Shaw, 2011).

- **Stage 3:** For each student, the themes coded in Stage 2 were tabulated for occurrence.

Using these tabulations, I looked for patterns between students with positive, neutral, or negative experiences using the mixed-methods-analysis technique of matrices (Miles & Huberman, 2013), which organizes data along two or more dimensions, one of which is ordinal (e.g., positive, neutral, negative), to look for patterns in the data between cases.

In Stage 3 of analysis, I draw on interview segments, combined with examples from the classroom audio, to explore similarities and differences in how students with positive, neutral, or negative perspectives spoke about the classroom. I include these classroom examples not to causally link the perceptions students shared to a particular classroom event, but rather to illustrate examples of the classroom phenomena students identified.

Stage 1: Classifying experiences. The main research question of this project examines how students vary in their perceptions of the same classroom practices and phenomena. Given the diversity of the eight interviewed students, classifying experiences using meaningful categories poses a challenge. Course outcomes provide a well-defined option, as do demographics such as gender or race, but findings presented in Chapter 3 illustrated that grades, mathematical background, and demographics did not clearly relate to affective differences or course persistence, suggesting these are not good choices for examining this research question. Instead, I use student experiences, as determined by their recommendations. That said, categorizing experiences necessarily removes texture and nuance, so all results should be interpreted as limited in this capacity.

In this project, I rely primarily on students' responses to the interview question "would you recommend *Mathematical Literacy* to others who were considering taking the class?" to

categorize their experiences as positive, neutral, or negative.²⁰ This was one of three evaluative questions asked during the interview, and the only one pertaining to students' overall opinion of the class.²¹ Using this question assumes students who recommend the class have had a generally positive experience, and would fail to or qualify their recommendation when they have generally not found their experience worthwhile. Given the neutrality of the question and the fact that it was asked prior to the students knowing their outcomes in the class, this assumption seems reasonable. The responses to this question were not included in any other part of the analysis.

Two individuals trained in mathematics education participated in the classification of students' experiences and agreed on the final categorizations. For one interviewee, the two individuals disagreed. To resolve the conflict the second coder read the entire interview and, after rereading the recommendation response, agreed with the first coder. In debriefing this stage of coding after all coding for this project was complete, both coders agreed that the final recommendation codes aligned with the overall affective nature of students' experiences.

Stage 2: Coding student interviews. Interviews used a semi-structured format, meaning that students answered a common set of key questions, with follow-up questions dependent on the issues raised in their responses to the initial questions. This method allowed the students to guide their interviews towards the classroom practices and issues that they found most relevant to their experiences. However, this method of interviewing also means that the questions asked did not uniformly adhere to a well-defined framework. Open coding (Creswell, 2014; Emerson, Fretz, & Shaw, 2011) allows for a more holistic approach to coding, wherein the analysis of the data involves a set of deliberate steps to develop codes rooted in the emerging themes of the data.

²⁰ The codebook used for the coding of this question is in Appendix G.

²¹ The two other evaluative items asked students the (a) strengths and (b) weakness of the class.

Given that this study examines students' perceptions of the class, using a coding scheme that allows for the data to guide the analytic codes is a natural choice.

Coding took place iteratively, with the number of rounds dependent on the volume of material that fell into each initial code. That said, three main phases of coding occurred:

1. **Main Codes** were used to parse the transcripts into mutually exclusive segments that corresponded to the general guiding questions of the interviews.
2. **Sub-codes** were developed for main codes when the volume of material under a particular code warranted further parsing. This process was applied to the majority of the main codes and, when necessary, some of the sub-codes.
3. **Themes** were developed in the final stage of coding, and represented ideas or classroom phenomena that captured the essence of the sub-codes.

I discuss each phase of coding in more detail below, but for each coding phase, codes were assigned at the sentence level and were mutually exclusive. I did not code my own speaking in the transcripts when the student utterances stood alone. In Phases 1 and 2, all student utterances had a code assigned. I coded Phase 1 independently. For Phases 2 and 3 both myself and a second researcher trained in mathematics education coded all utterances separately using codes I developed. After coding, we worked together to reconcile the assigned codes and, where necessary, refine the codes for each segment.

Coding Phase 1: Main codes. The guiding question for this analysis examines how diverse students differed in their perceptions of various class phenomena. The class itself was built around two main ideas: group work and a problem-rich curriculum, which shifts the role of the instructor. Thus, the interviews had two main purposes: (a) to document the history of the student, especially mathematically and (b) understand students' perceptions of the class and their

feelings about classroom events. For the latter, I focused on students' experiences of the mathematics curriculum, group work, and the instructor, as these elements broadly encompass the main elements in the classroom. I include the full interview protocol in Appendix F.

The interview protocol explicitly focused students on their experiences in and perceptions of the class, with targeted questions related to the mathematics curriculum, group work, and instructor. Thus, these three codes served as a starting point in this phase of coding. The *Mathematics Curriculum* code captures students' experiences with and reactions to the problem-centered curriculum. *Group Work* focuses on student experiences and reactions to working in groups. The *Instructor* code centers around students' descriptions of their interactions with and perceptions of the instructor. These codes are elaborated, with examples, in Table 4.2. Additional codes were developed (e.g., *Student Background*, *Time Outside of Class*), but other than the *Recommend* code, which was used to classify students' experiences in Stage 1 of analysis, these were not analyzed further for this project, as the codes did not relate to students' experiences in the class.

Elements of the classroom are closely tied together, which occasionally made mutually exclusive coding difficult. For example, sometimes students spoke about their group interactions with the instructor. Broadly, this discussion fell into both the *Group Work* and *Instructor* codes. In instances like this, the default code was always *Instructor*, with the rationale that *Instructor* sub-codes developed in Phase 2 of the coding would pick up on group versus individual interactions with the instructor.

As already briefly noted, only I coded in this phase. As the three main codes mapped fairly directly onto questions developed from the interview protocol, this initial stage of coding proved relatively straightforward.

Table 4.2

Main Codes

Code	Description	Example
1. <i>Mathematics curriculum</i>	Students discuss the curriculum materials used in the class, including their experiences of, feelings related to, and reactions to learning and doing mathematics entirely presented as word problems. They may also discuss their like or dislike of problem solving. This code also includes when students discuss whether they believe they are learning the mathematics they need for their future career trajectory, and comparisons of <i>Mathematical Literacy</i> to other mathematics classes.	<i>Craig</i> : I've noticed that at least the guys that wrote the binders have—they put a lot of useless information in the word problems. Which that's probably true of any—they'd want to try and stump you with “oh, in 2008 this rocket” —you know. So, I don't know—they're okay, I guess when you're able to break down.
2. <i>Group Work</i>	Students discuss themes related to group work, including both the general structure of group work and their experiences in it. This includes: • Group composition • Typical interactions within groups • The amount of time they spend working together versus individually This may also include discussions of how they see group work as a whole and their general issues about group work.	<i>Dave</i> : An equal one would be the first group I had. During the group project we—the work load was split up equally three ways. We each had our own part. And then the second group I had, I had one member decide he didn't want to do anything so I ended up doing the whole project.
3. <i>Instructor</i>	Students discuss the role of the instructor or their interactions with her. This includes discussions about whether she is necessary to the class and whether anybody would be able to teach the class. If the instructor is discussed in terms of interactions with groups, those are given a code of <i>Group Work</i> instead. This code trumps both group work and problem solving. That is, if the student, for example is talking about her experiences working with the instructor in their group, the related passage will be coded as <i>Instructor</i> , not <i>Mathematics Curriculum</i> . Sub-codes (described in Appendix G) within <i>Instructor</i> separate individual versus group experiences of the instructor.	<i>Carley</i> : Ms. Ann—I like her a lot. She's actually one of my favorites. She's to the point. She does get distracted—I'll like ask her about, like, uh, stuff not dealing with mathematics and that's what I like about her because most of the teachers I'm in class with now, like, I don't really know them beyond just, uh, that class. But no, she's a lot of help.

Coding Phase 2: Sub-codes. After the main codes were identified, I developed sub-codes for codes that still contained multiple ideas related to the research questions. Sub-coding was an iterative process, with some sub-codes subjected to additional coding rounds. For each main code and any sub-codes that needed further breaking down, I applied the following process:

1. I developed the sub-codes using an open coding approach.
2. Two individuals independently coded all utterances for initial codes using the sub-codes.
3. The two coders met to reconcile and refine the sub-codes. For less than 2% of utterances, the two coders could not agree. For these, I made the final decision.

The final sub-codes for each initial code, with examples, are provided in Appendix G.

Coding phase 3: Themes. Once the data for a sub-code captured a distinct idea related to the research question, both coders independently reread the text tagged for each sub-code and generated lists of the specific ideas, or *themes*, students expressed within each sub-code. These were meant to capture the essence of the sub-codes.

For example, a sub-code that emerged for the initial code of group work was *Copying*: students reproducing each other's work, rather than completing it alone or with the group. When talking about copying, students discussed their level of participation in the practice and their reasons for, or reactions to, copying. Themes for this sub-code then were (a) *engages in copying*, (b) *lets others copy*, (c) *observes copying*, or (d) *classroom management of copying*. The first three themes capture ways to participate in copying. The last theme covers the ways students attempted to or envisioned managing the copying behavior of others.

After this round of coding was complete, I tabulated the presence or absence of themes for each focus student. The decision to tabulate the presence or absence of themes, instead of

examining prevalence, for each focus student reflects the fact that the interviews had a common set of questions, but also pursued different topics based on students' responses to the main questions, which could increase the amount of coverage a particular theme had in the final transcript.

Note, that unlike Phases 1 and 2 of coding, themes were not intended to capture all student utterances. Instead, themes served to capture distinct but important dimensions related to students' perceptions of the class within each sub-code. The nuance in how students differed in their discussion of these themes occurs in the last stage of analysis, discussed in the next section.

Stage 3: Convergent and divergent patterns. In the last stage of analysis, how students spoke about the different phenomena in the class are contrasted, using whether they would recommend the class to define the contrasts. The presence and absence of the themes identified above were transcribed in an analytical matrix. Matrices are a form of mixed method analysis that display data using “defined rows and columns” (Miles & Huberman, 2013, p. 109) and it is generally recommended to have at least one ordinal dimension. Each cell of the matrix contains data from the project and the entire matrix can be used to draw inferences and detect patterns. For this project, I apply matrices with a convergent-divergent purpose in mind, using students' experience type (i.e., positive, neutral, or negative) as the ordinal dimension and themes along the other, looking for similarities and differences in how students spoke about themes.

Analysis: Instructor Interview

The initial round of coding of the instructor interview relied on the same three main codes as students (i.e., *Mathematics Curriculum*, *Group Work*, and *Instructor*), with appropriate adjustments made for the fact that the subject of discussion had switched from perceptions of the classroom to intentions for the classroom. Only the components of the interview that related to

the instructor's experiences of these three things were considered, although the interview itself covered substantially more material not related to the research questions for this chapter.²²

I wrote these results to represent the intended curriculum with respect to each of the three codes. After analyses of the student interviews were complete, I returned to the instructor's interview, rereading it with a lens toward the sub-codes developed from the student interviews. The analysis of the intended curriculum for each of the three codes identified above was then refined to reflect the student sub-codes, noting places where the instructor's intentions did not have comparable student codes.

Results

The main research question of this chapter examines how students with different experiences in *Mathematical Literacy* vary in their perspectives of the class and the classroom phenomena, contrasting these with instructor intentions. Presentation of the results takes place in several stages, starting with a section introducing the focus students and detailing students' recommendations, which were used to classify student experiences. I then provide a brief overview of the focus students' participation in their groups. This short analysis provides context for the results I present related to students' perceptions of specific aspects of the class.

The remainder of the results are presented in three sections, organized around the initial codes of *Mathematics Curriculum*, *Group Work*, and *Instructor*. In each section, I present:

1. Results related to the instructor's intentions with respect to the code.
2. A matrix of sub-codes and themes for the six focus students.

²² Discussions from the instructor interview that were omitted include the mathematical history of the instructor, the process of bringing *Mathematical Literacy* to FCC, the professional development of instructors new to teaching *Mathematical Literacy* at FCC, future plans for the curriculum, and structural issues related to changing developmental mathematics within an institution.

3. Results related to the patterns in the occurrences of sub-codes and themes between students with positive, neutral, or negative experiences. I use interview transcripts to illustrate the similarities and differences between students with different experiences. When appropriate, divergent perceptions are further explored and illustrated using classroom transcript data from around the time of the interviews.
4. A short discussion section contrasting the students' perceptions with the instructor's intentions related to the code.

Focus Student Introductions, Recommendations, and Group Participation

In this section, I first present short descriptions of each of the six focus students. I then provide an overview of their recommendations for the class, and close with a discussion of their participation within their groups.

Carley. Carley, a 19-year-old White female student, initially placed into prerequisite arithmetic classes at FCC and worked her way into *Mathematical Literacy*. She planned to become a school social worker. Carley regularly appeared enthusiastic, open, and social, and she often greeted friends walking by the classroom or former group mates in different groups during class. Her enjoyment of the class, especially the social aspect, stood out during her interview. Although sometimes her group could talk quite negatively about other students, she tended towards the positive in her comments about others, both in class and during her interview.

Carrie. Carrie, a 20-year-old Asian female taking her first developmental class, intended to become a nurse practitioner. She spoke softly, but regularly, and generally made insightful contributions to the mathematics discussions within her groups, although she was often quick to undermine the value of her ideas. During her interview, she spoke positively about the class and

other students, but comments from others suggested that she was sometimes frustrated by the behaviors of her classmates when they were not working to her standards.

Craig. Craig, a 25-year-old White male in his first developmental mathematics class, had recently returned to school after several years in the workforce to earn a degree in journalism. He was articulate during his interview, describing his initial skepticism about the class and change of heart once he realized how helping others supported his own learning. Craig was a clear leader both intellectually and socially within his groups. Within the privacy of his group, Craig could be quite harsh and sometimes mean-spirited in his comments, including about other students, but generally worked patiently with those who required support.

Dave. Dave, a 20-year-old White male in his first developmental class, planned to study agriculture. He, more than any of the other interviewed students, gave the impression of an individual being exposed, through his group work interactions, to individuals and ideas not common to his rural upbringing, some of which seemed to challenge him greatly. Dave could be quite terse, both within his group and during his interview, but seemed to enjoy socializing with his group mates, and even, on occasion, the instructor.

Emilia. Emilia, a 19-year-old Black female, was in her first developmental mathematics class. Quiet and thoughtful, she intended to pursue a degree in theater. As she rarely spoke in class, her interview offered one of the few opportunities to hear Emilia's voice, either socially or in terms of representing herself. She expressed a lot of unhappiness about the class on various occasions during her interview, noting that she did not like talking to people and resented her group mates' failure to consider her needs, even if she appreciated them as individuals.

Tyrone. Tyrone, a 48-year old Black male, had started his education at FCC in the GED track, with the goal of eventually earning a degree in social work. Tyrone was a presence in the

classroom: loud, profane, and persistent in his talking. Although he could be abrasive, to the point of perceived rudeness in both his social and mathematics interactions, Tyrone was quick to acknowledge he was a difficult personality and could be hard to work with. In private, Tyrone was quite reflective about his own shortcomings as a student and appreciative of those who were willing to persist in their support of him.

Student recommendations. Student recommendations fell into one of three categories: positive, neutral, or negative. Students who recommended the class tended to provide an overwhelming positive and immediate response to the question. For example, Craig started answering the question with “I would now. Now definitely, especially if they were like me.” Carrie and Carley also immediately affirmed their recommendations, commenting “Yeah, I think I would” and “Yeah, I would,” respectively. Those who were negative tended to qualify their answers, saying that the class might be appropriate for some students, but not for them personally. For example, Tyrone recommended the class for students “if they’re up for a challenge,” but would not recommend it for “people like me.” Emilia, who expressed a strong dislike of mathematics during her interview, recommended *Mathematical Literacy* “if you like mathematics and want to understand the basics better” but would not recommend it if “you hate math.” Dave, in his response, did not indicate his personal feelings, but said he “would definitely recommend it to somebody....who hasn’t taken a math class in several years” and would not recommend it “if you just need a refresher.” Thus, his response was coded as neutral. Table 4.3 presents the recommendations of the students crossed with their anticipated grades. From classroom observations, I know that Emilia and Tyrone did not finish the class.

Table 4.3

Focus Students' Recommendations for the Class and Their Expected Grades^a

Expected grade	Recommendation		
	Yes	Neutral	No
A	Craig, Carrie	Dave	
B			
C	Carley		
Did not complete class			Emilia, Tyrone

^a As discussed previously, Vince and Bea are removed from the group of focus students because they have limited or no classroom data.

Students' participation in their groups. For the observation week closest to the time of the interviews, I examined the participation patterns of the six focus students and their non-interviewed group members, computing the average number of times they spoke a day and the average total time they spoke during the 80-90 minutes of group work on a given day (Table 4.4). These measures are rough, computed by taking the difference between speaker turns, which does not account for pauses between turns or overlapping conversations. However, the numbers still provide a window into the participation patterns within the groups. In general, students were fairly active in their group participation, but there was also tremendous range in participation patterns. For example, Emilia (in Group B with Carrie) spoke an average of 4 minutes a day, while Tyrone (in Group A with Dave) clockrd in around 30 minutes.

Table 4.4

Average Number of Turns and Length of Group Contributions by Individual per Day

Group	Person	Mathematics background	Days present	Average	
				Turns (SD)	Time (min) speaking (SD)
A	Dave	First developmental class; Statistics in high school	3	199(41)	12.2(2.4)
	Felicia	Previous developmental; Algebra II in high school	3	140(29)	9.3(2.9)
	Sarah	Previous developmental; Geometry in high school	3	231(36)	21.1(7.1)
	Tyrone	Previous developmental; GED	3	371(71)	30.4(8.0)
B	Beth	Previous developmental; Algebra in high school	3	260(38)	40.5(13.8)
	Carrie	First developmental class; AP statistics in high school	3	240(18)	30.5(11.3)
	Emilia	First developmental class; Trigonometry in high school	3	38(22)	3.4(2.3)
D	Carley	Previous developmental; Trigonometry in high school	3	231(82)	15.4(15.4)
	Craig	First developmental class; Trigonometry in high school	3	424(33)	45.3(2.6)
	Fiona	First developmental class; Geometry in high school	2	223(35)	15.1(3.5)
	Helen	First developmental class; unsure high school math	2	206(131)	14.3(9.1)

Convergent and Divergent Perspectives on Mathematical Literacy

To explore the instructor's intentions and how students with different experiences in *Mathematical Literacy* vary in their perspectives of the class and the classroom phenomena, I organize the remaining results sections around the three main codes, *Mathematics Curriculum*, *Group Work*, and *Instructor*. For each of these, as discussed in the introduction to the results section, I present (a) the instructor's perspective, (b) a table showing code occurrences, (c) results related to the patterns within the codes, and (d) a discussion of how the instructor's intentions and students' perspectives related to each other.

Main Code 1: Mathematics Curriculum

Mathematics Curriculum: Instructor's perspective. During her interview, Ms. Ann, the instructor, emphasized that real-world contexts played a critical role in the class. She and the others who brought *Mathematical Literacy* to FCC were interested in using the class to let students “be mathematically informed.” She elaborated:

This is a class that works on a lot of Beginning Algebra...but not the symbolic manipulation that goes along with it, just more the concept approach...we want them to be able to do some things by hand, but we're more interested in understanding the concept of how mathematical modeling works and what math actually does for us and how, to build some numerical literacy.

Thus, for her, the class was intended to provide some degree of procedural knowledge, but the larger focus was on developing students' abilities to reason quantitatively and appreciate the ways they do so in the real world. In talking about the fact that the students spend less time doing algebraic manipulations during *Mathematical Literacy* than they would in a more traditional developmental algebra class, she explained:

Sometimes their actual by-hand algebra skills remain weak...but I feel like even the weakest students have left with more than they would have gotten out of a Beginning Algebra class because they can actually tell me where something is used.

Thus, for Ms. Ann, the connections of the material to her students' lives and their ability to use mathematics were a big part of her intentions for the class. She reiterated this idea multiple times during her interview. At a later point she said that unlike in her traditionally taught developmental classes, when she asked students on an end-of-class-survey “Did you feel like most of the topics were relevant to real life?” students listed specific topics from class, which

impressed her, commenting “How often does that happen? And not only that, but it’s maybe something we did ten weeks ago.”

Ms. Ann, when pressed about the resulting large number of word problems that resulted from the real-world contexts, noted that she “hadn’t even thought about” the fact that students were almost exclusively solving word problems until a student told her about their anxiety related to seeing a textbook full of word problems. For Ms. Ann, the importance of the connection between providing real-world applications and the resulting implication for the textbook meant that she had not considered the implications for students outside of the curricular benefit until already implemented. Despite expressing concern that the change of format could impact students negatively and acknowledging that many students felt “incredibly uncomfortable and unsure about the material,” she felt these emotions were related to “learning you have to be uncomfortable for a while to really make a breakthrough.” Thus, for the instructor, the discomfort of moving to a problem-centered curriculum was in service of the greater goal of helping students use mathematics more independently in real-world situations.

Mathematics Curriculum: Students’ perspectives. Students talked about the mathematics curriculum in four main sub-codes: (a) *Feelings Towards Curriculum Materials*, (b) *Real World Contexts*, (c) *Learning and Using Mathematics*, and (d) *Feelings Towards Mathematics*. In the final analysis, it became clear that the themes that emerged under *Mathematics Curriculum* had a far more emotional component than the codes developed for *Group Work* and the *Instructor*. Thus, the final themes have a more affective nature than others used in this chapter. Table 4.5 presents the sub-codes and themes for this portion of the analysis.

Table 4.5

Mathematics Curriculum Sub-codes and Themes by Individual

Code	Sub-code		Experience					
			Positive			Neutral	Negative	
			Craig	Carley	Carrie	Dave	Emilia	Tyrone
1. Mathematics curriculum	(a) <i>Feelings Towards Curriculum Materials</i>	Positive				x		
		Neutral	x	x	x			
		Negative		x	x			x
	(b) <i>Real World Contexts</i>	Real-world content in the curriculum	x	x	x		x	x
		Mathematics is useful in career or life			x	x		x
	(c) <i>Learning and Using Mathematics</i>	Class material is useful in career or life	x	x	x		x	
		Class material is not useful in career or life	x			x	x	x
	(d) <i>Feelings Towards Mathematics^a</i>	Positive	x (27.1)	x (41.1)	x (30.1)	x (41.7)	x (38.8)	
		Neutral	x (6.0)		x (27.1)			
		Negative	x (67.5)	x (58.9)	x (41.6)	x (57.4)	x (60.9)	x (100.0)

^a Because all six students mentioned some negative feelings, this code was further examined for coverage of how much of the students' discussion of their feelings about mathematics related to positive, neutral or negative feelings. The percentages are reported in parenthesis for each individual.

a. Feelings Towards Curriculum Materials. Students discussed multiple facets of the curriculum, ranging from their reaction to exclusively working with word problems to the structure of the textbook, individual problems, or lessons. As such, specific content-related themes were rare. However, underlying most students' perceptions of the curriculum was an affective evaluation of their experiences with the materials as *positive*, *neutral*, or *negative*.

Only Dave identified as having a positive experience with the curriculum, saying "I don't mind word problems. I mean, I like being challenged and figuring out what they mean. It's kind of enjoyable for me." The remaining five students were similar in their perceptions of the curriculum, articulating neutral or negative experiences. No clear pattern in their neutral or negative reasons emerged. Carley expressed frustration that the word problems "try to trick you" while Craig commented that the authors of the text "put a lot of useless information in the word problems." Tyrone mentioned struggling with the vocabulary of the word problems, saying "you've got to, you know, understand....Like the word decay. When I think of decay, I think of something rotting." Others, such as Carrie, expressed general frustration with word problems, but noted within this sentiment that she found the structure of the text facilitated her learning. Thus, the problem-heavy nature of their work seemed to be a source of frustration for most of the students, regardless of their recommendations for the class.

Review of the curriculum demonstrates that the material is almost exclusively contextualized word problems (see supplementary analysis for Chapter 3 in Appendix E). Even fairly typical procedural problems usually come with non-procedural follow-up questions. For example, in the unit where students develop the principles of algebraic equation solving, a question asks, "Solve the equation. Did you get the same answer as in Question 2 of Lesson 2-8 Group?" (Sobecki & Mercer, 2015, p. 158). In this question, and many others like it, the students

must connect previous answers together and reflect on the relationships within their work, thus going beyond the traditional form of mathematical questions.

b. Real World Contexts. For the sub-code of *Real World*, students only had one theme: *real-world content in the curriculum*. Although students expressed mixed feelings about the curriculum, almost all of them gave specific examples of topics from the course they connected with, suggesting they found at least some of the real-world contexts relatable. Carrie listed “comparing gas prices or cell phone bills” as things she connected with, going on to comment “I never realized that you can kind of easily do that for yourself.” Tyrone mentioned “compound interest” and Carley, “monthly payments and loans,” adding “which is really helpful, because, you know you’re going to use that in life, obviously.” Thus, even though they were only about half way through the semester, students were connecting the mathematics from the curriculum materials to their daily lives.

c. Learning and Using Mathematics. In the above section, the students discussed real-world connections they made to the curriculum. More generally, students discussed their thoughts about whether they were learning mathematics they felt they would use, which fell into the themes of *mathematics is useful in career or life*, *the class material was useful in career or life*, and *the class material was not useful in career or life*.

Students, regardless of their recommendations, were mixed in their perception of whether mathematics was generally useful. Carrie said “I think so. Probably. One of my biggest fears actually is, like, having to do IV stuff and not knowing how to do those calculations” and Dave said “Geometry. I guess that’s the one I need the most. Business math is another.”

Those who would recommend the class thought they were learning mathematics in class that they would need. But, those who tended towards not recommending the class were less sure.

For example, when asked if he thought he would use the course content in the future, Tyrone commented, “Well, I really don’t, to be honest. I really don’t. But, you know, I’m sure it will come up when I start making money....But in my career, probably not.” Emilia commented:

It’s important to know addition, subtraction...I guess that part is important. But the rest of it....Like we had one question that said “estimate the wing of the plane.” I don’t think I’m ever going to need to estimate. Because I’m not going into that.

Thus, although the students may have seen real-world connections, they did not necessarily see those connections as directly relevant to their own needs.

d. Feelings Towards Mathematics. The generally neutral to negative reflections on the *Feelings Towards Curriculum Materials* code discussed above were reflected in sub-code of *Feelings Towards Mathematics*. These again broke down into *positive*, *neutral*, or *negative*.

All six students mentioned having negative emotions with respect to mathematics. Moreover, during the time they spent talking about their feelings about mathematics, they spent an average of 64% of that time discussing negative feelings, compared to an average of 30% about positive feelings. Craig, for example, mentioned that “A lot of the times, if I’m not getting something I get nervous, like, I get sweaty.” Tyrone said “I’m always unsure. I’m not confident when it comes to math.” Carley noted that “Depending on what the topic is, most of the time [it’s] kind of stressful. Because it’s like, if I don’t know what I’m doing I get frustrated really easily.” Thus, the focus students often had negative feelings when they were unsure about themselves while doing mathematics.

When students discussed positive feelings about mathematics, it was typically in conjunction with doing something they understood or had learned before. Carrie made this explicit, commenting, “if I understand it then I’ll be, like, ‘yeah, I’ve totally got this.’ Like, it’s

fine and I kind of like it.” Emilia expressed something similar, saying, “I feel a lot better doing, like, the algebraic equations because...I learned that in high school.” This suggests that most of the students, although having different recommendations for the class, shared similar feelings related to mathematics.

Discussion: *Mathematics Curriculum.* Overall, students expressed fairly similar views with respect to the curriculum and their feelings towards mathematics. One important difference was that students with more negative experiences did not envision themselves actually using the class material in their life or career as much as those who had more positive experiences.

Most of the students expressed frustration with the curriculum and its structure, but also connected with at least some of the tasks they completed. The instructor’s interview highlighted how much of her intentions with the curriculum centered around providing opportunities for the students to connect to the mathematics and increase their mathematical literacy. Although some students seemed to benefit as intended, most of these community college students seemed primarily concerned with gaining specific mathematics skills for their chosen careers. In contrast with the instructor’s intentions, they expressed little appreciation for gaining a broad awareness of mathematical applications in the world around them or with obtaining general mathematical literacy skills.

Main Code 2: Group Work

Group work: Instructor’s perspective. Group work was an important part of the course design, with Ms. Ann noting that, after outlining their mathematical goals for students in the class, she and the other individuals involved in implementing *Mathematical Literacy* at FCC realized that:

To get at some of this conversation and interpretation and thinking about math that we want them to be able to do, lecture classes aren't just going to be able to work. They need to be having these conversations in class.

Thus, the choice to implement group work was driven by the curriculum objectives, intended to help students think about the mathematical content in a richer way than a traditional, instructor-centered developmental class allowed.

During her interview, Ms. Ann explicitly discussed how she created groups, explaining that she liked to spread her top- and low-performing students evenly between groups, but within this also considered “personalities and attendance” to create groups that provided a productive environment for all her students. She tried to include at least one “strong” member in each group:

The format with the groups does rely on having at least one member of the group that's a little bit stronger. I don't think that it necessarily assumes that they already know how to do things. But it does work best with somebody who's a little stronger who does a good job of figuring things out as they go.

Thus, the instructor explicitly considered the range of abilities within the groups. She noted that miscalculations on her end about how different personalities would work together did occur, and usually this resulted in groups that did not function well together.

An underlying assumption of much of Ms. Ann's discussions related to group work was creating conditions where students worked together. Early in her interview she talked about a group that had started by working as separate pairs, with little interaction between the two dyads. After several attempts to bring the pairs together, she felt that it was “working better” but the group still generally operated as two pairs of students, rather than a unified group. For the instructor, then, togetherness was a goal, and one that she regularly attempted to achieve within

and outside of class. Indeed, during her interview she discussed many instances of reaching out to students to help manage group relationships and keep students working together.

Ms. Ann acknowledged that group work did allow for some students to take advantage of their groups, minimizing the amount of work they contributed, commenting that “for some of them yes, it’s that they’re just copying their group’s work and getting A’s on homework that they haven’t done,” but she went on to explain that the grading structure of the class meant that most of these students would not pass the class without some degree of personal understanding of the content. She also noted that the group project rubrics allowed students to grade each other, but she observed that “the students are not always willing to throw each other under the bus,” which she found frustrating because it limited her ability to hold students individually accountable.

Group Work: Students’ perspectives. *Group Work* sub-codes fell into six categories: (a) *Group Dynamics*, (b) *Togetherness*, (c) *Checking In*, (d) *Copying*, (e) *Accountability*, and (f) *Group Work Time*. Table 4.6 presents documentation related to these sub-codes and the resulting themes. The sixth sub-code, *Group Work Time*, although providing a window into how students viewed the amount of group work (i.e., whether they thought there was an appropriate amount), the themes did not have clear patterns between students, so it is not analyzed further in this section.

Table 4.6

Group Work Themes Raised by Individual Students

Code	Sub-code	Theme	Experience					
			Positive			Neutral	Negative	
			Craig	Carley	Carrie	Dave	Emilia	Tyrone
2. <i>Group Work</i>	(a) <i>Group Dynamics</i>	Group relationships	x	x	x		x	x
		Role within group	x		x	x		
		Diverse mathematics levels	x		x	x		
	(b) <i>Togetherness</i>	Presence of togetherness	x	x	x	x		x
		Lack of togetherness	x	x	x	x	x	x
	(c) <i>Checking In</i>	Help giving	x			x		
		Balance	x	x	x	x		
		Help seeking	x	x	x	x	x	x
	(d) <i>Copying</i>	Engages in copying					x	x
		Lets others copy	x	x	x			
		Observes copying	x			x		
		Classroom management of copying	x					
	(e) <i>Accountability</i>	Distribution of work load	x	x		x		x
		Lack of control	x		x			
		Peer regulation	x	x	x	x		
		Self-accountability						x
	(f) <i>Group Work Time^a</i>	Would like more lecture						x
		Balance between group and individual time	x			x		
		Creates positive atmosphere		x				

^a The sub-code of *Group Work Time* does not show any clear convergent or divergent patterns in what the students raised for this code, so no further analysis is conducted.

a. Group Dynamics. Three main themes emerged for the sub-code of *Group Dynamics*: *group relationships*, their *roles* within groups, and the *diverse mathematics levels* in their groups.

Almost all the students discussed their relationships within groups, but no clear patterns emerged between students who had generally positive versus negative views of the course. Similarly, when discussing group roles, although students with positive experiences were the only ones who brought them up, no clear patterns in their ways of talking about them emerged.

Many of the students with more positive experiences explicitly noted that groups usually contained students with diverse mathematics levels. Dave commented that sometimes groups have “someone who knows a lot about something with someone who doesn’t know anything about it” and Carrie observed, “everyone is at a different levels [*sic*] and they all kind of contribute their own things.” These remarks suggest that students, although perhaps not explicitly aware of the mathematical backgrounds of their group mates (a sample of which was presented in Table 4.4), did recognize that a range of background knowledge existed in their groups.

b. Togetherness. The sub-code of *Togetherness* broke down into two themes: a *presence of togetherness* and a *lack of togetherness*.

Craig, Carrie, and Tyrone, who ranged in their recommendations for the class, each acknowledged the sense of togetherness that occurred when either the entire group was stuck on the same problem or had independently arrived at the same answer. However, the majority of the students’ discussion related to *Togetherness* discussed division within the groups. All six students noted that groups did not always collectively work together. Important differences in how they talked about it occurred.

Emilia and Tyrone, students who would not recommend *Mathematical Literacy*, both noted they usually found themselves behind in their groups. Tyrone commented, “sometimes I might be behind. I’m always behind. And then I look, ‘hey where you at?’ I’m just like man, ‘you all just go ahead—I’ll catch up’” and Emilia, in talking about a previous group remarked “I would still be like, reading the question and they would be like three questions ahead of me.” For both, a lack of togetherness resulted in being left behind.

Diagrams of Tyrone’s and Emilia’s groups for a day that was close to the time of their interviews (Figures 4.1 and 4.2 respectively) indicate that both students lagged behind their group mates. Like most observation days, on the day diagrammed, the students spent most of the period working in groups. The lesson was the last one in the chapter, so groups had both their usual classwork and two group homework assignments to complete. On this day, Tyrone talked regularly but for the most part, only discussed the mathematical content of the unit with his group mate Sarah (Figure 4.1). Sarah talked with their other group mates, seemingly working ahead and then stepping back to help Tyrone as needed. The diagram for Emilia’s group on the same day, shown in Figure 4.2, reveals that Emilia rarely spoke. When she did, she was usually talking to the instructor about problems her group mates, Carrie and Beth, had already discussed.

Recall that Emilia and Tyrone were, of the eight interviewed students, the only two who did not complete the class. Although not shown here, a similar lack of togetherness, with both Emilia and Tyrone lagging behind, existed in transcripts from the first week of class. Similar patterns were also observed for other students who did not complete the class but were not interviewed for this dissertation. This suggests that an early lack of togetherness in groups might signal the need for additional support or intervention.

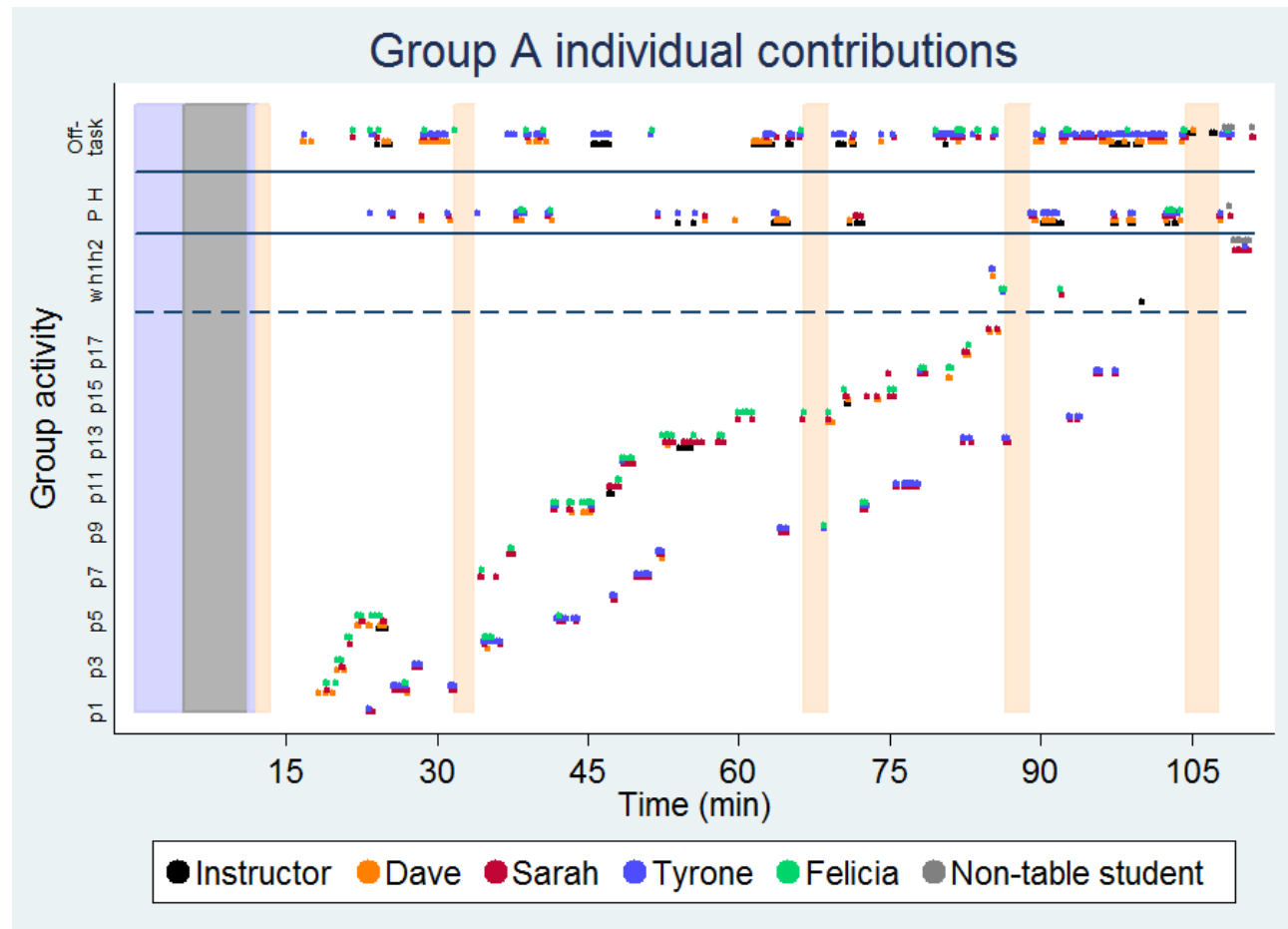


Figure 4.1. Individual Contributions in Group A. Each dot indicates when an individual started a new speaking turn. Recording of individuals started when the instructor opened the classroom up for group work (here, around minute 15). The light blue regions indicate when the instructor was returning assignments and checking in with students. The grey regions are when the students were engaged in a quiz or an activity related to the study. The light orange regions are when the instructor was lecturing. White regions are when the class working in groups. The Group activity labels mean, in ascending order: problems 1 through 17 (skipping even numbers on the labels), written reflection task (w), group homework assignments 1 and 2 (h1, h2), group planning discussions (P), helping other groups (H), and off-task talk.

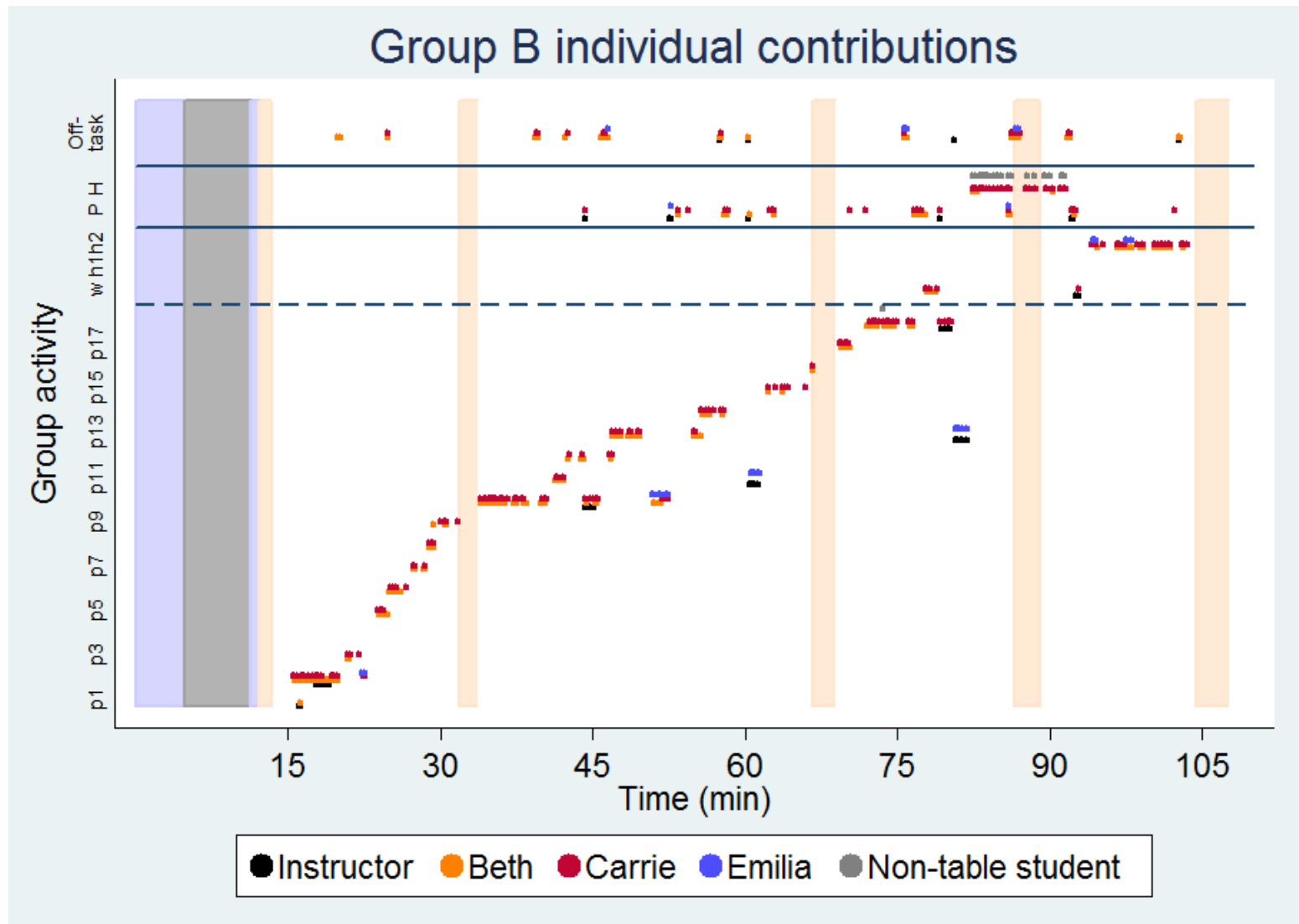


Figure 4.2. Individual Contributions in Group B. See note for Figure 4.1.

In comparison to Emilia and Tyrone, the four other focus students did not mention feeling left behind when talking about a lack of togetherness within their groups. However, both Carley and Craig, who would recommend the class, indicated that they found a lack of togetherness problematic and gave examples of the ways they strove to bring groups together. Craig discussed his strategy of working a little ahead so he could later step back, as Sarah seemed to do in Tyrone's group. Craig felt that completing the problems ahead of others allowed him to "better...explain it to [his group] afterwards" suggesting that sometimes a lack of togetherness may serve the good of the group. Carley commented that a lack of togetherness indicated a lack of communication within a group, suggesting the burden was on all parties to both check in with each other and ask for help.

Unlike Carley and Craig, Carrie and Dave distanced themselves from the responsibility of keeping groups together. Carrie observed:

Most of the time you'll have someone else in the group that works at the same pace as you. And then, like, the other person will work at the same pace as the other person....So even though it wasn't totally all of us were on the same page at the same time we'd always, like, check in.

Similarly, Dave noted that "it's really difficult to get things done when you're in a bad or...not a good group...I mean once you've got a good motion going then there's no reason really you should have to stop." It should be noted that Carrie and Dave were in groups with Emilia and Tyrone respectively around the times of their interviews (Figures 4.1 and 4.2). As previously mentioned, Emilia rarely spoke with anyone in her group, despite Carrie saying that usually everyone had someone to work with. Tyrone was helped in the group depicted in Figure 4.1, but not by Dave, who only once spoke to Tyrone about the mathematical content on the day pictured.

The lack of togetherness the students note and that is illustrated by the above diagrams show that togetherness was an issue. Dave and Carrie, in their interviews touched on reasons why this might be the case, noting that the act of slowing down could be disruptive or distract them from the goal of quickly completing the material.

A review of the audio used to create the diagram in Figure 4.1 offers additional insight into this phenomenon. Towards the end of class on the day, during which Tyrone lagged behind for almost the entire period, he expressed his frustration with his group for working ahead.

Tyrone: Dave. You're full of shit.
Sarah: [unrelated utterance]
Dave: What's your problem, bro?
Tyrone: Huh?
Dave: What's your problem, Tyrone?
Tyrone: Man, how you going to move that fast, man?
Dave: We're all done.
Tyrone: Man, I don't [inaudible] that. And if I don't pass this test, man, I'm blaming all y'all.
Sarah: Can't blame me because I'm the one who's been helping you.
Tyrone: Yeah, I ain't going to blame you.
Felicia: Can't blame anyone, actually.
Tyrone: What? I'm blaming you and Dave.
Felicia: You can't blame me.
Tyrone: No. I ain't.
Felicia: I'm not a teacher.

(150227, Group A, 824-838)

As in the interviews of Dave and Carrie, Tyrone's group, even when directly challenged, distanced themselves from the responsibility of keeping the group together. Felicia notes she is not the instructor, suggesting she feels she does not have either the responsibility, or perhaps ability, to aid someone like Tyrone, who needed a lot of support from those around him.

c. *Checking In.* In a quote highlighted above, Carley observed that group togetherness occurred when students checked in with each other. In fact, *Checking In* emerged as a *Group Work* sub-code, with students talking about it in terms of *help giving*, *balance*, and *help seeking*.

Students varied in reporting help giving or balance in checking in depending on whether they would recommend the class or not. The students who positively or neutrally recommended the class engaged in help giving or felt that groups were balanced in the feedback they gave each other. Carley, for example, indicated that in her groups:

We discuss each question and we all say, like we all put in what we think the answer is and we explain how we did it. And if like, two people are different about it we'll...just say "I did it this way" or "I agree" and "I disagree because I did it this way."

The students who would recommend the class expressed the sentiment that group work provided an opportunity to share and defend ideas while getting feedback from others. The ability to provide help also, at least for Craig, came with the satisfaction of learning the material better, noting "helping other people learn does teach me better."

All six students talked about engaging in help seeking: asking others for help or being asked by group members if they needed assistance. Moreover, all six students described the help they received from their group mates as useful. However, Emilia and Tyrone both mentioned times when they had needed help but encountered barriers to receiving it. Emilia expressed feelings of stress when others checked on her, noting that in one group "they would like stop occasionally to see if I need help but it just, it makes me feel like 'Oh my god! I need to step it up.'" Tyrone discussed a group member who "really knows her shit, but I don't even speak to her." When pressed about the relationship, he indicated that he thought their lack of communication was because "she just don't like me." In both cases, the students who would not recommend the class experienced a lack of trust that their group would provide the help they needed or wanted.

Review of the transcripts from the groups are full of instances when students either asked for help or asked each other whether they had completed a problem. A typical example occurred in Craig's group during a week close to the interviews.

Craig: What are we being asked to find?

Fiona: Where did you put -- where do you put in, oh, the three nails needed? So I think it's just wanting us to, like, single out the information that's important there. So, like, 48 inches and the 10 inches wide.

Craig: Oh, I see.

Fiona: I think that's what you're doing.

Craig: So there's going to be a six inch –

(150223, Group D, 83-86)

Here, Craig asked his group for help in identifying the main purpose of the problem. His group mate, Fiona, explained her perspective, which Craig seemed to agree with, as he then went on to start organizing the problem information.

d. Copying. The *Group Work* sub-code of *Copying* resulted in several themes: *engages in copying*, *lets others copy*, *observes copying*, and *classroom management of copying*. While all the students acknowledged copying occurred within the groups, clear divisions in how students talked about copying, dependent on whether they recommended the class, existed.

Both Tyrone and Emilia, who negatively recommended the class, said they copied. Emilia said her group at the time “just tell me to copy down the answer,” suggesting an element of group-sanctioned copying to quickly address Emilia's questions or catch her up to the rest of the group occurred. Tyrone differed slightly from Emilia, admitting to initiating the copying:

I've copied off of my classmates if they got like showing their work... so I can go back and look at it and do it like that. Because when I copy it down, I always, like, go back and look at it so I can understand it.

For Tyrone, copying from others was a strategy for learning the material, allowing him access to the content he was not able to cover during class. Thus, Tyrone and Emilia identified copying as a coping strategy for the lack of togetherness within their groups.

The four other students acknowledged copying occurred in the class but did not admit to themselves copying. The three students who positively recommended the class all noted that they had let others copy, although none specifically mentioned encouraging the practice. Instead, these students distanced themselves from the practice. For example, Carley, in talking about a woman who often copied, said “I’ll let her copy, but it’s...just going to hurt you in the long run.” Craig expressed a similar sentiment, noting “I feel bad if you’re going to copy my answers...come the test time you’re just, you’re not going to know what’s going on.” Thus, while the students universally acknowledged copying, the roles they played in the practice varied between the students, depending on whether they would recommend the class.

Review of the classroom audio demonstrates instances of copying. Although the transcript is subtle, in Tyrone’s group on the day diagramed in Figure 4.1, Tyrone started copying the work of Sarah and Dave when he realized he did not have enough class time to complete the material, even with help. This may explain why, in the diagram, a gap between the two sets of students grows until around 70 minutes into the period and then narrows slightly by the end of class. Tyrone did not need correct written work to earn credit for the assignments he was copying. On the problems he was copying, the instructor performed checks for completeness only, meaning Tyrone received no penalty for incorrect work. Tyrone’s quote above suggests he genuinely wanted correctly solved problems to examine later.

e. Accountability. The sub-code of *Accountability* deals with students' perspectives on graded assignments. Themes addressed the *distribution of the workload, lack of control, peer regulation, and self-accountability*.

Distribution of the workload and a lack of control were themes common among the students who were positive or neutral in recommending the class. They focused on the fact that the workload on group assignments was not always even and their frustration at their lack of control over these assignments. For example, in talking about the latter, Craig remarked:

I was sick one day and I was supposed to be recorder and turn our stuff in, so one of them had to turn it in instead and apparently we hadn't been on the same page because hers was a couple points off.

In talking about uneven workloads, Carley mentioned that "for our group project, two of my group members just decided not to do anything. So it was me and, uh, just me and this one other kid." For Carley, group members failed to follow through, so, to get her desired grade, she needed to do more work. Craig felt he had done his part by trying to make sure everyone understood, but when the submitted material was out of his control, the penalty frustrated him. In talking about the imbalance and lack of control, all of the students with positive experiences described conflicting feelings about trying to regulate their peers, either by reporting the imbalance to the instructor or speaking directly to the student they felt was not doing a good job.

In comparison to the students discussed above, Tyrone and Emilia, the students who negatively recommended *Mathematical Literacy*, said very little about their experiences within the groups on graded assignments. Emilia did not bring up her experiences with graded assignments in the context of the group at all. Tyrone did, but, rather than talking about

participation and the fact that the quality of the work was sometimes out of his hands, noted that group grades hid the fact that not everyone in the group necessarily understood the group's work.

The contrast between the experiences of the positive and neutral recommenders compared to the negative recommenders might be at least partially understood by examining an instance during which Carrie and Emilia's group negotiated a graded group assignment. The assignment was completed in the same week the rest of the transcript excerpts come from. For two of the three days that week, Emilia did not participate in completing the Reflections assignment. However, on the day she was recorder, and thus responsible for submitting the group's work, Emilia contributed to the conversation about the Reflection task. The task is shown in Figure 4.3.

Reflections Type a short answer to each question. 1. ☐ Explain in your own words what it means to solve an equation. If your answer doesn't use the word "true," it probably stinks. 2. ☐ What exactly is an equation? How does an equation differ from an inequality? 3. ☐ Take another look at your answer to Question 0 at the beginning of this lesson. Would you change your answer now that you've completed the lesson? How would you summarize the topic of this lesson now? 4. ☐ What questions do you have about this lesson?
--

Figure 4.3. Reflections Assignment for Emilia's Group. Taken from Sobecki and Mercer (2015, p. 151)

The transcript segments related to the group conversation about this assignment appears below, with the digressions from the conversation about the Reflections question removed. Spaces between speakers indicate jumps in the transcript.

Beth: You can write whatever you want for number one.

Emilia: What's that?

Beth: Oh, these are -- the reflections are really easy. Just write whatever for number one. Number two is done.

(150225, Group B, 324-326)

Carrie: Do you like -- you taught us how make the best decision, right?

Beth: Oh, yeah.

Emilia: Going on the road trip.
Carrie: We use mathematics to learn how to make the best-- to choose the best option.
Beth: Financially.
Carrie: Yeah. [inaudible] together.
Emilia: We use math?
Carrie: And critical thinking.
Emilia: Thinking to --
Beth: [unrelated utterance]
Carrie: Choose the best option financially. "What do you think the point of this lesson is?" And be like, this is an important skill for the rest of our lives.
(150225, Group B, 352-362)

Carrie: What's the next question?
Emilia: What did you guys say for question zero?
Carrie: Choosing the best option.
Beth: I said something about making decisions.
Emilia: I said making a decision.
Beth: I think that's what I said.
Emilia: So, making --
Beth: Using mathematics to make decisions. I wouldn't really change my answer, but now I know how to do lots of mathematics to learn nothing that I don't care about.
(150225, Group B, 369-375)

Emilia: Do we have any questions?
Beth: Nope.
(150225, Group B, 379-380)

In this conversation, Emilia functions primarily as a scribe, with Carrie and Beth effectively dictating answers, and minimal group-level reflection on the questions. Further, within this interaction, Carrie—who during her interview indicated she disliked not being in control of her grades—and Beth managed the group dynamic to produce an acceptable product *efficiently*. Thus, even positioned through classroom roles to act as a critical person in the discussion, Emilia lost the opportunity to reflect with and learn from her group on the assignment in the name of completing the assignment quickly. Without the classroom roles, Emilia's participation might have vanished entirely, but the assignment structure masked her lack of knowledge from the instructor.

Note that the scribe work Emilia did in this example differs from the copying discussed earlier. Here, Emilia was completing a group-graded assignment where each individual in the

group received the same grade, regardless of who completed the assignment. In contrast, when engaging in copying, the students were doing so for work graded for completeness, not correctness, so only the student who copied stood to lose.

Discussion: Group Work. The results demonstrate some of the consequences of group diversity, focusing on how students with diverse mathematical knowledge working together can create conditions where student goals come into conflict. During her interview, the instructor suggested that she *relied* on a diversity of mathematics knowledge within groups to provide the best opportunity for students to learn effectively from the curriculum. Although students recognized that groups often contained a large range of knowledge levels, not all students found while those in a position to help did not always believe checking in with and supporting others was a productive use of time. This resulting lack of togetherness in some groups did not meet the instructor's intentions for group work, and although she noticed it and worked to address the underlying causes by talking to students and attempting to bring groups together, these measures were not always enough. Despite the resulting issues and tensions for students related to diverse mathematics knowledge, the instructor suggested that the price was worth it to help support the overall classroom learning.

Relatedly, many of the classroom practices that students discussed were consequences of, or coping mechanisms for, addressing the range of needs within the groups. Through this lens, an uneven workload was a consequence of having high-knowledge students not trusting their slower moving group mates to do the work. Copying was, for at least some students, a coping mechanism to help them acquire access to the course materials when they could not participate fully in the discussion during class. Indeed, given the problem-heavy nature of the workbook and the lack of model problems in the textbook (see the supplementary textbook analysis in the

Appendix E). Under these conditions, the act of copying when students ran out of time in class became a quick way to generate study materials.

During her interview, Ms. Ann indicated awareness of the issues raised by students, and highlighted grading processes that allowed students to provide feedback on who contributed to various assignments, but also observed that students did not always take advantage of this option. Thus, although the curriculum allowed for formal measures of accountability for group projects, students themselves were not always willing to use them, which may speak to a broader goal of wanting to maintain social relationships within the class, particularly given the requirement for students to continue working in assigned groups throughout the semester.

Main Code 3: Instructor

The Instructor and Her Role: Instructor's perspective. Early in her interview, Ms. Ann stated, “my role is to facilitate conversations, I guess, and then to help fill in the gaps. I’m still their teacher.” She went on, saying, “they don’t already know how to do all of this,” indicating that she believed her content knowledge served an important purpose in the class.

In talking about her interactions with students, Ms. Ann said her main goal was to nudge students towards important mathematical ideas through questioning, such as “How do you think about this? How do you figure out how to solve this problem?” Although she intended to ask these questions, she admitted that she struggled to do so, explaining that she often defaulted to comments such as “I’m seeing something here that I’m not liking. Maybe you should go back and look there at it.”

Underlying all Ms. Ann’s discussions about student interactions was a focus on knowing her students as individuals and respecting them both mathematically and personally. At one point, she commented that one of her messages for students was “I just want everyone to feel

comfortable in my class.” As part of this, Ms. Ann identified off-task conversations as an opportunity to get to know her students better and create connections. For example, early in her interview Ms. Ann discussed a student who, in the context of helping him work more amicably in groups, she had given social skills feedback to, saying that “he wouldn’t talk to anyone in his group at the beginning.” As her relationship with this student developed, she found herself giving more general social feedback related to talking about others in non-offensive ways, which culminated in the student asking her to give him more such feedback when she felt it was appropriate.

Ms. Ann not only viewed off-task conversations as a way to get to know her students better but also as an opportunity to help students see broader mathematical points, commenting, “I can hear something they’re saying and go off on a little bit of a tangent that relates back sometimes. “Oh, that’s not really what I intended with this problem, but that’s really interesting.” Thus, while Ms. Ann primarily intended to use her position to help students learn the course content, she did not restrict herself to covering the curriculum as written, and valued the opportunity the format afforded her to get to know her students.

The Instructor and Her Role: Students’ perspectives. Table 4.7 shows the presence of themes for the six focus students related to the main code of *Instructor*, which had three sub-codes: (a) *Interactions*, (b) *Role*, and (c) *Attributes*. A majority of student comments fell into the Interactions sub-code. Although students’ comments about the teacher’s role and their interactions with her tended to differ for students who had positive versus negative reactions to the course, there were no such patterns for student comments about the instructor's attributes. In fact, only two themes emerged, with one student (Tyrone) remarking that she is knowledgeable about mathematics, and the majority of students saying generally positive things about the

instructor such as they liked her or they found her helpful. Although it is important to note that students tended to view the instructor positively, given the lack of patterns in the data, the *Attributes* sub-code is not discussed further.

a. Interactions. When talking about their instructor *Interactions*, one theme that emerged was students being *told to slow down*. The remaining themes broke down into two pairs of related themes. These were *explaining the material* at the individual or group level, and *checking on progress* at the individual or group level.

The three students with a positive experience in the class all reported that the instructor had, at some point, asked them to slow down or stay together with their groups. In contrast, neither Emilia nor Tyrone mentioned the instructor asking others to back up and help them.

With respect to individual instructor interactions, only Emilia and Tyrone mentioned interacting with the instructor outside of class: Tyrone talked about going to Ms. Ann's office and Emilia said she interacted with her through email. When these two mentioned in-class interactions, they almost exclusively used "I" or "me" rather than "us" or "we," suggesting they primarily interacted with the instructor individually during class, rather than with their groups. Of the students with more positive experiences, only Carley mentioned individual interactions with the instructor, and those related to in-class experiences.

Table 4.7

Instructor Themes Raised by Individual Students

Code	Sub-code	Theme	Experience					
			Positive			Neutral	Negative	
			Craig	Carley	Carrie	Dave	Emilia	Tyrone
3. <i>Instructor</i>	(a) <i>Interactions</i>	Tells to slow down	x	x	x			
		Explains the material (individual level)		x				x
		Checking on progress (individual level)					x	x
		Explains the material (group level)	x	x	x	x	x	
	(b) <i>Role</i>	Checking on progress (group level)		x	x	x		
		Important - source of knowledge	x	x				x
		Important - keeps them on task		x		x	x	
		Guide or facilitator	x	x	x	x		
	(c) <i>Attributes</i> ^a	Knowledgeable						x
		Experience her with positive affect	x	x	x			x

^aThe sub-code of *Attributes* does not show any clear convergent or divergent patterns in what the students raised for this code, so no further analysis is conducted.

In contrast, all students with more positive experiences primarily spoke about instructor interactions at the group level. Carrie, in talking about her interactions with the instructor in class, said “she’s just checking up on us and asking us, oh, did we get this question.” Carley described that during class “she’ll look at what we did and she’ll explain....So she kind of guides us. She doesn’t exactly bluntly give us the answer.” Emilia briefly mentioned group interactions with the instructor, but devoted significantly more of her discussion to individual interactions.

One interesting difference that emerged was when students identified the instructor as *explaining the material* or as *checking on progress* during their interactions with her. All the students used a form of “explain” to describe at least some of their interactions with the instructor (whether individually or in a group), and in different sections of their interviews almost all also said the instructor regularly checked their progress as a form of interaction.

Examining the classroom transcripts, an example of the instructor checking progress occurred on a day when the students were engaged in solving a series of break-even problems. Ms. Ann stopped by Carrie’s group, where prior to her arrival they had been off-task. Beth started the table’s interaction with Ms. Ann by commenting about the group’s off-task conversation. Ms. Ann continued by examining their work and checking their understanding:

Beth: We were just having a moment.
Ms. Ann: I’ll come back -- so, I wanted to flip back and check out this option. Okay. So, you got the one, 347 decided it was about 400. That sounds about right. And again, they’ve messed with you on the average and claimed that it’s -- is that what you guys decided on?
Beth: Yeah. You’d have to drive 700 miles.
Ms. Ann: Yeah.
Beth: It’s not true.
Ms. Ann: Yeah. They’re just sort of messing with you in the article.
Carrie: So, does that mean that after 700 miles it’s going to be 54 cents continued?
Beth: No, cheaper. It keeps going down.
Ms. Ann: It will actually get cheaper after that.
Beth: Because these keep going down.
Ms. Ann: This one you maxed out at 300, but this was unlimited mileage, right?

Beth: Yeah.
Ms. Ann: So that one would actually get cheaper if you went over that. So, if you're driving over 700 miles, it's a pretty good idea to rent a car actually.
Carrie: That makes sense.

(150225, Group B, 220-233)

At a different table on the same day, Ms. Ann helped a group that indicated it was stuck finding a formula for one of the problems. Ms. Ann helped Craig, who initiated the exchange, come to an understanding while his group members followed along, and she stayed until Craig seemed to fully understand the solution, providing a nice example of explaining the material.

Craig: ... We're having some trouble tackling this formula.
Ms. Ann: Ah, yes.
Craig: So she's thinking -- I think she's right, \$2.30 plus 15 times--
Helen: Times .25.
Ms. Ann: Ah, okay.
Craig: It seems like it's on the right path.
Ms. Ann: But I think it's [long pause] backwards.
Craig: What?
Ms. Ann: ... I know how I did it, and that's not how I did it, and so I was trying to think for a second why that doesn't work.
Helen: What would you do?
Ms. Ann: Because logically it seems like it should. What I did is I just said is "M is whole miles." Instead of changing that, let's change the price.
Craig: Right.
Ms. Ann: So if it's 15 cents for a quarter mile--
Craig: That's 15 cents.
Ms. Ann: --what's it going to cost for a whole mile?
Craig: Oh, right. So .15 times four?
Helen: .15 times 4.
Ms. Ann: Yeah.
Craig: So 60 cents, so plus 60M. Gotcha.
Carley: So what plus 60M?
Craig: 2.30 for the first one.
Carley: 2.30 plus...
Craig: And the bottom one would be--
Ms. Ann: Because if somebody plugs a one mile in, you don't want to divide that by four, right? And say less.
Craig: I knew I was like on the right path, but not--
Ms. Ann: You want to change the price.
Craig: Wait. So the next one--
Ms. Ann: But it's a good thing that you caught that that was an issue.

(150225, Group D, 592-619)

Thus, checking on progress and explaining the material were regular functions the instructor performed during the class, and was a fairly universal experience for the students.

b. Role. The *Role* sub-code broke down into three main themes, two of which related to how she was important to the class. In particular, students identified the instructor as important as *a source of knowledge* and because she *keeps them on task*. In addition, some students identified her as a *facilitator or guide*.

Students across the recommendation spectrum identified the instructor as a source of knowledge or as someone who kept them on task. With respect to her knowledge, Emilia noted that “sometimes it’s like she might as well not be there. But other times I’m really glad she’s there because there are like questions that I can’t ask my peers because they don’t get it either.” For keeping students on-task, Dave said the instructor was there to “[aid] the groups along, trying to get them where they need to be.” In addition to her importance, all the students who positively recommended *Mathematical Literacy* identified the instructor as a facilitator or a guide, while neither Emilia nor Tyrone did.

Review of the classroom audio shows Ms. Ann moving around the room constantly throughout the time for group work. During this time, she talked to students about the content, enforced group norms, and checked in with students to make sure everyone understood the expectations and big ideas of each activity. Thus, she regularly interacted with students in multiple capacities. In the excerpts discussed in the previous section, she intervened with Carrie and Emilia’s group when they were off-task. In the case of Craig and Carley’s group, she thought about the mathematics the students had done, attempting to understand the strengths and weaknesses of their solution in real time, while guiding the group towards a sensible solution.

Discussion: *The Instructor and Her Role.* Both the students and the instructor valued their interactions, although for different reasons. The students focused primarily on the ways in which the instructor supported their learning. In contrast, although the instructor identified the mathematical conversations as important, she also valued the interpersonal connections the class structure allowed her to make.

Just as for *Group Work*, the diversity in mathematics knowledge within groups seems to underscore the differences in how students spoke about the instructor. Although the students with mostly positive experiences talked about group interactions with the instructor, the students with negative experiences generally focused on individual instructor interactions. This difference in language could signal that the instructor spent more time talking to Emilia and Tyrone individually. The results for *Togetherness in Group Work* showed an example where Emilia spoke exclusively to Ms. Ann about material her group mates had already covered. However, the divide between who mentioned group versus individual experiences with the instructor may simply demonstrate that Emilia and Tyrone did not consider group conversations with the instructor as integral to their instructor interactions. Both were usually present when Ms. Ann spoke with their groups, but this did not mean they participated in the same way as their group mates. Not identifying the instructor as a guide or facilitator suggests they had different opinions about the role the instructor plays in the room, and that role is about their individual learning, not about the experiences of the group. Indeed, given that they were often behind in their groups, Emilia and Tyrone may not have felt empowered to engage with the instructor at the group level when it came to discussing the mathematics curriculum materials.

Discussion

The results presented in this chapter demonstrate some of the complexity within students' perceptions of a single classroom. Although the students had different types of experiences, they almost all struggled with the curriculum and identified a lot of negative feelings associated with doing mathematics. This finding may demonstrate the fact that although some students in this class found success and joy in doing mathematics differently, their mathematical histories often come with a legacy of failure and struggle.

Many of the divergent patterns between students with different experiences might be rooted in the choice to have students with diverse mathematical backgrounds working together in groups. The six focus students and their groups had a wide variety of mathematical abilities, which influenced both group and instructor interactions. For example, all the students acknowledged that copying occurred, but examining how these students talked about it shows that some of the students copied to cope with a lack of togetherness and perhaps to gain access to model problems for independent study. The students letting others copy did not, in their interviews, necessarily express understanding of the reasons why students might choose to engage in copying. Instead, they distanced themselves from the practice, even while letting others copy their work.

Relatedly, how the students talked about a lack of togetherness in groups reveals two sets of values coming to conflict in the group space. Dave, from a knowledge point of view, seemed well positioned to help students like Tyrone, but, during his interview, Dave communicated the value he placed on quickness and efficiency. Instead of seeing helping students like Tyrone as an avenue towards learning the material more completely, Dave seemed to resent being asked to slow down and help Tyrone. As other have noted, community college students value efficiency

in their instruction (Cox, 2009), perhaps because they more fully understand the cost-benefit analysis of their time. At least a few students, such as Craig and Carley, either valued or came to value the opportunity that explaining work to others gave them.

Importantly, Emilia and Tyrone, the two African American students in the group of interviewed students, were also the only two students in the interview sample who did not complete the course. Their experiences are poignant and important to understanding the ways the *Mathematical Literacy* environment failed to meet the needs of some students, particularly two students of color. However, the small sample means it is important to limit generalizations about the experiences of students of color in the class: other, non-interviewed students of color were in the class and succeeded. Thus, while the experiences of Emilia and Tyrone should be considered within the context of students who had negative experiences in the class, attribution of their experiences to issues of identity or race should be drawn with caution. I discuss this in more detail in the discussion chapter.

Comparing students' perceptions of the class to the intentions of the instructor demonstrates another level of differences. Although the instructor often expressed awareness of the issues students struggled with or were frustrated by, many of these tensions were related to instructional choices connected to broader educational goals. For example, the instructor did not like seeing a lack of togetherness. However, she felt that mathematically diverse groups were the best way to support the learning of *all* students. That said, Cohen and Lotan (2014), in their widely cited work on group work in heterogeneous classrooms, suggested that two reasons to switch to a group relate to intellectual and equity goals. The instructor discussed intellectual goals for placing diverse students together, however this seemed to lead to issues of inequity

within the groups. The question then becomes one of whether and how to support students in navigating these divides to better meet equity needs, beyond what the instructor has already tried.

CHAPTER 5:

DISCUSSION AND CONCLUSIONS

This dissertation examines a recently developed developmental curriculum that uses group work and real-world problem solving to teach algebraic skills and concepts to developmental college students. These classes, often called *Mathematical Literacy*, represent a big shift in the curriculum and instruction of mathematics for both developmental students and instructors, raising questions about whether the enactment meets the intentions of those who implement it (Gehrke, Knapp, & Sirotnik, 1992; Stein, Remillard, & Smith, 2007). In Chapter 3, I presented findings related to what a *Mathematical Literacy* classroom looks like in practice and selected outcomes from the course. In Chapter 4, I examined the same classroom at a more personal level, contrasting the curriculum and instructional intentions of the instructor with students' experiences and perceptions of the classroom.

The findings I discuss complement the small but growing body of work examining community college mathematics curriculum and instruction (Mesa, in press). In particular, my dissertation provides a fresh lens on what occurs in developmental mathematics, which until fairly recently has been relatively unexamined at the classroom level by those trained in mathematics education (Mesa, Wladis, & Watkins, 2014). In addition, the qualitative and mixed methods I used to examine student perceptions in Chapter 4 add to the large-scale quantitative work done on the Carnegie Pathways, a different enactment of *Mathematical Literacy* (Norman, 2017; Sowers & Yamada, 2015; Yamada, Bohannon, & Grunow, 2016; Yamada & Bryk, 2016).

The research discussed in the last two chapters investigates three main questions. The first question examines what an implementation of *Mathematical Literacy* looks like. The second research question explores the persistence and affective outcomes associated with the course.

The last question takes a more personal look at the intended and enacted curriculum, focusing on how students' experiences varied within a single implementation and how their perceptions of these experiences contrasted with the instructor's intentions with respect to the course.

In this chapter, I briefly review the main results for each question. These findings are then linked across chapters and to the broader educational literature, offering future directions for study based on lingering questions. I then explore the limitations of this work and close with a discussion of the implications of my findings and final conclusions.

Research Question 1: What Does *Mathematical Literacy* Look Like in Practice?

Chapter 3 provided an overview of the curriculum and its enactment at the classroom level, identifying curriculum components and how the instructor allocated time to these components during instruction. Reforms in K-12 mathematics have advocated for classrooms that encourage collaborative discourse about the important mathematical ideas covered in class (National Council of Teachers of Mathematics [NCTM], 2000, 2014), which can take place at either the group or classroom level. I used the reform-based Three-Phase Lesson format of Van DeWalle, Karp, and Bay-Williams (2013) to analyze the enactment of a *Mathematical Literacy* curriculum. The analysis revealed that the curriculum elements, as represented by the assignments and curriculum structure, provided multiple opportunities for students to engage in real-world problem solving. In addition, the instructor role was highly decentralized in the observed implementation. Given that research at the K-12 level has demonstrated that teachers can struggle to cede classroom authority to students to the degree intended by mathematics reforms (Cohen, 1990; Heaton, 2000; Drake & Sherin, 2006), the instructor's ability to step away from classroom-level lecture for approximately 80% of the class period provides proof that a group-work-focused instructional model can be used in developmental mathematics.

Moreover, despite the high anxiety towards mathematics typically experienced by the developmental population (Sprute & Beilock, 2016) and the short period to acclimate to group work and problem solving, the students engaged for sustained periods of time with the curriculum. My examination of students' patterns of engagement with different curriculum activities showed that students within their groups spent only around 15 minutes total per class sessions in off-task conversations (which included a recommended 10-minute break). Moreover, they required only minimal direct teacher intervention to stay on-task. Although students may have engaged in some degree of *individual* off-task behavior, when they spoke to each other, it was generally related to the class.

At the K-12 level, studies of group work and books outlining effective group-work instruction (e.g., Cohen & Lotan, 2014) suggest one of the few reasons an instructor should intervene with groups is to reign in hopelessly off-task groups. In K-12 classrooms, this may pose an important function for effective group work: in their study of a fourth-grade group, Wood and Kalinec (2012) found that approximately 50% of group time was spent off-task. However, the off-task behaviors of the adult students in *Mathematical Literacy*, as discussed in Chapter 3 and summarized above, demonstrate different, more curriculum focused, patterns. That said, regular teacher "check-ins" may have influenced the students' behavior: one of the themes that emerged from student interviews, discussed in Chapter 4, identified the instructor's role as one of keeping them on-task. Given that the instructor rarely arrived at groups when they were off-task, the instructor's classroom presence and her regular assessment practices were, in combination with students' own goals, enough to keep students on-task. The regular engagement of the students with the mathematics curriculum may relate to the idea that community college students value their time (Cox, 2009) and have high achievement goal orientations (Mesa, 2012).

Thus, they may recognize that the opportunity to complete work during class allows for efficient completion of their goals. Studies of adult students working in groups, although in non-mathematical contexts, have shown similar focused behaviors (Barkaoui, So, & Suzuki, 2008). In combination, these results suggest that developmental students are capable of monitoring of their behavior without substantial teacher intervention in a way that K-12 students might not be able to.

The enacted curriculum, as described in Chapter 3, also differs from the problem-centered models recommended by the K-12 mathematics education reforms primarily because no classroom-level discussion about the big mathematical ideas of the section took place. Teaching in a manner that facilitates students' discussions is meant to support students in making connections and learning the material (NCTM, 2014), and many classroom studies have focused on examining issues surrounding whole-class discussions (e.g., Heaton, 2000; Herbel-Eisenmann & Cirillo, 2009; Jackson, Garrison, Wilson, Gibbons, & Shahan, 2013; Lampert, 1990). However, in the classroom observed for this dissertation, after the instructor let students start working in their groups, she did not usually call the class together again to discuss the content of the day. When the instructor did engage in whole-class teaching, she primarily did so to *lecture* about a key point or issue related to individual mathematics problems. Thus, the circumstances of this class seem to differ from common practices in reform-oriented K-12 mathematics classrooms. That said, the lack of classroom-level discussion about important mathematical ideas does not necessarily mean that discussions did not occur, only that these conversations were relegated to the group time.

Conducting conversations about big mathematical ideas within groups, especially in the community college classroom has merit. The curriculum materials in the observed *Mathematical*

Literacy classroom usually covered multiple multi-step problems in a single period. The diagrams of how groups moved through the curriculum, as described in Chapter 3, show that groups completed the problems at different rates. The sheer volume of material students covered each period may have made the feasibility of a classroom-level discussion difficult to implement. Using a problem-rich curriculum does not necessarily require that students have the chance to complete problems. Rather, the point is to let students engage in productive struggle so they are better equipped to understand the mathematical issues at play (NCTM, 2014). Thus, in developmental classrooms, classroom-level discussion might be appropriate, even if students have not completed all the problems. The question of whether a classroom-level conversation might be a direction for future implementations of *Mathematical Literacy* should be considered.

A lack of a whole-class discussion in *Mathematical Literacy* may also make sense in a developmental mathematics context for reasons beyond the amount of material and pacing of a particular lesson. As discussed earlier, developmental students seem to have a capacity to self-regulate. In addition, the range of mathematics backgrounds, from no prior algebra class to Calculus means a one-size-fits-all approach to classroom discussion simply may not regularly meet the needs of most students. In fact, this wealth of mathematical background knowledge means that some students might be well positioned to help those with less procedural knowledge navigate the mechanics of mathematics. Within the context of the observed *Mathematical Literacy* class, the most natural place to look for these conversations occurs when students discussed the Reflection questions because these questions were intended to engage students in thinking about the big ideas raised by the mathematics and were assigned a group grade, opening the door for students to discuss these problems together. However, the descriptive statistics presented in Chapter 3 show groups spent an average of only around two minutes per day on

these questions and textual evidence in Chapter 4 shows that, at least in some cases, these “discussions” looked more like “dictation” by the more quickly working students. These results suggest that the Reflections questions may not function as intended during enactment in the *Mathematical Literacy* classroom, minimizing the opportunities slower working students have to engage meaningfully with the big ideas of each section. A closer examination of the transcripts while students were working on individual problems may yield evidence of these conversations taking place, leaving the question of the location of the “After” discussion an open one.

Research Question 2: Persistence and Affective Outcomes of *Mathematical Literacy*

Results from Chapter 3 show that the students who persisted in *Mathematical Literacy* experienced generally positive affective outcomes. Although few of these results were statistically significant after corrections for multiple comparisons, the comparatively small sample size means that the trends should not be discounted. Statistical models looking for predictors of attitudinal change also show few clear patterns, with the exception that expecting to earn an A predicted attitudinal growth on three of the four scales. The general lack of significant predictors suggests that the benefit of the class on attitudinal change was fairly evenly distributed among students *who persisted*, regardless of their demographics or educational backgrounds.

Although similar sample size issues restrict the degree of generalizability of claims made about the differences between the persistent and non-persistent samples, important patterns between those who did and did not persist emerged. Comparisons of the pre-scores on each attitude scale did not reveal initial differences between the two samples on any of the tested comparisons, suggesting the students started in similar places when it came to attitudes towards mathematics.

However, results from Chapter 3 suggest that *Mathematical Literacy* does not produce equitable outcomes for all students. In particular, Black and White students do not persist at similar rates. As noted in Chapter 3, this result does not necessarily imply a failure of the *Mathematical Literacy* curriculum to effectively teach Black students, given the many factors external to the classroom that can cause a student to withdraw from a course. Nor does a lack of persistence an indicator of that these students lack the innate ability to succeed. Rather, these results mean that Black students, for one reason or another, were not empowered by the curriculum in the same ways as their White peers. Thus, although the research questions of this study do not directly address issues of identity or race, and the study was not designed to facilitate close examinations using identity as an analytic lens, the findings related to race should not be ignored. As noted earlier, the students who persisted in my sample were less likely to be Black. In Chapter 4, the two students who had negative experiences (Emilia and Tyrone) were both Black, while the remaining focus students came from different racial and ethnic backgrounds. These results raise questions about the role of equity and race in the *Mathematical Literacy* context.

Previous results examining developmental education show that Black students disproportionally enroll in developmental education (Attewell, Lavin, Domina & Levey, 2006), while previous work examining college mathematics classrooms engaged in group work shows that groups can be a powerful tool for improving the success of students of color (Treisman, 1992). Mathematics education scholars such as Gregory Larnell and Danny Martin are engaged in examining issues related to racial identity in more traditionally taught developmental mathematics classes (Larnell, Boston, & Bragelman, 2014; Larnell, 2016; Martin, 2006). The added complexity and social layers a problem-centered, group-intensive instruction brings to the

developmental context suggests that future work on *Mathematical Literacy* classrooms should consider how Black and other traditionally underserved students fare in this environment.

Research Question 3: Contrasting Students' Experiences and Instructor Intentions

Chapter 4 picks up where Chapter 3 left off, examining the perceptions of students who had positive, neutral, or negative experiences in the class, with the purpose of identifying relationships between student experiences and their ways of talking about the class. The results demonstrated almost all the students connected with at least some of the real-world content, which is consistent with the idea that community college students value understanding how what they learn connects to the real world (Cox, 2009). Here also, the students' experiences matched up with the intentions of the instructor, who mentioned wanting her students to see how mathematics connected to the world.

Despite some commonalities, often students with different experiences saw and discussed the same classroom practices in very different lights. Of the six focus students in this study, Emilia and Tyrone were the two with negative experiences, and during their interviews both emphasized their frustration with often being behind and needing more support than they felt they received from either their instructor or group mates. The group-level diagrams presented in Chapter 4 show divisions within Emilia and Tyrone's groups: some students within their groups moved through the curriculum much more quickly than Tyrone and Emilia. Issues of togetherness in small group work are not new (e.g., Cohen & Lotan, 2014). However, the interviews reveal that although all of the focus students demonstrated awareness of divisions within groups, both in terms of mathematics ability and in terms of how the groups worked together, the students with more positive experiences did not necessarily connect their own actions with the needs and frustrations of the slower moving students.

As previously mentioned, one might view the *Mathematical Literacy* context as offering valuable peer-to-peer teaching opportunities. However, students with stronger content knowledge did not necessarily believe their role was to support other students, given that doing so worked against the goal of completing their work efficiently. Community college students value their time (Cox, 2009) and have strong achievement goal orientation (Mesa, 2012). Completing classes like *Mathematical Literacy* is a necessary, but rarely welcome, step towards students' goals. Thus, the competing needs for efficiency (such as the ability to finish all homework in class) and to learn well (as some students in the groups needed) fell into conflict.

Alternatively, it might be that efficiency was not what prevented students from helping. During their interviews, all the focus students mentioned negative feelings while doing mathematics, even those with positive experiences. Given the generally high anxiety towards mathematics of the developmental population (Sprute & Beilock, 2016), students may not have felt equipped to explain the material in a confident or knowledgeable way. Take, for example, Felicia, a group member of Tyrone's, who, when challenged by Tyrone about working ahead, commented, "I'm not a teacher." Thus, the avoidance of responsibility from some students seems, if not particularly kind or fair, then at least rational. It is also important to note that the lack of togetherness and the distancing of students from the responsibility of helping those around them was not a universal event in the classroom. Group- and classroom-level diagrams presented in Chapter 3 show some groups working together. Examinations where all the group members participated in interviews would be needed to determine whether groups that

functioned well together did so because the students with more knowledge were willing to help or because the group members had more evenly distributed mathematical needs.²³

The instructor's intentions with respect to the class were reflected in the classroom experiences students described, although sometimes her intentions contributed to students' frustrations in unintended ways. For example, during her interview, the instructor identified creating mathematically diverse groups as a strategy for helping all students get through the curriculum with maximal support. However, as the above demonstrates, and the instructor recognized, this did not always play out as intended for students, even with her efforts to help bring groups together both inside and outside the classroom. Despite these difficulties for students, the instructor felt the benefits outweighed the risk of creating groups that occasionally did not work well together. Experimentation with alternative group assignment strategies that prioritize knowledge levels differently might be an avenue of future research, especially given the ability of adult students to self-regulate. For example, grouping more independent students together might free up instructor time to focus on the students requiring more support through the material.

Alternatively, devoting more effort to helping students understand each other and their differences might improve outcomes. For example, a mismatch between students with different experiences occurred with students' perceptions of classroom practices related to copying. The students with negative experiences tended to identify copying as a learning strategy that helped them cope with a lack of togetherness. Their need for copied materials is particularly salient

²³ Textual analysis of group transcripts can provide some window into students' knowledge levels, but does not allow for non-interviewed students to articulate their reasons for or against helping others. The week chosen for analysis was the only observation week during which three pairs of interviewed students were grouped together.

given that the non-traditional curriculum materials do not provide easy access to example, or model, problems to study outside the classroom. Other students encouraged copying to efficiently close gaps in completion while still others distanced themselves from the practice, even though they let their work be copied. It would be interesting to see whether encouraging open discussion about the reasons why some students use copying as a strategy might improve group dynamics. However, instructor resources are limited. The instructor's primary role is to teach students, so asking her to also engage in these social goals might prove more than a single individual can accomplish in a semester.

Limitations

Although Field Community College's (FCC) program has a large student population taking *Mathematical Literacy*, this was still only a single-site study. FCC, as argued previously, was a valuable location in which to examine an enactment of *Mathematical Literacy*. Ms. Ann, the instructor from whose classroom the majority of the data came, had been instrumental in bringing *Mathematical Literacy* to FCC and was one of the first instructors at FCC to teach it. As a result, she had several years of experience with the course prior to this project. Moreover, her educational training includes both a content Masters in mathematics, which the majority of community college mathematics instructors have, in addition to a less commonly held PhD in education. Her dual content expertise positions her as someone who can navigate nuanced mathematical questions and discussions with flexibility and knowledge. She was thus highly invested in the success of the course and more prepared, by her education and interests, than most community college instructors are to take on such a dramatic shift in instruction.

Conclusions based on this work do not help us understand how intentions and enactment might change in classrooms taught by less invested instructors or at sites where the *Mathematical*

Literacy implementation occurs differently. The survey results attempted to partially address the bias introduced by examining only one classroom by including six additional sections. However, the sample of sections was one of convenience, and they did not necessarily reflect all *Mathematical Literacy* sections at FCC, not to mention elsewhere. All but one surveyed section was taught by full-time rather than adjunct faculty, despite the fact that adjunct faculty, including at FCC, routinely teach developmental mathematics around the country (Cohen, Brawer, & Kisker, 2013; Blair, Kirkman, & Maxwell, 2013). Although this study intentionally focused on a classroom in which there was a good chance of a strong implementation of the *Mathematical Literacy* curriculum, in studies of broader implementation of *Mathematical Literacy* and other novel instructional methods in developmental mathematics, it is important to include adjunct faculty.

By the same token, the sample of interviewed students, while reflecting demographic and mathematical diversity, was comparatively small and lacked variety along several background characteristics of interest (e.g., family status). Again, student participation was one of convenience, and participation was non-random. In the future, I would think more carefully about how to structure both incentives for participation and data collection processes to better accommodate the needs of students with busy and demanding extracurricular commitments. In addition, the students were only interviewed once, around the middle of the semester. Individual students' experiences can vary widely, even within a single class, over a single semester. Restricting my analysis of student experiences to a single time point minimizes the amount we can understand about a particular individual's lived experience throughout a semester-long course.

Although the results of this study suggest that summative discussions about important mathematical ideas are not occurring at the classroom level, I did not perform a textual analysis at the group level to identify whether these conversations occur within groups instead, and what each student's contributions might be to such discussions. Future studies could delve below the patterns in lesson structure and student engagement uncovered in this study, to more closely examine individual students' mathematical contributions to their groups and their learning in this and other novel developmental mathematics contexts.

Implications

The results of this study suggest that many of the elements of the intended curriculum of *Mathematical Literacy* are being enacted for at least some of the students, including a problem-centered approach to learning, centered around real-world contexts. However, the drastic differences in experiences between students raises questions about the overall effectiveness of the implementation and whether the class is reaching those who most need the help.

Mathematical Literacy represents a new instructional approach for students who have previously had largely negative mathematical experiences. While questions remain about how to best leverage the unique diversity of the developmental mathematics population in a problem-centered classroom context to support all students in accessing the curriculum, the level of activity and engagement students exhibited, regardless of the nature of their experience, provides hope that the instructional method can be modified, over the long run, to provide a more personal and empowering mathematical experience. In this implementation, although students were positioned to support each other in certain types of mathematics learning, they did not necessarily buy into the notion that doing so was a valuable use of their time. The question then becomes whether *Mathematical Literacy* instructors should consider alternative methods of

supporting students. For example, they could devote their efforts to helping students understand how different values explain certain behaviors. A second option might be to let students work in separate groups while devoting more of their instructional resources to students like Tyrone and Emilia. Acknowledging the strengths of the developmental population (i.e., can self-regulate, value efficiency, goal oriented) opens the door to many creative approaches to classroom management.

Given the diversity in mathematics backgrounds of developmental mathematics students, and given the degree to which this diversity seemed to impact their experiences in the *Mathematical Literacy* classroom, future work in college-level mathematics classrooms should carefully consider how a large diversity of prior mathematical experiences impacts the findings in these classrooms. This is particularly relevant to results related to the effectiveness of novel instructional methods such as group work or flipped instructional designs (McGivney-Burelle & Xue, 2013; Ziegelmeirer & Topaz, 2015).

The lack of togetherness exhibited by Tyrone's and Emilia's groups provided an early, key clue to predicting their ultimate withdrawal from the class. As previously discussed in Chapter 4, students (like Emilia and Tyrone) who did not complete the class were almost universally lagging behind in their groups the first week of the semester. College-level instructors teaching mathematics classes using group work might be able to use a lack of togetherness as an early indicator that a student is at risk of not successfully persisting through the course. While instructors may have been aware of this phenomenon on some level, deciding to act on it and provide intervention early might be a necessary step to help students like Emilia and Tyrone thrive in group work environments. By noticing and intervening early enough, these students might start to experience different outcomes.

Lastly, the classroom- and group-level diagrams I introduced in Chapter 3 have many implications for future classroom research. The methodology allows for tracking the instructor through time and space, even without video data. Moreover, the syntax that generates the diagrams, once created can easily be adapted to highlight different events of interest over time and space. The use of such classroom visualizations opens the door for many new and creative ways of blending discourse analysis with more quantitative methodologies.

Conclusions

Community college mathematics classrooms are an important and under-examined area in mathematics education. My dissertation contributes to this small but growing field of literature focused on the curriculum and instruction of the developmental mathematics sequence, demonstrating that problem-centered, group-intensive instructional methods can be implemented with the developmental population, and in fact these methods may leverage some of this adult populations' strengths, such as a desire for real-world contexts and the ability to stay on task and work independently. However, the implementation of group work and problem solving in *Mathematical Literacy*, while providing students with a relevant mathematics curriculum that many students connected with, also raises questions related to who persisted through the course and points to the difficulties of supporting diverse students with competing values. The possibilities of these classes are exciting, but much work is still needed to help us understand the challenges and benefits of such courses, and the ways in which these challenges can be overcome.

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APPENDIX A

POST-OBSERVATION PROTOCOL AND SURVEY INSTRUMENTS

Classroom Post-Observation Protocol

Date:

Time of class observed:

Time of observation protocol being filled out:

Number of students present:

Number of groups:

1. What chapter/section of their text did the students work on today?
2. Describe the classroom and first few minutes before class started.
3. Describe the general flow of the class period and the general teacher actions throughout the time. Include approximations of how much time was spent on each phase of the class period.
4. Describe the general atmosphere of the classroom during the lesson.
5. Describe the general engagement of the students in their class work.
6. Describe moments in class that seemed to surprise the students or teachers.
7. Describe any moments during class that seemed interesting or important for student learning.
8. Describe any moments during the class that seemed interesting or important for managing the classroom norms.
9. Describe any moments during the class that surprised me.

Pre-Survey

Name: _____

Mathematical Background & Attitude Survey

1. In high school, the highest level of math I took was: _____

2. This is my first math class in college: ___ yes ___ no

If no:

(a) I have taken other math classes at FCC: ___ yes ___ no

If yes, please list those classes here:

(b) I have taken mathematics at other colleges: ___ yes ___ no

If yes, please list those classes here:

3. I intend to earn a degree at Parkland or another school: ___ yes ___ no

If yes,

(a) what is your intended major?

(b) how certain are you of your intended major?

___ Very certain ___ Somewhat certain ___ Somewhat uncertain ___ Very uncertain

(c) what is the highest degree do you plan to earn?

___ Associate

___ Bachelor

___ Masters or higher

___ Other: _____

4. The thing I like most about mathematics is:

5. The thing I dislike most about mathematics is:

6. My race or ethnicity would best be described as:

7. Gender: ___ Male ___ Female ___ Other

This survey consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Check the box that most closely corresponds to your feelings about the statement. Please answer every question.

	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
Mathematics is a worthwhile and necessary subject.					
I want to develop my mathematical skills.					
I get a great deal of satisfaction out of solving a mathematics problem.					
Mathematics helps develop the mind and teaches a person to think.					
Mathematics is important in everyday life.					
Mathematics is one of the most important subjects for people to study.					
This math course will be very helpful no matter what I decide to study.					
I can think of many ways that I use math outside of school.					
Mathematics is one of my most dreaded subjects.					
My mind goes blank and I am unable to think clearly when working with mathematics.					
Studying mathematics makes me feel nervous.					
Mathematics makes me feel uncomfortable.					
I am always under a terrible strain in a math class.					
When I hear the word mathematics, I have a feeling of dislike.					
It makes me nervous to even think about having to do a mathematics problem.					
Mathematics does not scare me at all.					
I have a lot of self-confidence when it comes to mathematics.					
I am able to solve mathematics problems without too much difficulty.					
I expect to do fairly well in any math class I take.					
I am always confused in my mathematics class.					
I feel a sense of insecurity when attempting mathematics.					
I learn mathematics easily.					
I am confident that I could learn advanced mathematics.					
I have usually enjoyed studying mathematics in school.					
Mathematics is dull and boring.					
I like to solve new problems in mathematics.					
I would prefer to do an assignment in math than to write an essay.					

	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
I would like to avoid using mathematics in my future studies.					
I really like mathematics.					
I am happier in a math class than in any other class.					
Mathematics is a very interesting subject.					
I am willing to take more than the required amount of mathematics.					
I plan to take as much mathematics as I can during my education.					
The challenge of math appeals to me.					
I think studying advanced mathematics is useful.					
I believe studying math helps me with problem solving in other areas.					
I am comfortable expressing my own ideas on how to look for solutions to a					
I am comfortable answering questions in a math class.					
A strong math background could help me in my professional life.					
I believe I am good at solving math problems.					
Learning mathematics is mostly memorizing facts.					
There is only one way to solve a mathematics problem.					
I enjoy working in small groups in math class.					
I learn mathematics best when I get to work in a group.					
I learn mathematics best when I work by myself.					
The math I learn in school rarely helps me when I use math in my daily life.					
In my previous math classes, the teacher usually lectured for most of the class period.					
In my previous math classes, we worked in groups almost every day.					
I liked how my previous math classes were taught.					

Thank you!

Post-Survey

Name: _____

Mathematical Attitude Survey

1. Was this class different than most of your prior mathematics classes? ____y ____n

If yes, how was the class different?

2. Did you find this class harder or easier than other mathematics classes? Please explain.

3. What things about this class most helped you learn mathematics?

4. What things about this class were not useful in helping you learn mathematics?

5. My expected grade in the class is: ____A ____ B ____C ____D or lower

6. (a) what is your intended major?

(b) how certain are you of your intended major?

____Very certain ____Somewhat certain ____Somewhat uncertain ____Very uncertain

This survey consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Check the box that most closely corresponds to your feelings about the statement. Please answer every question.

	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
Mathematics is a worthwhile and necessary subject.					
I want to develop my mathematical skills.					
I get a great deal of satisfaction out of solving a mathematics problem.					
Mathematics helps develop the mind and teaches a person to think.					
Mathematics is important in everyday life.					
Mathematics is one of the most important subjects for people to study.					
This math course will be very helpful no matter what I decide to study.					
I can think of many ways that I use math outside of school.					
Mathematics is one of my most dreaded subjects.					
My mind goes blank and I am unable to think clearly when working with					
Studying mathematics makes me feel nervous.					
Mathematics makes me feel uncomfortable.					
I am always under a terrible strain in a math class.					
When I hear the word mathematics, I have a feeling of dislike.					
It makes me nervous to even think about having to do a mathematics problem.					
Mathematics does not scare me at all.					
I have a lot of self-confidence when it comes to mathematics.					
I am able to solve mathematics problems without too much difficulty.					
I expect to do fairly well in any math class I take.					
I am always confused in my mathematics class.					
I feel a sense of insecurity when attempting mathematics.					
I learn mathematics easily.					
I am confident that I could learn advanced mathematics.					
I have usually enjoyed studying mathematics in school.					
Mathematics is dull and boring.					
I like to solve new problems in mathematics.					
I would prefer to do an assignment in math than to write an essay.					

	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
I would like to avoid using mathematics in my future studies.					
I really like mathematics.					
I am happier in a math class than in any other class.					
Mathematics is a very interesting subject.					
I am willing to take more than the required amount of mathematics.					
I plan to take as much mathematics as I can during my education.					
The challenge of math appeals to me.					
I think studying advanced mathematics is useful.					
I believe studying math helps me with problem solving in other areas.					
I am comfortable expressing my own ideas on how to look for solutions to a					
I am comfortable answering questions in a math class.					
A strong math background could help me in my professional life.					
I believe I am good at solving math problems.					
Learning mathematics is mostly memorizing facts.					
There is only one way to solve a mathematics problem.					
I enjoy working in small groups in math class.					
I learn mathematics best when I get to work in a group.					
I learn mathematics best when I work by myself.					
The math I learn in school rarely helps me when I use math in my daily life.					
This course made me think about mathematics differently than I had before.					
I enjoyed this course more than most of my prior math classes.					
I found the format of this class frustrating.					
I would take another mathematics class that was taught the way this one was.					
In this class, the teacher usually lectured for most of the class period.					
In this class, we worked in groups almost every day.					
I like how this math class was taught.					

Thank you!

APPENDIX B

SURVEY SAMPLE AND DATA CLEANING DETAILS

This appendix provides supplementary statistics and coding notes related to the pre- and post-survey data. This survey was administered in two waves: the Pilot, which took place in Fall 2014, and the full study, which took place in Spring 2015. The survey was modified between the two waves to include more demographic data and additional background questions. The spring 2015 versions of the surveys are included in Appendix A. In total, 131 individuals completed the pre-survey and 82 took the post-survey. Table B.1 provides details about the breakdown and retention of the survey by wave.

Table B.1

Sample by Wave and Retention

Wave	Sections	Instructors	Pre-survey		Post-survey	
			Individuals	%	Individuals	%
Fall 2014	2	2	35	26.7	16	19.5
Spring 2015	5	4	96	73.3	66	80.5
Total	7	5	131		82	

ATMI

For both the pre- and post-ATMI, student answers were transcribed as numeric values reflecting their 5-point Likert scale choices (5 corresponding to “Strongly agree” and 1 to “Strongly disagree”). If a student checked two boxes, both values were transcribed as a two-digit number. In the cleaning stage of analysis, these values were replaced with missing values. Cleaning also included recoding and replacing the original transcription of reverse-coded items. Survey data for each wave were cleaned separately and then merged together.

Missing data summary. Of the 131 individuals in the pre-survey sample, 33 had missing values for at least one item in the ATMI (25.2%). Eighteen of these students were missing only one item on the ATMI (13.7%).

Confirmatory Factor Analysis on the ATMI. The full list of items for each of the four attitude scales (confidence, enjoyment, motivation, and value), as defined by the ATMI (Tapia & Marsh, 1996) is presented in Table B.2 below. Prior to using the attitude scales in the planned analysis, I ran descriptive statistics for the pre- and post-survey attitudes. For each scale, for both the pre- and post-survey, using the students with complete item-level data for the scale, I computed:

1. The mean value of the scale.
2. The amount of missing data.
3. The distribution of the scale scores.
4. Cronbach's alpha.

These statistics are presented in Table B.3.

Using the full pre-survey sample, I ran a confirmatory factory analysis (CFA) using maximum likelihood estimation, removing items that did not fit the data well, until the overall fit statistics (i.e., RMESA, CTI, TLI) fit the desired parameters. In particular, I was looking for $RMESA < .05$, $CFI > 0.95$, and $TLI > 0.95$ (Hu & Bentler, 1999). I then conducted a face validity check, examining the retained items for cohesiveness with the named construct. This resulted in one item being removed from the *Motivation* scale (Motivation 1 in Table B.2). Lastly, I conducted factor rotations and examined individual item loadings. The *Value* scale had two items that did not load as well as the others, but they were close to the 50% threshold and the face validity check seemed reasonable, so I retained them for the scales.

Table B.2

Full ATMI Instrument by Attitude Scale

Scale	Items
Self-confidence	1. Mathematics is one of my most dreaded subjects. (R)
	2. My mind goes blank and I am unable to think clearly when working with mathematics. (R)
	3. Studying mathematics makes me feel nervous. (R)
	4. Mathematics makes me feel uncomfortable. (R)
	5. I am always under a terrible strain in a math class. (R)
	6. When I hear the word mathematics, I have a feeling of dislike. (R)
	7. It makes me nervous to even think about having to do a mathematics problem.
	8. Mathematics does not scare me at all.
	9. I have a lot of self-confidence when it comes to mathematics.
	10. I am able to solve mathematics problems without too much difficulty.
	11. I expect to do fairly well in any math class I take.
	12. I am always confused in my mathematics class. (R)
	13. I feel a sense of insecurity when attempting mathematics. (R)
	14. I learn mathematics easily.
	15. I believe I am good at solving math problems.
Enjoyment	1. I get a great deal of satisfaction out of solving a mathematics problem.
	2. Mathematics is dull and boring. (R)
	3. I like to solve new problems in mathematics.
	4. I really like mathematics.
	5. I am happier in a math class than in any other class.
	6. Mathematics is a very interesting subject.
	7. I am comfortable expressing my own ideas on how to look for solutions to a difficult problem.
	8. I am comfortable answering questions in a math class.
Motivation	1. I am confident that I could learn advanced mathematics.
	2. I have usually enjoyed studying mathematics in school.
	3. I would prefer to do an assignment in math than to write an essay.
	4. I would like to avoid using mathematics in my future studies. (R)
	5. I am willing to take more than the required amount of mathematics.
	6. I plan to take as much mathematics as I can during my education.
	7. The challenge of math appeals to me.
	8. I think studying advanced mathematics is useful.
Value	9. A strong math background could help me in my professional life.
	1. Mathematics is a worthwhile and necessary subject.
	2. I want to develop my mathematical skills.
	3. Mathematics helps develop the mind and teaches a person to think.
	4. Mathematics is important in everyday life.
	5. Mathematics is one of the most important subjects for people to study.
	6. This math course will be very helpful no matter what I decide to study.
	7. I can think of many ways that I use math outside of school.
	8. I believe studying math helps me with problem solving in other areas.

Table B.3

ATMI Attitude Scales Statistics for Pre- and Post-survey Samples

Attitude	Scale	Total items	Pre								Post				
			<i>n</i>	Mean	Skew	Kurtosis	Alpha	RMSEA	CFI	TLI	<i>n</i>	Mean	Skew	Kurtosis	Alpha
Confidence	Original	15	111	2.94	0.08	2.24	0.95	0.145	0.836	0.809	67	3.00	0.12	2.46	0.94
	Confirmatory	7	116	2.88	0.04	2.17	0.92	0.039	0.996	0.993	73	2.99	-0.05	2.33	0.92
Enjoyment	Original	8	123	3.00	0.10	2.46	0.88	0.108	0.936	0.910	78	3.09	0.09	2.48	0.86
	Confirmatory	7	123	2.95	0.15	2.52	0.88	0.049	0.990	0.985	78	3.03	0.13	2.51	0.85
Motivation	Original	9	123	2.88	0.00	2.84	0.87	0.129	0.883	0.844	78	2.93	-0.12	2.75	0.88
	Confirmatory	5	127	2.70	-0.02	2.63	0.81	0.017	0.999	0.998	81	2.80	0.00	2.47	0.85
Value	Original	8	115	3.77	-0.05	2.58	0.83	0.078	0.946	0.924	73	3.76	-0.48	3.79	0.88
	Confirmatory	6	116	3.72	-0.07	2.61	0.76	0.000	1.000	1.035	75	3.70	-0.47	4.07	0.83

Note. The values in this table reflect the statistics for the sample with complete data for the given scale.

Using the final item lists from the above fit criteria, I created my final scales and then reran the descriptive and fit statistics discussed earlier. These are also reported in Table B.3 above. The final retained items for each of the four attitude scales are reported in Table B.4 below. Table B.5 reports the correlations between the scores on the scales with imputed values. The correlation between motivation and enjoyment is somewhat high (.86), as is the correlation between enjoyment and confidence (.69). The remaining correlations are below .65. Because the attitude scales on the pre-survey population were generally normal, I imputed values for individuals with at most one item missing on a given scale using means for the final analysis. I do not report means for these versions of the scales.

Demographic and Mathematics Background Data Sources and Cleaning

The HLM models used in this analysis draw from demographic and mathematical background data gathered on either the pre- or post-survey. The coding conventions and level detail for the final categories are included below.

Gender. Gender was asked on the pre-survey with three categories: Male, Female, and Other, with space provided for students to write their gender if they did not identify as male or female. Using this information, an indicator for Male was created, with 1 corresponding to male students and 0 to females. No students who answered the question chose “other.”

Table B.4

Confirmatory Factor Analysis Items for ATMI by Scale

Scale	Items
Confidence	1. Mathematics is one of my most dreaded subjects. 2. My mind goes blank and I am unable to think clearly when working with mathematics. 4. Mathematics makes me feel uncomfortable. 5. I am always under a terrible strain in a math class. 7. It makes me nervous to even think about having to do a mathematics problem. 8. Mathematics does not scare me at all. 13. I feel a sense of insecurity when attempting mathematics.
Enjoyment	1. I get a great deal of satisfaction out of solving a mathematics problem. 2. Mathematics is dull and boring. 3. I like to solve new problems in mathematics. 4. I really like mathematics. 5. I am happier in a math class than in any other class. 6. Mathematics is a very interesting subject. 8. I am comfortable answering questions in a math class.
Motivation	3. I would prefer to do an assignment in math than to write an essay. 4. I would like to avoid using mathematics in my future studies. 5. I am willing to take more than the required amount of mathematics. 6. I plan to take as much mathematics as I can during my education. 7. The challenge of math appeals to me.
Value	2. I want to develop my mathematical skills. 3. Mathematics helps develop the mind and teaches a person to think. 5. Mathematics is one of the most important subjects for people to study. 6. This math course will be very helpful no matter what I decide to study. 7. I can think of many ways that I use math outside of school. 8. I believe studying math helps me with problem solving in other areas.

Note. Numbers reflect the original ATMI scale numbering.

Table B.5

Pairwise Correlations Between ATMI CFA Factors

Scale	Self-confidence	Enjoyment	Motivation	Value
Self-confidence	1.00			
Enjoyment	.69	1.00		
Motivation	.62	.86	1.00	
Value	.38	.63	.61	1.00

Race. Race variables were transcribed from the pre-survey and coded into one of the five racial/ethnic categories used in this study:

- White (i.e., Caucasian, white)
- Black (i.e., African American, Black)
- Asian (i.e., Pilipino, Vietnamese, Asian)
- Hispanic (i.e., Latino, Latina, Hispanic)
- Other (i.e., mixed race, two or more races indicated)

In the HLM models, these were entered as separate indicator variables, with White serving as the dummy variable.

Age. Birthday was transcribed from the consent documents and then converted to age using the date of their pre-survey. This variable was then centered so that a value of 0 corresponded to the mean sample age. This statistical adjustment means that the value of the age coefficient in the output table should be interpreted as the added contribution of each year of age above that of the average-aged student.

Prior developmental mathematics. These data were collected on the pre-survey. In the pilot, students were asked directly whether they had taken prior developmental mathematics and asked to list the course names. In the main survey, students were asked what other math classes they had taken at either FCC or at another college and to list them. From the titles of these courses an indicator of prior developmental mathematics coursework was created, with 1 corresponding to having taken prior developmental coursework. The level of the developmental class was not considered in creating the indicator.

Expected grade. On the post-survey the students were asked the grade they anticipated earning in their class, with four choices: A, B, C, or D or lower. A few students selected two choices. These were converted to the lower grade indicated. No students who took the post-survey indicated they expected to earn a D or lower. Indicators for the three grade choices were

created and entered into the HLM models, with anticipated grade of C serving as the dummy variable.

Highest anticipated degree. On the pre-survey, students were asked to indicate the highest degree they planned to earn, with four choices: Associates, Bachelors, Masters or higher, or Other, with space provided to write in an answer. Several students chose “Other” and then described a degree that corresponded to one of the other choices (e.g., PhD, JD). These answers were converted to the appropriate category. These four levels were entered into the HLM models as separate indicators, with Associates as the dummy variable.

Highest high school mathematics class. These were free response items and were coded into one of eight categories. If students listed several classes, the highest level was transcribed (e.g., if someone wrote “Algebra/Trig,” it was transcribed as Trigonometry):

- Pre-algebra
- Algebra (of any kind other than college algebra (e.g., Algebra, Algebra I, Algebra II))
- Geometry
- Trigonometry or Pre-calculus
- Calculus
- Statistics
- Other (e.g., discrete mathematics, business math)
- Unknown high school math (e.g., either stated they did not know or left question blank)

This variable was not ultimately included in the HLM models, since prior developmental mathematics coursework also measures mathematics history and was a more recent measure of the students’ mathematics ability given that FCC places students in developmental mathematics using a standardized content exam. Table B.6 reports the cross-tabulations and percentages of prior developmental enrollment with the highest mathematics course taken in high school.

Table B.6

Mathematics Backgrounds and Prior Developmental Mathematics Experience

Highest high school mathematics	Prior developmental experience	<i>n</i>	Percent	
			Total	High school math level ^a
Pre-algebra (<i>n</i> =8)	Yes	6	4.6	75.0
	No	2	1.5	25.0
Algebra of some kind (<i>n</i> =52)	Yes	18	13.7	34.6
	No	33	25.2	63.5
Geometry (<i>n</i> =16)	Yes	6	4.6	37.5
	No	10	7.6	62.5
Trigonometry or Pre-calculus (<i>n</i> =28)	Yes	8	6.1	28.6
	No	20	15.3	71.4
Statistics (<i>n</i> =7)	Yes	3	2.3	42.9
	No	4	3.1	57.1
Calculus (<i>n</i> =5)	Yes	1	0.8	20.0
	No	3	2.3	60.0
Other or unknown (<i>n</i> =15)	Yes	6	4.6	40.0
	No	8	6.1	53.3
Total		131		

^aThis column reports the percentage of those students within the category for the highest high school mathematics, using the sample size reported in that row as the base. Some students were missing data on their prior developmental mathematics enrollment, so the percentages do not necessarily add up to 100% for each pair in this column.

Supplementary Analysis Using Original and Final ATMI Scales

The pages that follow contain the same tables presented in Chapter 3, but with outputs using both the original ATMI scales and the final scales (thus, the results for these scales are replicas of what was presented in Chapter 3). Table B.7 presents the *t*-test outputs initially presented in Table 3.8 and Table B.8 presents the HLM models from Table 3.10. Lastly, Table B.9 presents the pre-attitude score coefficients for the supplementary analysis predicting growth based on the same covariates in the main analysis. I leave off reporting the other coefficients as they replicate those in Table B.8.

Table B.7

Attitude Change Results for Persistent Students for Original and Final ATMI Scales

Attitude	Scale	N	Mean score		p-value	t-statistic
			Pre-survey	Post-survey		
Confidence	Original	75	2.91	3.01	0.175	1.369
	CFA	78	2.82	2.96	0.167	1.395
Enjoyment	Original	78	2.97	3.12	0.022	2.344*
	CFA	78	2.93	3.06	0.047	2.019*
Motivation	Original	80	2.87	2.94	0.184	1.340
	CFA	78	2.67	2.77	0.166	1.399
Value	Original	80	3.74	3.81	0.236	1.195
	CFA	82	3.69	3.71	0.702	0.385

* $p < 0.05$

Note. Attitude scores were scaled to be on a 5-point scale with 1 corresponding to “Strongly agree” and 5 corresponding to “Strongly disagree.” The reported test statistics and their significance are for the individual tests. Applying a Bonferroni results in the Enjoyment coefficient no longer being significant. The number of individuals for each scale varies due to missing data for some individuals on some scales.

Table B.8

HLM Coefficients for Models Predicting Post-survey Attitude Scores by ATMI Scale

	Confidence		Enjoyment		Motivation		Value	
	Original	CFA	Original	CFA	Original	CFA	Original	CFA
Fixed effects								
Pre-attitude scores	0.712*** (0.093)	0.619** (0.104)	0.481*** (0.084)	0.510** (0.085)	0.695** (0.071)	0.657** (0.087)	0.711** (0.111)	0.782** (0.141)
Male	0.054 (0.156)	0.317+ (0.189)	0.263* (0.121)	0.289* (0.129)	0.262* (0.113)	0.226 (0.151)	0.039 (0.124)	0.060 (0.149)
<i>Race/Ethnicity^a</i>								
Black (n=9)	-0.279 (0.198)	-0.130 (0.252)	0.145 (0.175)	0.220 (0.183)	0.123 (0.150)	0.259 (0.198)	-0.071 (0.167)	-0.024 (0.204)
Hispanic ^b (n=4)	-0.008 (0.267)	0.446 (0.337)	0.150 (0.219)	0.169 (0.233)	-0.025 (0.208)	0.101 (0.279)	-0.545* (0.240)	-0.454 (0.292)
Asian/Other ^b (n=5)	-0.221 (0.250)	-0.003 (0.295)	0.224 (0.188)	0.260 (0.200)	-0.104 (0.179)	-0.085 (0.240)	0.416* (0.202)	0.540* (0.242)
Age (years)	0.012 (0.010)	0.013 (0.012)	0.022** (0.008)	0.021* (0.009)	0.016* (0.008)	0.017+ (0.010)	-0.004 (0.009)	-0.004 (0.011)
Prior developmental (n=27)	0.106 (0.145)	0.233 (0.182)	-0.061 (0.115)	-0.047 (0.125)	0.149 (0.109)	0.023 (0.146)	-0.142 (0.124)	-0.271+ (0.142)
<i>Expected grade</i>								
A (n=20)	0.521* (0.221)	0.787** (0.275)	0.510** (0.162)	0.471** (0.172)	0.421** (0.156)	0.554** (0.207)	0.114 (0.178)	-0.197 (0.211)
B (n=31)	0.342+ (0.188)	0.449+ (0.236)	0.145 (0.151)	0.071 (0.161)	0.029 (0.140)	0.061 (0.188)	0.022 (0.156)	-0.148 (0.186)
<i>Anticipated degree</i>								
Bachelors (n=28)	0.109 (0.226)	-0.052 (0.263)	-0.145 (0.169)	-0.215 (0.180)	-0.072 (0.162)	0.053 (0.214)	0.078 (0.175)	0.106 (0.211)
Masters or higher (n=21)	0.336 (0.232)	0.182 (0.281)	0.023 (0.185)	-0.081 (0.196)	0.042 (0.178)	0.143 (0.231)	0.301 (0.190)	0.223 (0.232)
Unknown ^b (n=2)	0.458 (0.397)	0.095 (0.499)	0.624+ (0.325)	0.469 (0.345)	0.435 (0.308)	0.593 (0.407)	0.396 (0.335)	0.400 (0.409)
Constant	0.498 (0.328)	0.607 (0.384)	1.366*** (0.314)	1.337** (0.329)	0.649* (0.252)	0.595+ (0.317)	1.047** (0.406)	0.925+ (0.513)
Random effects								
Teacher	0.000+	0.000**	0.146***	0.127**	0.092**	0.026	0.000*	0.144**
Residual	0.466***	0.598**	0.378***	0.403**	0.362**	0.491**	0.399**	0.477**
N	54	57	58	58	59	60	58	60

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

^a The samples sizes for these demographic categories are not necessarily reflective of the sample for any given model. Each analysis was run on the sample of students with complete data on all items included in the model, with a maximum possible sample of 63 individuals, with the implication that the *N*'s vary by model.

^b Sample sizes for race run smaller than desirable for this type of analysis. However, given that the coefficients for "Hispanic" and "Asian" have opposite signs and combining them into a single category would erase this nuance, I leave them separated. However, results and relationships between race for these categories and the outcome should be interpreted with caution.

Table B.9

Pre-attitude Coefficients for Models Predicting Attitude Growth by ATMI Scale^a

	Confidence		Enjoyment		Motivation		Value	
	Original	CFA	Original	CFA	Original	CFA	Original	CFA
Fixed effects								
Pre-attitude scores	-0.288**	-0.381***	-0.519***	-0.490***	-0.305***	-0.343***	-0.289**	-0.218
	(0.093)	(0.104)	(0.084)	(0.085)	(0.071)	(0.087)	(0.111)	(0.141)
<i>N</i>	54	57	58	58	59	60	58	60

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

^a The same covariates as the results presented in Table B.8 were included in these models. However, since the coefficients on the other included independent variables are the same, they are not reported again.

APPENDIX C

ANNOTATED STATA SYNTAX FOR THE CREATION OF GROUP-LEVEL DIAGRAMS

In this Appendix, I outline the steps necessary to prepare Excel transcripts for Stata import and then, within Stata, create the basic code used to construct the group-level diagrams discussed in Chapters 3 and 4 of this work. As part of this, I provide an annotated version of my Stata syntax for the group-level diagrams. Annotations relate to the architecture of the code and the adjustments made to keep the code flexible. Creating the classroom-level diagrams uses similar structure and syntax strategies, with appropriate adjustments for groups rather than individuals. All the names included in the figures and example syntax are pseudonyms.

Step 1: Preparing Excel Transcripts for Stata Import

The Stata code used to construct the final group-level diagrams in Chapter 3 was created so that transcripts from different days and different groups were located within a single file. I created this file by merging the individual timestamped transcripts for each group and day (i.e., the 12 separate Excel files from each observation were combined). A typical excerpt from an Excel transcript is pictured in Figure C.1 below.

Transcripts were prepared for Stata import in two important ways:

1. Header names (variables) used underscores instead of spaces when a space was warranted (e.g., `instructor_present` instead of “instructor present”).
2. Once all the changes were made, the files were saved as tab delineated text files.

Step 2: Clean Transcript Data in Stata

In a separate Stata syntax file, not discussed here, the text file versions of the transcripts were read into Stata and cleaned so that:

	A	B	C	D	E	F	G	H
1	id	time	adj_time	diff	turn	wd_ct	problem	instructor present
264	Jen:	2482	2507	16	Which one? I have the two 135's and the girl next to me has the	21	Off-topic	1
265	Henry:	2498	2523	1	Are they the same page?	5	Off-topic	1
266	Jen:	2499	2524	2	They're the same page, but they screwed up _____.	10	Off-topic	1
267	Gabby:	2501	2526	1	The numbers throw you off?	5	Off-topic	1
268	Ann:	2502	2527	8	That's weird. So what it almost sounds like is they caught a mistake and tried to fix it and made another one in the process.	25	Off-topic	1
269	Jen:	2510	2535	1	Yeah.	1	Off-topic	1
270	Henry:	2511	2536	7	Dang. Less than 15.10.	4	2-8, Applications 1-5	0
271	Gabby:	2518	2543	3	What is it? Less--	4	2-8, Applications 1-5	0
272	Henry:	2521	2546	2	When you use less than 100 minutes.	7	2-8, Applications 1-5	0
273	Jen:	2523	2548	7	Describe when the remaining value... When you've used more than 60 minutes.	12	2-8, Applications 1-5	0
274	Henry:	2530	2555	8	Less than 70, right? Oh, yeah. Okay, all right. You're right.	11	2-8, Applications 1-5	0
275	Jen:	2538	2563	6	Used more than 70, yeah.	5	2-8, Applications 1-5	0
276	Henry:	2544	2569	3	The two tables below display the charts--	7	2-8, Applications 1-5	0
277	Gabby:	2547	2572	1	Used more than 70?	4	2-8, Applications 1-5	0
278	Jen:	2548	2573	21	Yeah, more than 70. My lovely classmates with calculators, these are going to be up to you.	17	2-8, Applications 1-5	0
279	Henry:	2569	2594	5	The cost to ride with the yellowish taxi is...	9	2-8, Applications 6-10	0
280	Jen:	2574	2599	2	Oh, okay, so it's gonna be--	6	2-8, Applications 6-10	0
281	Henry:	2576	2601	1	2.30.	1	2-8, Applications 6-10	0

Figure C.1. Example of Excel Transcript from a Single Group and Day

1. All names were consistent in the transcripts across days and groups. The general purpose of this step was to remove typos in names and variable labels I was using from the data file.
2. Categorically coded items (such as **problem** in the Excel file excerpt in Figure C.1) were assigned a unique numeric value so that each problem graphed had a number, not a text-string, associated with it. In addition, these numbers reflected a logical order for the purposes of identifying their location in the curriculum, discussed in more detail below. An example of a recoded variable is below in Table C.1.
3. The transcript included variables indicating the associated date and group.

A couple of things are worth noting about the recoded variable example in Table C.1. Recall that the data for each day and group were merged into a combined file. This serves the purpose of allowing the code that creates the diagrams to pull a single file each time it starts a new diagram. However, it comes with the complication that some problems, like reflections, could be done each day. The recoding scheme shown above assigns each mathematics problem a unique number, chosen so that problems within a lesson were consecutive and corresponding to the textbook order. Sections occurring later in the curriculum received higher numbers. When a new section started, the numbering skipped ahead to the next multiple of ten to keep the mathematical transformations done in later steps uniform. Class activities that could happen every day (i.e., off-task, helping other groups, planning, homework assignments), were assigned the same values (the highest numbers, starting with 50) regardless of on which day they occurred.

Table C.1

Example of Recoded Categorical Variable

Categorical Code	Recoded number	Categorical Code	Recoded number
2-7, Class 3	0	2-9, Group 1	30
2-7, Applications 1	1	2-9, Group 2	31
2-7, Applications 2	2	2-9, Group 3	32
2-7, Applications 3	3	2-9, Group 4	33
2-7, Applications 4	4	2-9, Group 5	34
2-7, Group 1	5	2-9, Group 6	35
2-7, Group 2	6	2-9, Group 7	36
2-7, Group 3	7	2-9, Group 8	37
2-7, Group 4	8	2-9, Group 9	38
2-8, Class	20	2-9, Group 10	39
2-8, Group 1-6	21	2-9, Group 11	40
2-8, Group 7-12	22	2-9, Group 12	41
2-8, Applications 1-5	23	2-9, Group 13	42
2-8, Applications 6-10	24	2-9, Applications 1	43
Reflection	50	2-9, Applications 2	44
Project	51	2-9, Applications 3	45
Review	52	2-9, Applications 4	46
Planning	53	2-9, Applications 5	47
Helping other group	54		
Off-task	55		
Technology	56		
Lecture	57		

Note. The dashed lines in the table indicate number jumps in the assigned values. For example, when the switch from problems from section 2-7 to problems from section 2-8 occurs, there is break in the assigned number from 8 to 20. Similar number gaps occur between the problems in section 2-9 and the problems that were common to all sections. This convention allowed problems from different days to always start on a multiple of 10, making later computations in the Stata code more consistent.

Step 3: Build Syntax

To keep the code as simple as possible while demonstrating the general structure, I present code that has been written for one day and one group, with notes indicating where adjustments would be made when producing diagrams for multiple days and groups. The green text is text annotation about the general purpose of the code following it. More specific annotations are in the right column, color coded to match the code with which it corresponds.

The code, as transcribed here, is not ready to be run in Stata. There are line breaks that would not be read properly by Stata in its current form. For analytic purposes, the code below would need to be edited for such issues.

Syntax	Explanation
<pre> cd "C:\File pathway to data set" foreach d in 150225{ foreach t in a{ clear use transcript_data_MWF_161110, clear drop if prob_num==56 drop if date!=`d'         drop if table!="`t'" ****Inserting date specific values for the graphs if `d'==150227{ loc plb=30 loc pub=47 loc prange=24 loc pline=1875 loc hline=2225 loc offline=2500 loc off_adj=200 label define id_prob_num 100 "p1" 300 "p3" 500 "p5" // 700 "p7" 900 "p9" 1100 "p11" 1300 "p13" 1500 "p15" // 1700 "p17" 1950 "w" 2050 "h1" 2150 "h2" 2300 "P" // 2400 "H" 2700 "technology" *x-axis day-specific values loc l3=2650 loc a=4 loc c1e=291/60 // Begin loc c2e=677/60 // Assessment loc c3e=729/60 // Begin loc c4e=806/60 // Before </pre>	Set appropriate directory. Starting loops for different days & groups. Here I am only calling one day (d) and one group (t). Calling data set. Dropping non-day and non-group data. Starting day-specific data. There will be one loop like this for each day of data. Local values that indicate the upper and lower bounds of the problem numbers associated with this day. Values for the placement of the blue lines in the final graphs. Assigning whole number labels to the problems that will be displayed on the y-axis. Setting the location of the off-task separator line. Setting values associated with the time at which different class activities started; the number of values corresponds to the maximum

```

loc c5e=1907/60 // Group time
loc c6e=2031/60 // Lecture
loc c7e=3985/60 // Group time
loc c8e=4141/60 // Lecture
loc c9e=5190/60 // Group time
loc c10e=5347/60 // Lecture
loc c11e=6265/60 // Group time
loc c12e=6466/60 // Technology
loc c13e=6601/60 // Class over
*colors of regions
loc r1="blue*.2"
loc r2="gs10"
loc r3="blue*.2"
loc r4="orange*.2"
loc r5="white"
loc r6="orange*.2"
loc r7="white"
loc r8="orange*.2"
loc r9="white"
loc r10="orange*.2"
loc r11="white"
loc r12="orange*.2"
loc r13="white"
}

g grp_id_num=6
  replace grp_id_num=1 if idn==1 // "Ms. Ann"
**Table A
  replace grp_id_num=2 if idn==7 // "Dave"
  replace grp_id_num=3 if idn==15 // "Sarah"
  replace grp_id_num=4 if idn==16 // "Tyrone"
  replace grp_id_num=5 if idn==17 // "Felicia"
**Table G
  replace grp_id_num=2 if idn==2 // "Beth"
  replace grp_id_num=3 if idn==4 // "Carrie"
  replace grp_id_num=4 if idn==8 // "Emilia"

loc i1="Ann"

```

number of regions in the data set. For this example, the day used all the regions. On other days, this was not the case. In those cases, these variables were still defined, but were assigned a value of "missing".

Assigning a color to each region that will be in the final graph to differentiate between...

Ending day-specific loop

In the original file, individuals have a separate number assigned to them. At this point, the data set has been reduced to a single day and group. This code creates a variable that assigns the retained group members consecutive, evenly-spaced numeric values that are subsequently consistent within the code. "Ms. Ann" is the instructor.

Creating a local variable that will take on the name of the instructor for diagram-labeling purposes.

<pre> if "`t'"=="f"{ loc i2="Dave" loc i3="Sarah" loc i4="Tyrone" loc i5="Felicia" loc i6="Non-table student" loc range=.15 replace grp_id_num=6 if idn!=1 & idn!=7 & idn!=15 & idn!=16 & idn!=17 loc o="24 25 26 27 28 29" } ***Setting up the hidden points necessary to plot the area regions of the graphs loc max=`offline'+`off_adj' g e1=(`prange'+`a')*100 if time>0 & time<=`c1e' g e2=(`prange'+`a')*100 if time>`c1e' & time<=`c2e' g e3=(`prange'+`a')*100 if time>`c2e' & time<=`c3e' g e4=(`prange'+`a')*100 if time>`c3e' & time<=`c4e' g e5=(`prange'+`a')*100 if time>`c4e' & time<=`c5e' g e6=(`prange'+`a')*100 if time>`c5e' & time<=`c6e' g e7=(`prange'+`a')*100 if time>`c6e' & time<=`c7e' g e8=(`prange'+`a')*100 if time>`c7e' & time<=`c8e' g e9=(`prange'+`a')*100 if time>`c8e' & time<=`c9e' </pre>	Starting a loop that creates labels for the group that the diagram will be constructed for. The code must include this loop for each group in the data set. Assigning labels to each person in the group using local variables. This value adjusts the space between individuals in the final diagrams. It is computed based on the number of individuals in the group. Assigning a single value to all students not at the table for the plot. Ordering the individuals in the label of the final diagram (dependent on number of group members). Ending loop for group specific label values. Sets an upper boundary on the range of the plot using previously defined, day-specific values. Plotting the colored regions using the area plot command requires coordinate points with valid axis-scale values to exist within each region. In these plots, the range of the y-axis (problem) varies by day and the x-axis (time) points depend on the timestamps of individuals talking, which may not occur when needed. This code
--	--

<pre> g e10=(`prange'+`a')*100 if time>`c9e' & time<=`c10e' g e11=(`prange'+`a')*100 if time>`c10e' & time<=`c11e' g e12=(`prange'+`a')*100 if time>`c11e' & time<=`c12e' g e13=(`prange'+`a')*100 if time>`c12e' & time<=`c13e' sum(time) loc maxtime=`r(max) '  ****RENUMBERING THE PROBLEMS TO MAKE THE NUMBERING CONSECUTIVE AND CONSISTENT BETWEEN DAYS loc crange=50-(`pub'-`plb')-1  g adj_prob_num=.     replace adj_prob_num = prob_num-`plb' if prob_num>=`plb'     & prob_num<=`pub' replace adj_prob_num = prob_num-`crange' if prob_num>=50  g id_prob_num=(1+adj_prob_num)*100     replace id_prob_num = (1+adj_prob_num-`range')*100 if grp_id_num==2 replace id_prob_num = (1+adj_prob_num-2*`range')*100 if     grp_id_num==1     replace id_prob_num = (1+adj_prob_num+`range')*100 if grp_id_num==4 replace id_prob_num = (1+adj_prob_num+2*`range')*100 if     grp_id_num==5     replace id_prob_num = (1+adj_prob_num+3*`range')*100 if grp_id_num==6 label values id_prob_num id_prob_num ****IDENTIFYING WHERE THE Y-AXIS LABELS WILL GO *Creating Level 1 labels for the group activity axis (problem solving, classroom activities, and off-task) loc l1=`hline'/2 </pre>	creates a set of uniform point values to guarantee the existence of a point in each region. Finds the upper bound of the x-axis (time) and creates a local variable with that value so it can be used as a point value later in the code. As discussed previously, problem numbers were structured both to reflect order in the curriculum and also to make mathematical manipulation easier, resulting in a more flexible code. The crange variable identifies the number of problems in a section; the adj_prob_num variable readjusts the numbering of the problems so the y-axis scale is consistent between days. The id_prob_num variable rennumbers the problem numbers of each individual in the group so that there is a slight offset to separate individuals within the same problem (i.e., if the problem number was originally 5, students might have their individual problem numbers assigned to be 4.7, 4.85, 5, 5.15, and 5.3).
--	---

<pre> loc l2=(`offline'-'hline')/2+'hline'  loc problems=" " loc activities=" "  graph twoway ///  (scatter id_prob_num time if grp_id_num==1 &   id_prob_num<`max', ms(0) mc(black) msize(vsmall)) /// (area e1 time, color(`r1')) /// (area e2 time, color(`r2')) /// (area e3 time, color(`r3')) /// (area e4 time, color(`r4')) /// (area e5 time, color(`r5')) /// (area e6 time, color(`r6')) /// (area e7 time, color(`r7')) /// (area e8 time, color(`r8')) /// (area e9 time, color(`r9')) /// (area e10 time, color(`r10')) /// (area e11 time, color(`r11')) /// (area e12 time, color(`r12')) /// (area e13 time, color(`r13')) /// (scatteri `offline' 0 `offline' `maxtime', recast(line) lc(navy) ls(refline)) /// (scatteri `hline' 0 `hline' `maxtime', recast(line) lc(navy)   ls(refline)) /// (scatteri `pline' 0 `pline' `maxtime', recast(line) lc(navy) lpattern(dash)) /// (scatter id_prob_num time if grp_id_num==1 & id_prob_num<`max', ms(0) mc(black) msize(vsmall)) /// (scatter id_prob_num time if grp_id_num==2 &   id_prob_num<`max', ms(0) mc(orange) msize(vsmall)) /// (scatter id_prob_num time if grp_id_num==3 & id_prob_num<`max', ms(0) mc(cranberry) msize(vsmall)) /// (scatter id_prob_num time if grp_id_num==4 &   id_prob_num<`max', ms(0) mc(blue*.7) msize(vsmall)) /// </pre>	Identifying midpoint of each Level 1 range. Creating Level 2 empty rows to have two-row labels from different sources. The remaining code creates the final figure. The plot itself is a combination of multiple plots. The order of the creation of these plots is important for the final figure. Plotting the instructor (first of two). Plotting the diagram background, colored, rectangular regions. Plotting the blue dividing lines separating different types of coded elements. Plotting the individual colored dots on the main diagram.
---	--

```

(scatter id_prob_num time if grp_id_num==5 &
  id_prob_num<`max', ms(0) mc(mint*1.2) msize(vsmall)) ///
(scatter id_prob_num time if grp_id_num==6 &
  id_prob_num<`max', ms(0) mc(gs8) msize(vsmall)) ///
(scatter id_prob_num time if grp_id_num==. &
  id_prob_num<`max', mc(black) msize(large)) ///
(scatter id_prob_num time if grp_id_num==. &
  id_prob_num<`max', mc(orange) msize(large)) ///
(scatter id_prob_num time if grp_id_num==. &
  id_prob_num<`max', mc(cranberry) msize(large)) ///
(scatter id_prob_num time if grp_id_num==. &
  id_prob_num<`max', mc(blue*.7) msize(large)) ///
(scatter id_prob_num time if grp_id_num==. &
  id_prob_num<`max', mc(mint*1.2) msize(large)) ///
(scatter id_prob_num time if grp_id_num==. &
  id_prob_num<`max', mc(gs8) msize(large)) ///
, ///
xtitle("Time (min)") ytitle("Group activity") ///
xscale(range(0 110)) xlabel(15 30 45 60 75 90 105) ///

ylabel(`11' `""Assignment" "`problems'"" `12' `""Class
  activity" "`activities'"" `13' "Off-task" 100 200 300 400
  500 600 700 800 900, valuelabel labsize(vsmall) noticks
  nogrid) ///

legend(order("`o'") label(24 "Instructor") label(25 "`i2'")
  label(26 "`i3'") label(27 "`i4'") label(28 "`i5'")
  label(29 "`i6'") rows(1) colgap(2) keygap(.5)) ///

title("Group `t' individual contributions")

}

}

```

Replotting the individual colored dots with non-existent data using a larger marker. This results in no additional points on the diagrams but enables the legend to have larger markers than are used in the actual plot.

Setting up x-axis scales and labels (does not change between days).

Setting up y-axis scales and labels. To do this, the command line calls several previously created local variables to identify label placement.

Creating the legend using larger markers and with appropriate names. (Done with a large number of local variables.)

Closing the day/group loops.

APPENDIX D

EXAMPLE UNIT INDEX FROM TEXTBOOK

The lesson reproduced comes from *Pathways to Math Literacy* by Dave Sobecki and Brian Mercer (2015). In this Appendix I include the unit title page outline (Figure D.1) showing all of the lessons in the unit. The lesson pages that students worked through during all the classroom examples included in Chapter 3 come from this unit, which was covered over a four-week period.

Outline
Lesson 1: What Are the Chances?
Lesson 2: Of Planes, Boats, Doll Houses, and Dr. Evil
Lesson 3: 88 Miles Per Hour!
Lesson 4: It's All Relative
Lesson 5: Ins and Outs
Lesson 6: Oh Yeah? Prove It!
Lesson 7: What's Your Problem?
Lesson 8: Indecision May or May Not Be My Problem
Lesson 9: All Things Being Equal

Figure D.1. Index on Title Page for Unit 2 in Textbook (Sobecki & Mercer, 2015, p. 85)

APPENDIX E

TEXTBOOK ANALYSIS SAMPLING, CODING, AND SUMMARY STATISTICS

This appendix describes the sampling procedures, coding, and general findings of an analysis designed to gain a measure of the amount of real-world problem solving that was embedded into the curriculum materials. As students spent the majority of their time solving problems from the course textbook while in their groups, an analysis of the nature of the problems in the text offers some measure of the students' exposure to mathematics used in real-world contexts during their *Mathematical Literacy* class.

As discussed in the results section of Chapter 3, the text for the course (Sobecki & Mercer, 2015) was packaged as a loose-leaf workbook. Not including the table of contents, acknowledgements, and publishing inserts, the textbook had 338 pages devoted to lesson content or organization. Table E.1 presents the different types of pages that occurred in the textbook and a count of how many pages in the text fell into that categories. Categories are organized by the approximate order each page type occurred in within individual lessons.

Using a random number generator in Excel (the **rand** function), I assigned a random value between 0 and 1 to each of the 338 pages within the main body of the text. The pages were then sorted according to their random values and the first 33 in the new order that were not blank, a Unit Title Page, an Extension, or a Portfolio page. The Blank, Unit Title Pages, Portfolio, and Extension pages were omitted from this analysis because they were primarily about organizing the unit, supporting students in their own organization, or very uncommon.²⁴

²⁴ Reflection questions were always included on the Portfolio pages. Although these are questions of interest in this dissertation, the purpose of the analysis in this section was to gauge the amount of real-world connections in the curriculum materials, and Reflections questions were generally about mathematical ideas rather than mathematics problems the students were asked to solve.

Table E.1

Workbook Page Types and Descriptions

Page type	Description	<i>n</i>	Percent
Unit title page	Title pages to each four-week unit.	4	1.2
Introduction/class	Usually the first page of each lesson, with a brief introduction describing a motivating reason or question related to the work students will be doing in the lesson. Also included Class math problems (see Class for a description of this type of problem).	23	6.8
Introduction/group	Sometimes the first page of each lesson, with a brief introduction describing a motivating reason or question related to the work students will be doing in the lesson. Also included Group math problems (see Group for a description of this type of problem).	13	3.8
Class	Class problem page; These were usually the first questions in the unit, intended to be completed individually.	69	20.4
Group	Group problem page; These questions intended to be completed with group mates and usually built off the class problems. Problems contained some degree of scaffolding.	110	32.5
Portfolio	Portfolio checklist and reflections page; included a description of all the associated assignments for the lesson, with check boxes for students to keep track of whether they had completed the project or not.	36	10.7
Applications	Application problem page; These were math problems that were turned in for homework and usually built off the group problems, but had less scaffolding.	64	18.9
Extension	Problems at the end of the unit that were meant to be completed when groups had finished all their other mathematics problems from the textbook (rare).	1	0.3
Blank	Blank pages.	18	5.3

An examination of 33 of the 338 pages is roughly 9.8% of the total pages, and 13.6% of the pages that fell into one of the included pages ($n=279$). For each page included in the analysis, I listed every problem on the page and coded it for (a) whether the problem was a word problem, expressed as a complete sentence, (b) whether the problem required the students to use data, and (c) whether the problem was embedded within a real-world context. These three codes used a simple binary coding scheme. A further elaboration of these three codes is included in Table E.2.

Table E.2

Coding Categories and Descriptions

Code	Elaboration on code
Word problem	If the problem was presented verbally, in complete sentence form, it was coded as a word problem. The problems shown on page 67 of this document (Figures 3.1 and 3.2) are examples of problems worked by students would both be coded as word problems.
Using data	The problem used data that was either collected within the context of the class or lesson (e.g., report how many hours a night they slept) or came from a cited report or article that was included within their course materials. The group problem (Figure 3.1) presented on page 67 of this document both use data from an article to help frame the work of the students for those problems.
Real-world context	The problem frames the mathematical work involved in the problems with a real-world context, regardless of whether data were used to help provide the context (e.g., a problem that asks students to find the volume a cylindrical oil tank would be “real world context” but not necessarily “Using Data”). The problems on page 67 (Figures 3.1 and 3.2) and discussed in Chapter 3 would both be coded as real world.

Using these methods, 121 problems were coded. Of these, all but two were word problems, 106 (87.6%) were embedded in a real-world context, and 26 (21.4%) required the use of data that was either gathered in class or came from an article or report they had to read for class.

APPENDIX F

FULL INSTRUCTOR AND STUDENT INTERVIEW PROTOCOLS

Student Interview Protocol

Participant Code _____

Consent Form Received _____

Thank you for agreeing to meet with me. I am interested in learning more about *Mathematical Literacy* and its impact on students. In this interview, I will ask you questions about your opinion of *Mathematical Literacy*, previous mathematics classes you have taken and your academic plans. I will use this data, along with other data gathered from students and faculty involved in *Mathematical Literacy*, to explore how *Mathematical Literacy* changes students' conceptions of mathematics and themselves as doers of mathematics.

I previously sent you a voluntary consent form by email. Did you have a chance to review it? Do you have any questions regarding this form before you sign it or before we begin the interview? (COLLECT SIGNED CONSENT FORM)

If you have any concerns after the interview, please feel free to contact me. While the interview is completely voluntary and the information you provide will be confidential, you may request at anytime to withdraw your interview from the study.

May I record the interview? The recording will be transcribed so that we may analyze the data gathered.

With that, we'll get started! I'll start with some questions about your plans and what *Mathematical Literacy* is.

1. Please tell me a little bit about yourself

Prompts:

How long have you been taking classes at Fields Community College?

What is your major?

What drew/draws you to that major?

Do you think you need mathematics for your future career? Why or why not?

2. Tell me about how your semester is going.

Prompts:

What other classes are you taking?

Does the work load you have this semester feel manageable?

3. How would you explain *Mathematical Literacy* to someone that was thinking about taking it?
4. I notice in this class that you spend a lot of time working in groups. Tell me about your group and about how you work together.
 - a. Please tell me about a typical lesson goes.
 - b. How much time you spend working in groups each class period?
 - c. How much time do you spend talking to your peers about the work?
5. When you are doing mathematics, how do you feel? Can you give an example from this class?
 - a. Is this different than you've felt in the past?
6. In this class most of the math problems I see you doing are word problems. Can tell me about how you like this format and how this compares to other math classes you have taken?
7. I know that in this class format you are supposed to use your peers as a resource for the mathematical ideas you are covering. Please tell me about a typical interaction you have with your group mates in class.
8. Tell me about the typical interactions you have with Ms. Ann.
 - a. How important is the teacher in this class?
9. Do you think in Mathematical Literacy you are getting the mathematics you think you need for your future career?
10. Would you recommend the class to someone who was considering taking it? Why or why not?
11. What do you think are the biggest strengths of a class like *Mathematical Literacy*?
 - a. Please elaborate on [something interesting they bring up].
12. What are your biggest concerns about a class like *Mathematical Literacy*?
 - a. Please elaborate on [something interesting they bring up].

Instructor Interview Protocol

Participant Code _____

Consent Form Received _____

Thank you for agreeing to meet with me. I am interested in learning more about *Mathematical Literacy* and its impact on students. In this interview, I will ask you questions about your opinion of *Mathematical Literacy* and your role in teaching it. I will use this data, along with other data gathered from students and faculty involved in *Mathematical Literacy*, to explore how *Mathematical Literacy* changes students' conceptions of mathematics and themselves as doers of mathematics.

I previously sent you a voluntary consent form by email. Did you have a chance to review it? Do you have any questions regarding this form before you sign it or before we begin the interview? (COLLECT SIGNED CONSENT FORM)

If you have any concerns after the interview, please feel free to contact me. While the interview is completely voluntary and the information you provide will be confidential, you may request at anytime to withdraw your interview from the study.

May I record the interview? The recording will be transcribed so that we may analyze the data gathered.

With that, we'll get started! I'll start with some questions how you came to be involved with *Mathematical Literacy* and what *Mathematical Literacy* is.

1. How long have you been teaching at Fields Community College?
2. How did you come to be teaching at the community college level?
3. How would you describe *Mathematical Literacy* to someone who was interested in teaching it or starting a similar class at their own college?
 - a. How does the class differ from the more traditional developmental algebra sequence?
4. How would you describe *Mathematical Literacy* to a student interested in taking the class?
 - a. What type of student should take *Mathematical Literacy*?
 - b. Do you think some types of students are more successful in the class than others?
 - i. If so, can you articulate what sets these students apart?

5. Describe a typical *Mathematical Literacy* period in your class.

For adjunct instructors

How did you come to teach *Mathematical Literacy*?

Did you receive training on teaching *Mathematical Literacy*?

Did you find it useful?

Would you want more training or opportunities to develop your thought process about the class?

If so, what would be most useful for you?

For all:

I'm interested in what makes *Mathematical Literacy* unique. The next section will focus on this area.

6. Have you taught other mathematics classes like *Mathematical Literacy*?
- If yes, where and what did you teach? How was it similar?
7. Do you enjoy teaching *Mathematical Literacy*?
- If yes, please elaborate on why you enjoy it.
8. Is teaching *Mathematical Literacy* different than teaching other developmental mathematics classes?
- Please elaborate on *[something interesting they bring up]*.
9. Can anyone teach *Mathematical Literacy*? Why or why not?
- What skills does an instructor need to teach *Mathematical Literacy*?
10. What do you think students gain from *Mathematical Literacy* that they do not get if they take the traditional algebra sequence?
- From your point of view, how do students like the group work aspect of the class?
 - From your point of view, how do students like having word problems frame most of the mathematical ideas they are introduced to?

For the instructors who developed the class

I'm also interested in the rationale for creating *Mathematical Literacy*, so my next few questions will focus on that.

11. How did Fields Community College come to develop *Mathematical Literacy*?
- What made you interested in being a part of creating *Mathematical Literacy*?
 - What were some of the biggest challenges in getting the class started?

- c. In the design phases were there any compromises between administrative needs and structures that are thought to impact student success? If so, what were they? Based on your experience, how have compromises panned out?
- d. What were some important lessons you learned when developing the class and the materials for the class?
- e. What, today, do you think is the biggest challenge facing the institution with respect to the class?
- f. Have other colleges been interested in what you are doing? What sorts of questions do you get and how do you answer them?

Questions for focus teacher at the end of the semester:

- Would you say that the class was typical of other *Mathematical Literacy* sections you have taught?
- From your point of view, how did the semester go?
- Are there any stories from the semester that stand out to you as noteworthy?
- How do you plan to adjust the class moving forward?
- Do you think having me [the researcher] there changed the experience students had in the class?

APPENDIX G

FULL CODING RUBRICS FOR STUDENT INTERVIEWS

Table G.1

Rubric Used for Coding Responses to Question About Whether Students Would Recommend

Mathematical Literacy to Others

Code	Explanation	Example
Positive	Students positively recommend the class without qualification.	<i>Craig:</i> Now definitely. Especially if they were like me—they hadn't had math in a while. Or wasn't that confident with math. I think it's a good precursor to whatever else, whatever college level math you want to take.
Neutral	Students recommend the class, but include some kind of non-personal qualification such as "it depends on the person" or "this class would be appropriate for students with x, y, and, z characteristics." This is distinguished from negative recommendations by the non-personal element of their answer. Negative recommendations also qualify their answers but specify they would not recommend the class for people like themselves.	<i>Dave:</i> Someone who hasn't taken a math class in several years. They have not had math, maybe math is not a routine part of their day.
Negative	Like the neutral recommendation code, students qualify their recommendations. These differ from neutral recommendations in that the student indicates that in some way the <i>Mathematical Literacy</i> class was not an appropriate choice for them, personally, although it might be appropriate for students not like them.	<i>Interviewer:</i> I wanted to ask, so who would be the students that you don't think this would be a good class for? <i>Tyrone:</i> People like me. You know what I mean, I mean, just because probably I'm maybe so far off from, you know—and then, I shouldn't say that. Because man, I ain't even going to lie, I'm just making my way through.

Table G.2

Mathematics Curriculum Sub-codes

Code	Description	Example
(a) <i>Feelings Towards Curriculum Materials</i>	Students discuss the structure of the text, problems from the text, or their general reaction to these elements of the curriculum within the context of <i>Mathematical Literacy</i>. This also includes instances where the students are comparing or contrasting the degree of problem solving they are doing in this class with their previous mathematics experiences. Themes i. <i>Positive</i>: Students describe positive perceptions of or experiences with the curriculum materials or structure. ii. <i>Neutral</i>: Students describe mixed perceptions of or experiences with the curriculum materials or structure. iii. <i>Negative</i>: Students describe negative perceptions of or experiences with the curriculum materials or structure.	<i>Carley</i>: the questions, they try to trick you—like they give you the answer in the question and you just got to explain why that is... Or like a question in yesterday's, it was like "be careful: your answer might be different." But in reality, it wasn't different at all.
(b) <i>Real World Contexts</i>	Specific examples of real world problems or topics from the curriculum the students learned or solved problems related to as part of their time in <i>Mathematical Literacy</i>.	<i>Carrie</i>: ...we learned about, like, comparing gas prices or cell phone bills, and stuff like that, to see which would be, like, more, like the better option. So I got to see how math is used in, like, those situations. I never realized that you can kind of easily do that for yourself.

Table G.2 (cont.)

(c) <i>Learning and Using Mathematics</i>	Students discuss whether (a) they think they will use mathematics in their future and (b) they perceive the mathematics curriculum of <i>Mathematical Literacy</i> relates to the mathematics they need for their future career trajectory or in daily life. They might also discuss the learning outcomes, regardless of the utility of the mathematics, they perceive. Themes i. <i>Mathematics is useful in career or life</i>: Students discuss their perceptions and feelings about whether they will use mathematics, generally, in either their career or daily life. ii. <i>Class material useful in career or life</i>: Students discuss the ways they think the mathematics they are learning in class will help them in either their career or daily life. iii. <i>Class material not useful in career or life</i>: Students discuss that they think the mathematics they are learning in class will not help them in either their career or daily life.	<i>Craig</i>: Well, I could see me using math in everyday life, but maybe not so much in my career. I don't actually want to go into journalism. I want to be a comic book writer.
(d) <i>Feelings Towards Mathematics</i>	Students discussed how they felt when doing mathematics. This includes comparisons of how they felt in classes other than <i>Mathematical Literacy</i>. This code generally applies to the response and follow-ups to a particular question in the interview protocol. Themes i. <i>Positive</i>: Students discuss experiencing positive emotions or physical sensations while doing mathematics, including comments such as feeling confident, happy, or good. ii. <i>Neutral</i>: Students indicate their feelings about mathematics are dependent on context or that they do not have strong emotional reactions to mathematics. iii. <i>Negative</i>: Students discuss experiencing negative emotions or physical sensations while doing mathematics, including comments about feeling sweaty, nervous, anxious, or frustrated.	<i>Tyrone</i>: I'm always unsure. I'm not confident when it comes to math. I mean, other contexts, I'm so confident. I mean, I'm a confident person, man, I am. But when it comes to math I'm like a little—not good at all. So my confidence level, it sucks.
Other	Utterances that do not align with any of the above codes.	

Table G.3

Group Work Sub-codes

Code	Description	Examples
(a) <i>Group Dynamics</i>	Individual discusses the typical attributes of the individuals within the groups they have been assigned to, including those they attribute to themselves (i.e., the role they take on within the group). This code also encompasses discussions of their personal relationships with the individuals in their groups, such as whether they are friends with their group mates, or whether they think they have a good relationship with the individuals they are working with. This code applies to discussions of these relationships and the group composition not directly tied to assignments or classroom work. If the students are discussing the composition of their group in terms of the classroom activities, the code should be reliance or accountability. Themes i. <i>Group relationships</i>: Student discuss their relationships with others and whether they enjoy or dislike working with others in class as a required part of their curriculum. ii. <i>Role within group</i>: Students discuss the role they take on in their groups, either in terms of the official curriculum roles (e.g., recorder, outreach) or socially (e.g., leader or clown). iii. <i>Diverse mathematics levels</i>: Student discuss the composition of their group(s) in terms of the mathematics levels of the students they are working with.	<i>Vince</i>: Well, usually we have one or two people that are fast, in each group, who really speed through everything. And usually there is someone who is very quiet and very off to the side, and they have to catch up afterward.

Table G.3 (cont.)

(b) <i>Togetherness</i>	Refers to when the students discuss the degree to which groups operate as a single unit versus when individuals or pairs of students work separately from each other within the same group. These instances can be personal (i.e., I’m always behind” or “I tend to work ahead”) or descriptive in nature (i.e., we work together most of the time). Togetherness does not relate to utterances about graded assignments. So, if students discuss times when their group did not work together on a group project, that would be coded under <i>accountability</i> rather than togetherness. Themes i. <i>Presence of togetherness</i>: Students talk about times when their groups were together or their feelings about and perceptions of working in a group where all the members are engaged in the same activity. ii. <i>Lack of togetherness</i>: Students talk about times when their groups were not together or their feelings about and perceptions of working in a group where all group members are not all engaged in the same activity.	<i>Carrie</i>: So even though it wasn’t totally all of us were on the same page at the same time we’d always, like, check in to make sure we were, like, together, kind of. <i>Tyrone</i>: Sometimes I might be behind. I’m always behind. And then I look “hey where you at?” I’m just like man, “you all just go ahead—I’ll catch up.” You know, that’s how it will start. And then it’s like “let me see what you are doing” You know, and they’ll start like that. And we’ll go on.
(c) <i>Checking In</i>	Refers to specific instances when a student either asked for help or asked if others needed help. This includes discussions of the absence of checking-in behavior within groups (i.e., a student mentions that no one ever checks in on them) or a discussion that they feel like there are people they are not able to interact with mathematically. This is separate than <i>togetherness</i>, which is a more general, but related code. Themes i. <i>Help giving</i>: Students discuss checking-in instances during which the speaking individual was providing support. These include (a) giving help when asked, (b) asking others if they needed help, or (c) the limitations or benefits of their ability to help others in their groups.	<i>Dave</i>: Well, this past week I’ve been kind of not on top of things so I’ve had to refer, or ask them for help or help keep me up. <i>Emilia</i>: And they would like stop occasionally to see if I need help but it just, it makes me feel like “ooh my god! I need to step it up.” But it just doesn’t work out that way.

Table G.3 (cont.)

	ii. <i>Balance</i>: Students indicate that there are natural ebbs and flows between who checks in with whom and what each group member contributes. iii. <i>Help seeking</i>: Students discuss checking-in instances during which the speaking individual needed or asked for support. These include (a) asking for help, (b) were asked if the needed help, or (c) needed help but felt they could not get that help from individuals within their group.	
(d) <i>Copying</i>	Students discuss instances when they: • Observed copying by other students • Participated in copying and their reasons for doing so • Facilitated other students' copying and their reasons for doing so • General thoughts about copying and their perceptions about the pros and cons of facilitating or participating in copying. In general, this code applies to copying of individually graded or completed assignments. If groups grades apply, the text should fall under <i>accountability</i> rather than copying. Themes i. <i>Engages in copying</i>: Student identifies that they engage in copying as part of their class participation and their reasons for doing so. ii. <i>Lets others copy</i>: Student identifies that they let others copy, either actively or passively, their reasons for doing so, and their reactions to others copying from them. iii. <i>Observes copying</i>: Students do not admit to participating in copying directly, either by letting others copy them or copying from others, but do see instances of copying in the classroom and their reactions to it. iv. <i>Classroom management of copying</i>: Students discuss ways they either attempt to or could see others managing the copying behavior of others.	<i>Craig</i>: Maybe that should be more iterated in one of the roles, like manager, or something—make sure no one is copying. Make sure everybody is on the same page. <i>Carrie</i>: It's so they have something to fill their paper with. I've heard, a couple times, "oh, it's okay if you get this wrong because she'll never check."

Table G.3 (cont.)

<i>(e) Accountability</i>	The student discusses their own responsibilities with respect to grades or graded assignments. This code focuses on the student's discussion of group interactions and the responsibilities group members have to each other or themselves in terms of graded assignments, including: • Holding group mates accountable to work they have said they will do or that their role for the day assigned. • The work they do or think they should be doing <i>alone</i> to understand the content in the group assignments. • An individual discussing their own standards for the work the group is submitting. • The difficulty of maintaining their standards for group assignments while not micromanaging others.	<i>Bea:</i> So, if, like, someone that wasn't really following along during that chapter, and they're recorder, and they're just going to scribble down what we tell them. And maybe what they're scribbling it down, since they didn't do it themselves, they'll miss something. So when we're turning it in we'll end up getting, like, really low grades.
	If students discuss individually graded assignments in terms of needing groups mates to help them, so they could perform well on assessments, this falls under accountability. Otherwise, let the context of their discussion about those assignments guide the coding.	<i>Carley:</i> Um, okay. For, uh, for our group project, two of my group members just decided not to do anything. So it was me and, uh, just me and this one other kid, and, uh, we pretty much just like split up half the work.
Themes		
i.		
<i>Distribution of work load:</i> Students discuss their experiences, perceptions of, or feelings about working on assignments where they find the work load to be unevenly distributed between the group members.		
ii.		
<i>Lack of control:</i> Students discuss their experiences, perceptions of, or feelings related to not having control over all submitted work for which they will receive a grade.		
iii.		
<i>Peer regulation:</i> Student discuss their experiences, perceptions of, or feelings about holding other group members responsible for work they should be completing for the group.		
iv.		
<i>Self-accountability:</i> Students discuss their experiences, perceptions of, or feelings related to graded group assignments and what it means to complete those assignments in terms of their own learning.		

Table G.3 (cont.)

(f) <i>Group Work Time</i>	Students discuss what they generally do during group work time or how much of the class time is allocated to group work. Alternatively, they may discuss what they think the appropriate amount of time spent on group work should be in the class. This code also includes their discussion, in talking about group work, a preference for a different form of instruction during the class. Themes i. <i>Would like more lecture</i>: Students indicate that within the classroom, they think there is too much group work and would like more lecture instead. ii. <i>Balance between group and individual time</i>: Students indicate they think the balance between group work time and time to work on their own is appropriate. iii. <i>Creates positive atmosphere</i>: Student indicate the group work time gives the class a positive atmosphere to work in.	<i>Bea</i>: I think telling us how to do things first would make it go a lot faster rather than us just trying to solve it and trying to remember everything that, you know, we have learned in past semesters or in high school.
Other	Utterances that do not align with any of the above codes.	

Table G.4

Instructor Sub-codes

Code	Description	Example
(a) <i>Interactions</i>	Students describe a learning or class related interaction they had with her. These interactions can include descriptions of her teaching (so, not a direct interaction) or group level or individual interactions. In contrast the Role code, instances should be coded as interaction if they are about a specific example of teaching. This code can also include students discussing a lack of interaction (i.e., waiting) and their activities or feelings about their observations about when they cannot talk to her.	<i>Carley</i> : She'll look, look at what we did and she'll explain "this doesn't look right" or "you might want to change this." So she kind of guides us. She doesn't exactly bluntly give us the answer she just says "maybe try doing this."
Themes		
i. <i>Tells to slow down</i> :	Student describes or discusses experiences when the instructor suggested they work slower through the content or that they not get too far of group mates.	<i>Tyrone</i> : I'll go in her office a lot, you know what I mean, and she'll ask me, you know, did I study something and I'll say no. But she'll still work with me—she won't give up on me. That's what some of them do. And she'll just sit me down and show me how to do something, you know what I mean?
ii. <i>Explains the material (individual level)</i> :	The student describes instructor interactions during which she explained the material or otherwise helped the student understand something. For "individual" the student must use words like "I" or "me" in talking about the interaction.	
iii. <i>Checking on progress (individual level)</i> :	The student describes instructor interactions during which the instructor checks the progress or work. For "individual" the student must use words like "I" or "me" in talking about the interaction.	
iv. <i>Explains the material (group level)</i> :	The student describes instructor interactions during which she explained the material or otherwise helped the student understand something. For "group" the student must use words like "us" or "we" in talking about the interaction.	
v. <i>Checking on progress (group level)</i> :	The student describes instructor interactions during which the instructor checks the progress or work. For "group" the student must use words like "us" or "we" in talking about the interaction.	

Table G.4 (cont.)

(b) <i>Role</i>	Students discuss the instructor's general role in the class or her general instructional methods. These might be instances when they indicate the instructor is a mentor, guide, or source of knowledge. In contrast to the <i>Interactions</i> code, instances coded as role that relate to teaching should be general descriptions (i.e., she "teaches us using lecture"). Themes i. <i>Important - Source of knowledge</i>: Students discuss the instructor as important, elaborating in some way that it is because the instructor answers questions or provides information they need to complete their work. ii. <i>Important - Keeps them on task</i>: Students discuss the instructor as important, elaborating in some way that it is because the instructor keeps them on task or accountable to doing the required work. iii. <i>Guide or facilitator</i>: Students describe the instructor as a guide or facilitator.	<i>Craig</i>: ...I'm not trying to come off as pompous but if I don't know then usually my group doesn't know. Sometimes they do, like I said, the dimensional analysis stuff, but if I don't know—if she wasn't there who's going—I can read something in a book so many times but if I'm not understanding it I still need someone to bridge that little gap that I'm having.
(c) <i>Attributes</i>	Students discuss the instructor and her attributes as an instructor (i.e., helpful, smart, knowledgeable). This also includes evaluative times when the mention whether they like her or her teaching style. Themes i. <i>Knowledgeable</i>: The student describes the instructor as having a lot of knowledge or as being knowledgeable. ii. <i>Experiences her with positive affect</i>: The student describes the instructor using positive attributes, including caring, fun, thoughtful, or helpful.	<i>Tyrone</i>: ...she don't, like, you know, wear her emotions on her sleeve like a lot of people do, you know what I mean. I mean, you could see it, but she won't let it come out. You know, like her frustration, you know, her frustration don't come out as easily as a lot of instructors do.
Other	Utterances that do not align with any of the above codes.	

APPENDIX H
INSTITUTIONAL REVIEW BOARD APPROVAL

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Office of Vice Chancellor for Research
Institutional Review Board
528 East Green Street
Suite 203
Champaign, IL 61820



August 1, 2014

Sarah Lubienski
Curriculum and Instruction
303 Education
1310 S. Sixth Street
Champaign, IL 61820
M/C 708

RE: *Community College Students' Attitudes Toward Mathematics Before During and After a New Developmental Mathematics Course*
IRB Protocol Number: 15057

EXPIRATION DATE: 07/31/2017

Dear Dr. Lubienski:

Thank you for submitting the completed IRB application form for your project entitled *Community College Students' Attitudes Toward Mathematics Before During and After a New Developmental Mathematics Course*. Your project was assigned Institutional Review Board (IRB) Protocol Number 15057 and reviewed. It has been determined that the research activities described in this application meet the criteria for exemption at 45CFR46.101(b)(1).

This determination of exemption only applies to the research study as submitted. Please note that additional modifications to your project need to be submitted to the IRB for review and exemption determination or approval before the modifications are initiated.

We appreciate your conscientious adherence to the requirements of human subjects research. If you have any questions about the IRB process, or if you need assistance at any time, please feel free to contact me or the IRB Office, or visit our website at <http://www.irb.uiowa.edu>.

Sincerely,

A handwritten signature in blue ink that reads "Rebecca Van Tine".

Rebecca Van Tine, MS
Assistant Human Subjects Research Specialist, Institutional Review Board

c: Martha Makowski