

**(Mis)Measuring Developmental Math Success:
Classroom Participants' Perspectives on Learning**

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Abstract

Poor completion outcomes in community colleges' developmental education programs have spurred reforms in developmental education policies and practices in order to increase students' chances of success. In the case of developmental math, the focus of this paper, such changes include revisions to testing and placement policies, amendments to the intended curriculum, and restructuring of the format and sequencing of courses. However, the measures that have highlighted the inadequacies of developmental math are, in themselves, insufficient for assessing the effectiveness of reforms to developmental math. Drawing on interview data from a classroom-level study of a community college's pilot reform initiative in developmental math, we explore the learning goals articulated by the instructors and a sample of students across four pre-algebra classrooms. Through our analysis of their goals, as well as the extent to which students reported accomplishing those goals, our research underscores the important distinction between course completion and learning. This study highlights the need to assess the effectiveness of developmental math coursework in ways that extend beyond completion rates.

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Over the past decade, community college educators, researchers, and policymakers have reached consensus on the need to improve outcomes for students deemed underprepared for college-level coursework, as well as the level of urgency of accomplishing such improvements. The sense of urgency has been propelled, in part, by a particular approach to measuring the effects of developmental education coursework on students' postsecondary trajectories. Briefly stated, this approach has involved intensive examination of large datasets and the application of sophisticated statistical analyses, such as propensity score matching (Bettinger & Long, 2005), and regression discontinuity (Calcagno & Long, 2008; Martorell & McFarlin, 2007). These analyses have enabled comparisons of outcomes for similar groups of students and the tracking of students over time to understand which of the students deemed unprepared for college-level coursework successfully complete the developmental requirements.

Such analyses have provided crucial evidence that students placed in developmental education courses are, broadly speaking, more likely to fail and drop out than to succeed. In the case of developmental math, the amount of failure and attrition is particularly discouraging. Close to 60% of all students who begin at public, two-year colleges enroll in developmental math courses (Chen, 2016), while still more students are placed in developmental math, but do not enroll. Conservative estimates indicate that around 30% of the students placed somewhere within a conventional three-level sequence of developmental math coursework actually complete their remedial requirements (Attewell, Lavin, Domina, & Levey, 2006; Bailey, 2009). When non-credit coursework is included, as in Bahr's (2010) analysis of California community college developmental math, that completion rate is even lower (in the case of California, 24%).

Embedded within this overall pattern of failure and non-completion are multiple racial inequities. Bailey, Jeong, and Cho's (2010) examination of developmental education progression revealed that Black and Latina/o students in a sample of Achieving the Dream colleges were more likely than White students to require multiple levels of developmental coursework. In the case of developmental math, the authors found that Black students had significantly lower odds of completing the sequence when placed more than one level below college-level math. Using data from California's community college system, Bahr (2010) found that Black and Latina/o students were more likely than their white peers to start in the lowest level of developmental math and less likely to complete the developmental sequence. In Attewell et al. (2006) analysis of Black and White students enrolled in developmental education, the authors found substantial differences by race, even after accounting for the effects of students' socio-economic status and academic background. Thus, different success rates once enrolled in developmental math compound the already existing disadvantage for Black and Latina/o students upon entering the community college.

Poor completion outcomes have generated interest in changing developmental education policies and practices in order to increase students' chances of success. Such changes include revisions to testing and placement policies, amendments to the intended curriculum, and restructuring of the format and sequencing of courses. However, the measures that have highlighted the inadequacies of developmental math are, in themselves, incomplete. As we discuss below, completion rates offer a limited perspective on the effectiveness of developmental coursework, and are inadequate for assessing colleges' reform efforts. Given that community colleges across the country are engaged in an unprecedented level of activity to increase the

effectiveness of their developmental education programs, attending to an equally effective strategy for examining the results of those efforts is of utmost importance.

In this article, we examine various perspectives on the effectiveness of developmental math coursework. We begin with a review of the strengths and weaknesses of current measures of developmental math success, including completion rates and classroom-level evaluations of learning. Then, drawing on findings from a classroom-based study of developmental math, we explore the themes that emerge when developmental math instructors and their students describe their goals for developmental math, and how students discuss what they have gained from the math course. By examining students' accounts of their learning, we highlight the significant distinction between successfully completing the pre-algebra course and accomplishing participants' learning goals. Thus, we question the utility of system-wide assessments of developmental education that rely primarily on completion rates and suggest the need to examine the relationships among instructional goals, enacted curriculum, and students' learning, over time, within instructional contexts.

Completion Rates

The most basic outcome measure for developmental education revolves around course-level pass rates, typically defined as the percentage of students who earn a "C" or better in a given course. This measure is a standard dependent variable for researchers studying the effects of various reforms to developmental math (e.g. Bol, Campbell, Perez, & Yen, 2015; Logue, Watanabe-Rose, & Douglas, 2016; Okimoto & Heck, 2015) and a convenient proxy for evaluating the success of any given course (Cox, 2015).

However, using course-level completion rates as evidence of how students are faring in developmental math coursework is complicated by a number of challenges, including problems

with students' placement into developmental coursework as well as the difficulty of determining an appropriate benchmark for average pass rates. One issue revolves around students' placement into developmental coursework. Research on the placement process has revealed a range of concerns with how students are assessed as underprepared for college-level work. For instance, the testing process, while perhaps transparent to college administrators, may be less clear to students; students may be directed to sit for the exam without understanding the consequences or having had any opportunity to prepare (Fay, Bickerstaff, & Hodara, 2013; Venezia, Bracco, & Nodine, 2010). Researchers have also documented significant error rates produced by placing students solely on the basis of computer-adaptive test scores (Ngo & Melguizo, 2016; Scott-Clayton, Crosta, & Belfield, 2014). These studies suggest the tendency for students to be placed in a lower course in the sequence than is actually needed. In contrast, colleges that do not mandate placement and instead rely on students' self-assessed need may see lower enrollments and less failure at the developmental level, but much greater failure in the initial college-level math course. Certainly, this was the case across Florida's colleges following its statewide changes to developmental education placement policies (Park, Tandberg, Hu, & Hankerson, 2016).

Ultimately, the placement of students into the wrong level of coursework compromises the usefulness of course-level pass rates as a measure of success, whether the pass rates are for developmental courses or for students' first college-level math courses. As Hughes and Scott-Clayton (2011) pointed out, if students are not assigned to the appropriate course, then it is difficult to ascertain the benefits of the coursework. In such cases, passing the course would not necessarily represent students' increased mathematical proficiency. Furthermore, as colleges implement developmental math reforms that include new placement policies, differences in

completion rates will be difficult to interpret. In the case of Florida's developmental education redesign, for instance, Park et al. (2016) noted their uncertainty as to whether the significantly lower completion rates for gateway (college-level) math courses signaled a problem with students' self-placement or some other, as-of-yet undetermined issue. Thus, examining pass rates in college-level math did not offer an unequivocal measure of the reform's effectiveness.

Another challenge in using course-level completion rates involves determining the benchmark for success; or more precisely, deciding what constitutes an acceptable level of non-completion. Recent reports on developmental math reforms have consistently documented completion rates in comparison to pre-reform or traditional programming (see for example, Edgecombe, 2016; Khudododov, McKay, & Michael, 2016). The emergent assumption is that pass rates are best understood relative to the dismal pre-reform outcomes. However, such comparisons may obscure more than they reveal. For example, the fourth year impact report of the Carnegie Foundation for the Advancement of Teaching's (CFAT) Community College Pathways initiative relied on course completion rates to demonstrate the effect of the Statway and Quantway programs (Huang, Hoang, Yesilyurt, & Thorn, 2016). One finding particularly relevant to our study's focus on pre-algebra is the course completion rates over the four-year period for the one-semester Quantway 1 course, which ranged from 52% to 59% (Huang et al., 2016). Using institutional research data from the participating colleges, the authors compared these pass rates to a pre-reform baseline—the percent of students who passed their multi-course requirement in one year. By this measure (a baseline completion rate of 20.6%), they concluded that Quantway students accomplished “double the success of the typical approach in a single semester” (Huang et al., 2016, p. 7).

It is certainly fair to note that the one-semester course allowed students to complete the

developmental requirement faster, eliminating the possibility of attrition or delay between courses. However, this structural advantage complicates the evaluation strategy: If the benchmark for assessing Quantway's 56% average completion rate includes students who have not actually attempted comparable coursework, then what is an appropriate measure for evaluating the effectiveness of the instructional content of the course, rather than its compressed structure?

Contexts and Trajectories of Non-Completion

Not enrolling, enrolling then withdrawing, enrolling in and then failing the course: Each of these outcomes can be described as non-completion. Taken together, these distinct forms of non-completion that occur throughout the traditional sequencing of one, two, or three discrete developmental math courses are, indeed, worrisome. However, differentiating among these different kinds of non-completion, and exploring the underlying contexts of various developmental math trajectories are significant precursors to a better understanding of student success and failure.

Nuanced statistical analyses (e.g. Melguizo, Kosiewicz, Prather, & Bos, 2014) have contributed useful insights regarding students' trajectories into and through developmental math. Bahr (2012) explored different types of attrition (skill-specific, non-skill specific, and course-specific) in a sample of students across the California community college system, finding a significant amount of course-specific failure for students entering algebra from a lower level math course. Examining the outcomes for students across a large, urban district who actually attempted their developmental math coursework (i.e. enrolled and remained in the course beyond the no-penalty withdrawal date), Fong, Melguizo, and Prather (2015) calculated pass rates of 64% to 79%. They concluded that for students placed lower in the sequence, the "students who

are actually progressing through their sequence are passing courses at comparable rates to their initially higher placed peers.” (p. 742). Finally, they identified a crucial contextual reason for students’ tendency not to enroll in intermediate algebra: for many students, the course was not required for their intended credential. If completing the entire developmental math sequence is not required for a student’s degree program, non-completion may not be a failure for that student after all.

Such research underscores the need to examine and assess completion rates more critically, including further investigation of distinct forms of non-completion within the specific contexts of colleges’ placement policies, advising practices, course withdrawal deadlines, and students’ degree requirements. Finally, evaluating completion rates more critically involves recognizing the limits of the broad view of students’ paths into, through, and out of developmental math. As Bailey, Jaggars, and Scott-Clayton (2013) have explained, much of the research over the past decade on the effectiveness (or potential ineffectiveness) investigates “the *system* of developmental education, including assessment and placement procedures, coursework, and related supports” (p. 19).

While valuable, these analyses of students’ trajectories do not represent assessments of the effectiveness of developmental math *coursework*. Ultimately, the exact reasons for students’ various trajectories remain unclear. For instance, average completion rates mask the variation that occurs across and within colleges (Moss, Kelcey, & Showers, 2014), and in turn, fail to illuminate the specific contextual conditions that shape students’ paths. Ultimately, completion rates and other measures of students’ progress to degree reveal little about the quality of classroom-level teaching and learning (Cox, 2015), nor do they reflect the knowledge, competencies, or dispositions that students gain from attempting their developmental math

coursework (Quarles & Davis, 2017). Quarles and Davis's (2017) study of the relationship between student learning in intermediate algebra and students' paths through college-level math at a community college in Washington offers compelling evidence of the questionable value of students' gains in procedural fluency while enrolled in the developmental math course. Although these gains were linked to end-of-course grades in intermediate algebra, those procedural skills did not translate into greater success in college-level math courses. Furthermore, although students tended to retain their conceptual knowledge of math over time, regardless of delays in coursetaking, the intermediate algebra courses under investigation focused primarily on procedural knowledge. For the students in the sample, the learning accomplished in developmental math proved to be difficult to retain over time, and not particularly helpful to their successful completion of college-level math. These findings echo the work of Stigler, Givvin, and Thompson (Stigler, Givvin, & Thompson, 2010; Givvin, Stigler, & Thompson, 2011), whose math-focused interviews with community college students revealed several related patterns: students' reliance on sketchy procedural knowledge, little use of mathematical reasoning, and "conceptual atrophy" (Stigler et al., 2010, p. 15). At the same time, these researchers' interviewing process, which incorporated prompts to encourage students to engage in reasoning, uncovered students' willingness and interest in exploring connections among mathematical ideas. Overall, Givvin et al identified the limitations of developmental math curricula that prioritize procedural knowledge, leading them to conclude that developmental math students would benefit from instruction aimed at developing their conceptual knowledge. Together, these studies underscore the need for research that explores the connections (or disconnections) among the actual curriculum, student learning, and student progression.

Increased Mathematical Proficiency as a Measure of Success

Math educators over the past several decades have conceptualized robust mathematical learning as comprising multiple, interrelated dimensions. The National Research Council's Mathematics Learning Study Committee (Kilpatrick, Swafford, & Findell, 2001), identified five components of math proficiency, and the guidelines set forth by the American Mathematical Association of Two-Year Colleges (2006) echo this conceptualization of proficiency. Procedural fluency, defined as "skill in carrying out procedures flexibly, accurately, efficiently, and appropriately" is but one strand; the others are conceptual understanding, skill in representing and solving problems, competence in reasoning and justifying, and "productive disposition," which involves both regarding mathematics as "useful and worthwhile" and seeing one's self as able to do math (Kilpatrick et al., 2001, p. 5). Through classroom-based research on the kind of instruction that develops deep mathematical learning at the K-12 level, Schoenfeld (2014) has developed a multi-dimensional rubric. Designed to help researchers and teachers unpack the various aspects of powerful mathematics instruction, the rubric includes questions about the extent to which students are supported in engaging in "productive struggle" (p. 408) in building meaningful connections between concepts and procedures, and in developing their identities as competent mathematical problem-solvers.

In spite of math educators' endorsement of this multi-dimensional perspective on math teaching and learning, math instruction typically focuses on procedural fluency (Cox, 2015; Grubb & Gabriner, 2013; Hinds, 2011; Mesa, Celis, Suh, Lande, & Whittemore, 2011). This instructional focus, in turn, shapes students' beliefs about mathematics knowledge and learning in ways that may hinder their learning of math and adversely affect their math-specific identity (Muis, 2004; Wheeler & Montgomery, 2009). Muis (2004), in her review of studies on math

students' epistemological beliefs, concluded that students tend to maintain beliefs that do not facilitate deep learning, labeling these non-availing beliefs. Wheeler and Montgomery (2009), in their study of community college students' beliefs about math, found that nearly 40% of their sample of developmental students maintained strong, non-availing views of math. These beliefs included a view of mathematics knowledge as a set of disconnected facts that require memorization, limited confidence in their ability to solve math problems, and skepticism about the relevance of math to real life. Such research underscores the intersecting relationships among students' experiences in math classrooms, their attitudes about math as a domain of study, their self-concept as math learners, and ultimately, their performances on math assignments.

Re-thinking "Effectiveness"

The reliance in the extant research on completion rates certainly makes sense, in that researchers have sought to provide initial explanations for the large amount of failure and attrition in developmental math. Indeed, Grubb and Gabriner's (2013) observations of "remedial pedagogy" (p. 52), and Acevedo-Gil, Santos, Alonso, and Solorzano's (2015) study of developmental education students' descriptions of academic invalidation have identified essential classroom-level reasons for low completion rates. However, such work has sidestepped the broader issue of how these experiences shape students' learning of math, regardless of how incomplete that learning might be. Without a clear understanding of the learning (or non-learning) that occurs in such classrooms, the baseline for comparing developmental math reforms remains equally indeterminate. Ultimately, understanding what students are encountering inside developmental math courses, what students gain from those experiences, and the extent to which those experiences translate into increased mathematical proficiency is essential to assessing the effectiveness of developmental math coursework.

Bachman's (2013) study of developmental math at a research university offers an instructive example. In an effort to assess the effectiveness of the pre-algebra course and subsequent algebra course that she taught to a racially diverse group of students, Bachman measured multiple forms of student growth, including changes in students' conceptual understanding of the math topics, increases in their procedural skills, and changes in their attitudes about math. One considerable strength of Bachman's research consists of the tight link between those measures of effectiveness and the specific context of the courses under investigation. For instance, Bachman includes a robust description of the instructional goals and curriculum of each course, including her focus on improving students' conceptual understanding of the course topics. As a result, it is clear how her pre- and post- course measures of conceptual understanding and procedural skills are linked both to her specific instructional goals as well as the actual course curriculum. Similarly, the questions on her pre- and post-course survey of students' attitudes towards math clearly derive from her instructional goals. Bachman's survey asked students to indicate their level of agreement with statements like "I feel confident in my ability to do math," and "Math is useful in my daily life" (p. 271). Additionally, the survey included statements intended to measure potential change in students' attitude towards math as a set of rules requiring memorization and rote application, such as "Math involves a lot of memorization" (p. 271). Anticipating different responses to this question at the end of a course was predicated on providing instruction that was not focused solely on procedural fluency, and indeed, Bachman found that students who improved the most on the conceptual understanding measures also changed their minds about the role of memorization in math—expressing more disagreement with that statement at the end of the course.

This change in student attitudes contrasts with the results of Benken, Ramirez, Li, and

Wetendorf's (2015) study of university-level developmental math students' attitudes. In their examination of students' responses to pre- and post- course surveys about their confidence and comfort with math, Benken et al. found little change in students' responses to the statement: "Mathematics involves mostly facts and procedures to be memorized" (p. 20). However, in the absence of details about the instruction that the sample of students encountered, it is difficult to know whether the results reflected an underlying message of the developmental curriculum, or the difficulty of changing students' established beliefs even when the curriculum is designed to challenge students' conceptions.

Such research highlights the need to explore student learning in context; to clearly connect evidence of what students learn from particular courses to the instructional environment constituted inside those classrooms. Key components of the instructional context include the curriculum enacted within the classroom as well as students' experiences of the curriculum, both of which play a critical role in what students can and do learn from taking the course. In this paper, our analysis of student learning is informed by our understanding of the curriculum enacted inside the classrooms, and explicitly linked to the goals for the course as articulated by both instructors and students.

The Study

For this paper, we draw from a study of teaching and learning inside community-college developmental math courses. Over the 2010-2011 academic year, the first author (and PI of the larger research study) conducted extensive classroom observation of four sections of pre-algebra and conducted one-on-one interviews with the instructors and a sample of students in each section. By using an interpretive, qualitative approach (Denzin & Lincoln, 1998), she sought to understand various classroom participants' experiences of the enacted curriculum, and the

aspects of that enacted curriculum that shaped students' learning and successful completion of the course.

In this article, our analysis was guided by the following questions:

1. What goals did various participants (instructors and students) across these four pre-algebra classrooms identify as most important?
2. To what extent did students report having accomplished these goals within the pre-algebra course?

Ultimately, we explore the answers to these two questions in relation to the course completion outcomes, in effect addressing the question:

3. How do students' perspectives on their learning complicate the use of completion rates for evaluating the effectiveness of developmental math coursework?

Site and Participants

A large, urban-serving, two-year college, Northeast Community College (NCC) enrolls large proportions of Latina/o and Black students. At the time of the study, NCC had identified developmental education as an area in need of improvement and had implemented a pilot initiative in which small cohorts of students placed in developmental education were co-enrolled in linked courses in order to create a "learning community." While the coordinators of the initiative were concerned with improvement across all developmental education, they indicated that the course that typically resulted in the lowest pass rates was pre-algebra. This provided a good rationale for focusing the research on pre-algebra course. Each of the four sections of pre-algebra in the study was linked to a developmental English course or a student success course. In addition, various extra supports had been added to these linked classes, including extra tutoring, a designated academic counselor, and specialized supplemental workshops devoted to

study skills. The instructors had volunteered to participate in this pilot because of their interest in classroom innovation, and the coordinators of the developmental education initiative offered positive descriptions of the instructors' concern for students' learning and success. In other words, the purposeful selection of site and participating instructors was guided by an interest in exploring the conditions that facilitate student success inside developmental math classrooms.

Four pre-algebra instructors and 25 students participated in the study. Each class started with an enrollment of 20 students, and by the midterm, when recruitment for student interviews started, 78 students remained officially enrolled across the four sections. All 78 students were invited to volunteer for a one-on-one confidential interview with the offer of a giftcard to the college bookstore as a small incentive for participating. Fifty-one students expressed interest in volunteering; ultimately, the PI completed 23 one-on-one interviews and one interview with a pair of classmates. Across the four sections of pre-algebra, this sample included 15 women and 10 men, and within this group, 12 Black students, eight White students, and five Latina/o students (see Table 1).

Table 1

In terms of completing the course successfully (with a "C" or higher), 72% of this sample passed the course, whereas the completion rate for the entire set of students enrolled in the four courses was only 61%.

Data Sources

The data derive from three sources: classroom observations, course artifacts, and interviews. The PI observed over 22 hours of instruction in each of the four classrooms, totaling

110 hours overall, in order to understand the dynamics constituted by the interplay among students, teacher, and course content. Inside each classroom as well as after each class session, the PI wrote detailed field notes, describing what the instructor and students were doing throughout each class session, and documenting what the classroom participants said over the same period. She also collected instructional artifacts, including syllabi, textbooks, tests, handouts, PowerPoint slides, and web-based materials. Finally, the PI conducted one-on-one, semi-structured interviews with the instructors and the sample of student volunteers. All interviews were audio-recorded and transcribed for analysis. Every phase of the study was approved by the appropriate Institutional Review Boards.

One-on-one, semi-structured interviews with the instructors took place at the end of the teaching term. They lasted between 75 and 90 minutes, and explored such topics as the instructors' professional experiences and instructional philosophies, as well as discussions specific to the students, course content, and classroom dynamics that the PI had observed over the duration of the course. Nine of the student interviews took place near the end of the term or prior to the start of the subsequent term, while the majority of the interviews were conducted after the start of the subsequent term, allowing students to consider their experiences in pre-algebra in light of their subsequent developmental math coursework. Most lasted 45-60 minutes; two students had budgeted only 25 minutes for the interview, and several students were so engrossed in the conversation that they were willing to continue beyond an hour. Every interview included questions about what the student had gained from taking the course, and incorporated follow-up probes about what specific things the student had learned, as well as whether the student found the math relevant to life outside of the classroom. Additional questions included queries about the student's experiences taking the course, as well as

comparisons to other math courses and math instructors.

Data Analysis

The findings presented in this article build on a prior analysis of the curriculum enacted in the four classrooms. As documented in Cox's (2015) discussion of the classrooms at the college identified as "College A," the curriculum revolved around improving students' procedural skills. The vast amount of classroom discourse revolved around faculty talk about rules and step-by-step operations. Uniformly, the professors anticipated that students would take notes about these procedures, then use the notes to practice the steps. When faculty members asked questions in class, they tended to ask students to (a) define terms, (b) perform one-step operations, and (c) provide answers to sample problems. The pattern of questioning therefore prioritized what Mesa and Lande (2014) characterized as routine (as opposed to novel) questions. Finally, the professors tended to attribute poor test grades to students' failure to memorize the rules or inadequate practice applying the rules to sample problems. Analyzing the actual curriculum as it was enacted over the duration of the semester in each classroom led us to this current analysis of what students may have gained from taking the course, given the procedural focus of the curriculum.

We began with the transcripts from the student interviews, creating summaries for each student, then undertaking a cross-case coding process. Although our initial goal was to find explicit statements about the mathematical knowledge and skills that students gained from the math course, we found few references to the mathematical content. Ultimately, the sections of the transcripts that proved particularly salient to this analysis were the excerpts we coded as "value of the course," "approach to the course," and "instructional preferences." While the first two of these codes targeted students' descriptions of the math courses that the PI had observed,

the instructional preferences code included statements that students made about prior and subsequent math courses. As a whole, these three codes included information about students' goals for the course, what they gained from the course, and what they wished they had been able to gain from the course. We then examined the instructor transcripts to review how the four instructors articulated their goals for the course. Once we saw overlap between instructors' and students' goals, it made sense to consider the extent to which students' believed that they had accomplished those objectives in the pre-algebra course. What we found from this analysis underscores the challenges of exploring student learning, but also confirms the need to attend to the complexities not captured by conventional completion data.

Trustworthiness

Several aspects of our study have strengthened the credibility, confirmability, and dependability of our interpretations (Guba & Lincoln, 1994). First, we reviewed the instructor and student interview transcripts in conjunction with other sources of data, including the field notes from the PI's classroom observations, and the instructional artifacts collected during the study. This triangulation of data sources enabled us to situate what participants reported during interviews within the specific curricular context enacted in each classroom. Second, our analysis was strengthened by our collaborative approach. Throughout the processes of coding, generating possible interpretations, and verifying conclusions, we worked together to interrogate the analytical process and our developing interpretations at every stage.

Findings

We begin with a discussion of the classroom participants' goals for the four pre-algebra courses. After reviewing the goals shared by the four faculty members, then outlining the goals articulated by the students in our sample, we proceed with a discussion about the

accomplishment of those goals from the perspective of the students themselves. Finally, we examine the tensions that emerge in students' accounts of their learning, and explore the implications of these tensions for assessing the effectiveness of developmental math

Faculty Goals

Faculty members consistently articulated their hopes that as many students as possible would successfully complete the graded assignments and thereby pass the course. Learning constituted an implicit aspect of this completion goal, since all of the instructors were confident that passing their developmental course meant that students had acquired the necessary math skills to succeed in subsequent coursework. For example, Professor 4 explained that giving students a passing grade in her course constituted an affirmative reply to the question, "Do I really think these people are ready to take on the next class?"

In addition to the completion goal, faculty members stated two related learning goals: to increase students' confidence in dealing with math, and to help students recognize the relevance and usefulness of math in their everyday lives. Professor 1 summarized this goal by saying, "I want students to have a better relationship with math than they had when they came in." In describing students' relationships with math, instructors spoke of two related concepts: enjoyment and confidence, both of which the instructors conceived of as related to students' mathematical proficiency. Professor 2, for example, articulated her essential learning goals as "a good foundation and an enjoyment of math, so they can move on and be successful," indicating that later success depended both on students' math skills and their attitude. Likewise, Professor 3 expressed her hope that students would move away from fearing or hating math as a subject of study. Professor 3 explicitly linked this improved attitude towards math to students' self-confidence in their own mathematical ability.

Usually the biggest problem is that students' confidence is low, based on past experiences. And that's what the whole goal is, to build the confidence of the students. If they can come out [at the end of the course] saying, "you know what, I'm not afraid of it; I can do it; I'm confident and I'm not afraid to go on; I'm sure if I can tackle this, I can tackle the next thing," then I'm happy. Learning the material, mathematically is, of course, important. But I think those inner feelings, are almost more important, because that just allows them to be successful as they continue.

Using the term "self-esteem," Professor 1 shared a similar certainty about the importance of students' confidence. During her interview, Professor 1 described the issue as the need for the "secure feeling on the part of the students that they can do math." For students in developmental math courses, Professor 1 explained, she works hard to find ways to translate her confidence that students can learn and do math over to students. If students believe they can accomplish challenging problems, and they "really get into them," she asserted, "then they're thinking. And I love that--that's very important to me, that they learn how to think."

The instructors' other shared learning goal revolved around students' understanding of the usefulness of mathematics. Professor 2, for example, underscored the importance of providing examples in class "that are relevant," in order to demonstrate the usefulness of the math covered in the course. Similarly, Professor 4 hoped that students would better understand the importance of math in daily life. When asked what she hoped for by the end of the course, she replied,

I'd like to think that students have a better grasp of the importance of mathematics and understand that they deal with math every single day. When your boss says "cut your budget ten percent," what are you going to do? Somebody tells you that you've been

given a raise and it's supposed to be a five percent raise. How do you know that they gave you the right amount of money? ... You go sign up for a car loan, how do you know that they're charging you the correct amount?

In sum, all four instructors articulated learning goals that map onto the National Research Council's (NRC) description of productive disposition, a core math competency that combines an understanding of math as useful and helpful with a positive identity as a person who is capable of doing math (Kirkpatrick, Swafford, & Findell, 2001). Thus, these goals comprise an essential component of the NRC's conceptualization of mathematical proficiency, they represent an aspect of student learning that can be assessed, yet they are not accounted for in conventional completion measures.

Student's Goals

While discussing their experiences in developmental math, students, like faculty, identified both completion and learning goals. Completion goals included passing the pre-algebra course, as well as "getting through" the entire sequence of developmental math courses. Rosa, for example, described the amount of effort she was putting into studying and seeking extra help "so I can pass and get out of the class." Explaining her motivation to excel in the pre-algebra class as part of her plan to complete all three developmental math courses as quickly as possible, Lily said, "I wanted to do good in this course so I could skip Beginning Algebra and go straight into Intermediate Algebra." Michael expressed a sentiment shared by many when he noted "these math classes are definitely holding me back," along with his desire to complete them and move on to the coursework for becoming a physical therapist.

Students also articulated two learning goals. First, students wanted to learn math that would prove useful in "the real world." Students consistently expressed the hope that the math

they learned would be relevant to their lives—whether applicable to their personal lives, current jobs, or future careers. Indeed, as will become evident below, students assessed the value of math as a subject of study with statements about its usefulness.

The second learning goal that students articulated during interviews was what Rosa described as *really* understanding the mathematics. Describing her approach to the math class, Rosa explained that she carefully watched the instructor during every class, writing notes about each step. But, she added “I can write down notes as much as I want to. It doesn’t mean I’ll understand it. . . . I’m looking at [what the instructor is writing on the board], and I want to know why it is like that.” For Rosa, it was only during her extra help sessions with the instructor that she felt comfortable asking the instructor to provide that needed explanation. Meeting individually with the professor for “a one on one session with the problems” helped Rosa “really understand it.”

Lily shared a similar sentiment about wanting a fuller understanding of the procedures. Reflecting on a math teacher she encountered in high school who helped her enjoy and excel in math, she offered suggestions for good math instruction:

Tell me why I'm doing that. Tell me how to solve the problem, show me how to solve the problem, but then sometimes tell me *why* I am plugging this number in for this, or *why* I have to do this step before I'm doing that step.

Through such statements, students expressed a desire to understand the “why” underlying the procedures, and indicated a clear distinction between applying the rules (the how) and understanding the rationale for various steps in the problem-solving procedures (the why).

Across the sample of 25 students, 18 expressed their concern with understanding the “why.”

Students' desire to understand "why" within the context of a procedurally-focused curriculum led them to value instruction that went slowly and carefully through each step of the problem-solving process. Multiple students spoke explicitly of the importance of "breaking it down," while others elaborated their preferred instructional practice as one in which the professor explains each step, and confirms students' understanding before moving to the next step. Emily, for example, critiqued a prior math teacher's approach, noting that he "would have some students falling behind because he wasn't really going through anything that we didn't know and needed help with." Emily contrasted this to the more effective approach of teachers like Professor 2, who "wouldn't really skip over anything that we didn't know. She made sure that we all knew what was going on, and what she was talking about."

Similarly, Katie highlighted the successful features of Professor 3's one-on-one review of the worksheets that students completed during class. When asked what aspects of the course were helpful, Katie referenced the individualized instruction aimed at addressing each student's particular errors on the worksheet problems. She explained the benefits: "we got to do the problems ourselves and ... she explained everything and we got to ask her questions." Paradoxically, despite Emily and Katie's endorsements of their pre-algebra professors' instruction, neither student believed that she had actually gained an improved understanding of math from the pre-algebra course. As we discuss below, few students believed that they had learned much from taking the course.

What Students Gained From the Course

The instructional activities and assessments across the four classrooms focused on students' memorization and application of procedures. As a result, the observation data do not shed light on whether students developed a greater understanding of the "why" of math. Nor do

they provide evidence regarding the development of students' productive disposition.

Accordingly, we rely on the interviews with students to explore the whether students believed that they accomplished those goals.

Seeing the relevance of math to daily life. In response to the interview question about the relevance of pre-algebra, students responded in three distinct ways. Some students, particularly those in Professor 3's class, offered generalized statements about the usefulness of math in daily life. For example, Zara asserted, "yeah, bank and work and shopping and stuff involve numbers. So I guess you have to know your way with numbers in order to live life." Likewise, Katie identified the importance of math in students' daily lives:

It's like we *do* use it every day. You might not know it but...now that you're in college you need to have gas, you have to worry about payments, all this stuff, it's definitely in everyday life.

Maleah, who had already shared her aspiration to become a pharmacist, noted, "I'm going to need math, no matter if I try to avoid it or not."

About a third of the students offered more specific assessments about the relevance of the math topics covered in the course. Jordan, for example, identified percentages as particularly useful.

I had a job interview recently as a cashier. And I had to break down the percent discounts. So I remember the equation [the professor] gave to us in class to help me solve the problems, and so I wound up just passing the cashier's exam by the equation she showed us.

Isabella and Lily also provided examples from their jobs. Isabella, who worked in her parents' restaurant stated, "It is useful, actually. Because when I'm at work, sometimes our register is

down, so we all have to do math on a piece of paper.” Similarly, Lily, who worked part-time as a server, noted, “I find percentage stuff [relevant] because at work sometimes I have to take 20 percent or add 20 percent onto the check.” Clare identified the usefulness of percentages for calculating discounts, providing a recent example:

Like there’s a deal--I was going get a new iPod, and if you hand in your old iPod, you get 10 percent off, and I was like, ‘ooh, what’s 10 percent off of \$250?’ And then I was like, well, 10 percent is 100 so it’s going to be, like, \$14 or \$15, it’s not even going to be that much, and I was like, ‘oh, that’s not even worth it.’

Clare’s estimate was inaccurate, casting doubt on her ability to apply what she had learned; nevertheless, she recognized ways that she could apply math to real life.

Most students, however, stated that much of the coursework was not particularly relevant to their lives. These students agreed that basic computation skills are helpful and relevant to everyday life, and conceded that certain topics could prove useful. However, they also asserted that many topics were not necessary or particularly useful. Jordan, who had found the formula for percentages helpful to gaining employment as a cashier added, “but when it comes to advanced math, I just feel like it’s unnecessary because I’m not going to use it.” Likewise, James asserted, “To be honest, the math that is important is the math they taught you in first, second, and third grade. That’s the only math that really every person needs.”

Students were most dismissive of the algebraic topics they had encountered at the end of the course. Dominic noted, “You don’t go to the grocery store and be like this: minus x equals 4,” and Quincy insisted, “You don’t need it. I’ve never seen a cash register that says $7x$. I’ve never seen stuff like that.” Given that the next two courses in the developmental math sequence were beginning and intermediate algebra, this meant that students were likely to start the next

course with little appreciation of its possible relevance to real life. Indeed, Mariana's assessment of the relevance of the course after pre-algebra was, "not really." Continuing, she explained,

Not really 'cause right now I'm learning about the $y=mx+b$, the slope and stuff like that, and the equations. Like get y by itself, and stuff like that. I don't think it has to do anything with the real world, not unless you're an architect. I mean--if they need that.

Understanding the logic of math. Although the majority of students ($n=18$) indicated that they wanted to "really understand" math, including the logic of the procedures, only three students believed that they had gained a better understanding of math by the end of the course. Rosa, who had begun working extensively with her instructor in one-on-one sessions during the last third of the course, was one such student. Although Rosa ultimately failed the course, she recognized that the visits to her instructor's office had helped her begin to understand math in ways that had previously eluded her. The only other two students who described an improved understanding were Genevieve and Gabriela, both of whom successfully completed the course. Genevieve explained the value of the course by comparing it to her experience during high school:

And then some stuff ... it just went in one ear and out the other one when I was in high school, but after going over it with [Professor 3], I really understood it because she took the time to break it down, bit by bit and stuff like that. She was really helpful.

Like Genevieve, Gabriela noted that her instructor presented the material well. In addition, Gabriela attributed her success to her single-minded focus during class as well as her efforts outside of class to review the math on online websites until things "clicked." These three students were unique among the sample of 25, in that they complimented their instructors' teaching and also reported an increasing understanding of math as a result of taking the course.

Whereas many other students provided similarly positive assessments of their math instructors' teaching, they did not describe the result of that instruction as a better understanding of the math. Three students asserted that they already understood all of the topics prior to entering the course. Lucy, for example, was certain from the start of the course that she had been misplaced. She approached her instructor and the developmental math director about re-taking the assessment test, but felt discouraged by both of their responses, and decided not to pursue the re-testing option. In particular, Lucy recounted, the developmental math chair told Lucy that she could try to test out but that "no one ever passes it, so I don't know why you're going to try." In contrast, her developmental English instructor acknowledged that Lucy's assessment results had not reflected her actual skills, and signed a waiver so Lucy could skip the subsequent developmental English course. By the end of the term, Lucy was both adamant that she had not needed the math course and bitter about her experience. "I literally felt like it was a waste of money and a waste of my time." Zara also described her concern about being misplaced at the start of the term. By the end of the term, she confirmed that she had already known everything that the instructor covered. She did make friends during the course, so she counted that as a benefit.

But the thing is that you can't tell the teacher, "Oh, I already know this, I should leave."

Because then you either fail it or take it again. So I guess you have to keep the positive attitude.

Nisia, too, was certain that she hadn't been placed correctly in the course. She recounted asking her instructor if she could retake the placement test, explaining, "I'm like, 'can't I just take the test again?' She's like, 'no, it's too late.'" Like Zara, Nisia expressed a positive attitude about

the experience, noting, “I don’t regret it because I never regret doing anything in life. Everything happened for a reason.”

The majority of students (n=15) described the benefit of the course as “refreshing” their pre-existing knowledge of math. Clare, for instance, explicitly responded to the question of whether she learned math by saying, “No. I think I reviewed.” Similarly Nyya asserted, “Like, I know stuff, but you have to refresh my memory, you get what I’m saying?” Emily noted that the placement test had included “the obvious stuff,” which she knew how to do, “but there were little things that I had learned about in like middle-school or the beginning of high-school that I just forgot. Totally forgot.” As she put it, “over time I’ve kind of forgotten it, just because of all the other math that I have learned in past math classes.” Emily then provided an example of something that she had totally forgotten, and been able to review in the course:

I’ll give you an example. There was something a couple of weeks ago that I forgot. Like I know how to move decimals and change them into percents, but it was like, when you times the decimal by ten, or a hundred you’re moving it over to um, the right. No, when you change your percent to a decimal you move it to the left, and when you change it from decimal to percentage you move it to the right.

For Emily, this example illustrated information that she had previously encountered, forgotten, then become reacquainted with during the pre-algebra course. As Emily described the right way to “move the decimal point,” it made sense that she identified this as “reviewing” or “remembering” rather than learning.

Like Emily, Maleah explained her low placement test score to assessment score as a memory problem.

I guess because I took complex math for so long, since I was a [high school] freshman, that the easy stuff that you think is so simple, you forget about it when you take assessments like that. Your brain is so used to doing complex problems, and when a simple problem comes in you over-think it. So that was my problem. I needed to refresh my memory on everything I learned so long ago because that was elementary math, and you forget elementary math over the years.

Among the students who discussed the reviewing function of the course, many believed that they benefited from the experience. Maleah, for instance, asserted “When I do take college level math, it won’t be like I forgot it. It’ll still be fresh because it wasn’t too long ago that I took it.” In contrast to Maleah’s positive perspective on refreshing, Clare critiqued the course by saying, “it sucked a lot. I would rather be learning something that I didn’t learn, than reviewing something that I learned for four years.” Clare also acknowledged that the reviewing she accomplished during the course was temporary, noting “if you gave me the final right now I would probably fail.” She followed up by explaining,

If you gave me the book and I reviewed for maybe an hour, I could definitely pass the final. It’s just the reviewing because I forget so much, and it’s just hard remembering every single step.

Confidence. When responding to interview questions about what they gained from the course, two students mentioned their increased confidence. Gabriela noted, “I feel more confident, even helping my son with his math.” Likewise, Rosa reported, “I feel like my confidence is boosted. And I feel like I know the problems more than I did when I was in high school.” Significantly, these two students, Rosa and Gabriela, were two of the three students who had reported feeling that they had really started understanding the “why” of the math

procedures. In contrast, none of the students who described the “refreshing” value of the course noted any changes in their feelings of self-efficacy, confidence, or enjoyment of math. Aside from these two exceptions, taking this course did not alter students’ math identities.

The Limitations of “Refreshing”

The limitations of “refreshing” are perhaps best illustrated by the accounts provided by students who were interviewed after they had passed the pre-algebra course and were in the midst of taking the subsequent course in their developmental math sequence. Of the 15 students interviewed during the spring semester, three were in the midst of re-taking the pre-algebra course (having failed it the first time), and three had not enrolled in math despite having successfully completed the prior course. One student, Genevieve, had initially enrolled in the subsequent math course, but then dropped it after deciding it was scheduled too early in the morning.

Of the eight students taking the next developmental math course, three expressed confidence that they would be able to complete the course successfully. Clare, for example, was particularly happy that she was enrolled in an accelerated course that would allow her to complete the traditional two-course sequence in one semester. “I’m really happy that I’m actually in it because the teacher’s good and at least I don’t have to take two more classes to get into [college level courses].” In contrast to Clare, Mariana had considered the accelerated option, then decided it would be safer to take the two distinct courses so she wouldn’t “get stuck.” Mariana was happy with her decision to “suck it up,” and reported that her beginning algebra course was similar to pre-algebra, in that the instructor made the math “seem simple.” For both of these students, their satisfaction with the course resulted from their certainty that they would be able to complete the developmental math sequence easily.

This focus on completion rather than learning held true for Katie, as well. Despite her critique of the instruction in her beginning algebra course, she conceded,

it's not that bad, because of the fact that I've learned this stuff already. But if it was, let's say a calculus or a physics class or something, and it's the first time being taught to me, it would've been hard.

These students, however, were in the minority. Other students who had passed the pre-algebra course easily found themselves struggling in the subsequent course. Zara, for instance, announced,

I think I'm probably failing the class. The teacher: He says he's explaining it, but I don't know--I feel like I'm not learning anything. I passed my first test with a 70, but my last test was terrible--I got a 33 on that one.

Isabella, who hadn't yet been tested on any of the material, admitted that she was having "a little bit of trouble" in her class. Other students reported doing so poorly on tests that they considered dropping the course before the official drop deadline. Lily, for instance, was worried about the prospect of a low grade on her transcript, because of her hopes of transferring to a nearby university. In preparation for her first test, she asserted, "I tried to pay attention and I studied before. It wasn't like I'm just gonna wing it--I actually studied and I got 75 on it." Based on that initial grade, Lily decided to drop the class. "I wasn't understanding everything she was teaching or the way she was teaching." Similarly, Luna described being both "nervous" and "really depressed" about her math course, explaining, "Last semester, I passed with a B+. Now, I have, like, an F." Luna considered dropping the course, but then decided to stick it out and to try to pass. After all, she reasoned, "if I fail the class, I'm just gonna have to retake it again. If I drop the class, I'm gonna have to retake again."

Conclusion

The faculty members and students in this study articulated a valuable set of learning goals for developmental math. The four instructors hoped that students would learn to feel capable, confident, and effective in appropriately applying their knowledge of math. Furthermore, they wanted students to acquire the competencies that would allow them to complete future math courses. Students identified similar goals, expressing hopes that they would understand the logic and relevance of mathematics. However, across the sample of students in this study, few gained confidence or reported an improved relationship with math. The majority of students reported feeling temporarily “refreshed” on items they had known in the past but then forgotten. At the same time, these same students praised the instruction they experienced, asserting the usefulness of slow, step-by-step instruction while simultaneously acknowledging that they had not actually learned much from such instruction.

The specific context of this study, including the highly procedural curriculum enacted across all four classrooms, complicates our ability to assess the effectiveness of the course through completion rates. The hopes that students articulated for their learning (relevance and real understanding) are not limited to students in these classrooms (see, for example, Grubb & Gabriner, 2013). Yet students’ accounts of what they gained from the course were integrally linked to (and shaped by) the instruction they experienced in these particular classrooms. Not only do students’ accounts raise concerns about the effectiveness of the course, they also confound the completion issue: Focusing on students who passed the course handily and listening to what they gained from the course, and how they felt in the subsequent course suggests that completion was not necessarily accompanied by other evidence of learning other than short-term refreshing of procedural rules. The disconnect between completion and learning

confirms the need for creating a more comprehensive picture of what is happening inside developmental math classrooms, how that shapes student learning, and the connection (or disconnection) between learning and completion. Ultimately, this study not only highlights the importance of assessing students' *learning*, but it also points out the need to consider classroom-level instruction when assessing student learning, course completion, or developmental math reform.

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