Approaches to College Mathematics: Reimagining Remediation and Improving Student Outcomes in Precalculus

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This proposal reports on the impact of a course designed to prepare first-year students for success in Precalculus. The course, Approaches to College Mathematics (ACM), was developed as a prerequisite course in response to one university's high failure rate in Precalculus. In addition to a carefully designed yet flexible curriculum that aims to have students explore familiar topics in fresh ways, the course focuses on growth objectives meant to help students transition to their first semester as a college student. Institutional data and survey data from both students and instructors were collected. Preliminary results show that the overall failure rate in Precalculus decreased the semester after ACM was implemented. Additionally, a high percentage of students in ACM reported feeling that ACM was the right placement for them. Finally, ACM grades and the ACM instructors' sense of their students' mathematical confidence significantly predicted grades in Precalculus.

Keywords: Precalculus preparation, mindset, retention

We report on a study that involved the development and implementation of a course, Approaches to College Mathematics (ACM), for students who require an additional college course to prepare for Precalculus. The study is based on 15 sections of the course from Fall 2024. Going in, we were acutely aware of the unique circumstances that were a reality for these students who, as first-year undergraduates in 2024, had been in eighth grade at the onset of the COVID pandemic. This meant that they had spent most of their freshman year in high school learning mathematics online, even though their teachers had not been supported in online pedagogies given the pandemic's abrupt and urgent demands (Engelbrecht et al., 2020). In other words, it is likely that many of the students entering college in 2024 had significant gaps in their mathematical skills and knowledge, particularly with respect to content covered in Pre-Algebra and Algebra I. In addition to these mathematical obstacles, we knew that ACM students would be navigating additional challenges commonly experienced by students transitioning from high school to college learning.

Because the primary goal of the ACM course was to prepare students for Precalculus, we chose to focus on content and skills that would be foundational to that course (e.g., proportional reasoning, graphing, and order of operations). However, we kept this list relatively short to allow for flexibility and responsiveness in our practice, providing space for instructors to address student misconceptions as they emerged in class. Further, we designed several inquiry-based group work activities for ACM that would promote the development of rich, conceptual understanding. Finally, to prepare ACM students more broadly for learning mathematics at the college level, we incorporated a number of *growth objectives* intended to encourage productive habits of mind and actions. These objectives focused on seeking support from professors, managing time, taking advantage of college resources (such as the tutoring center), and managing stress. Thus, we took on the charge to reconceptualize what it means to prepare

students for college level mathematics, and to investigate the efficacy of our new course. The following research question framed our study: *What is the impact of the Approaches to College Mathematics course on students' preparedness for Precalculus, as assessed by their grades in Precalculus and their own sense of the usefulness of ACM?*

Conceptual Framing

The early history of remedial education began with the passage of the GI Bill in 1944, which sparked a proliferation of postsecondary institutions (Adams, 2000). This meant that thousands of high school graduates, many of whom were not prepared to study mathematics at a college level, suddenly had access to a tertiary education. In this environment, mathematics departments began to offer remedial mathematics courses to help improve students' mathematical knowledge and skills. By the end of the 20th century, remedial mathematics had become "a formal discipline of study, as institutions of higher education recognized that the need to provide remedial education to their students was now a continuing one" (Shaddai, 2018, pp. 389-390).

Whether or not remedial courses in mathematics ultimately result in the intended benefits for students is a matter of debate. While successfully completing a remedial mathematics course may improve the likelihood a student will earn a college degree (Sanabria et al., 2020), the high failure rates in these courses position them as "a systemic black hole from which students are unlikely to emerge" (Jimenez et al., 2016, p. 1). In recent years, this perception has led several institutions to reconsider how best to support their undergraduate students who are not yet ready to study college level mathematics. For example, some institutions have reported improved student outcomes in introductory mathematics courses after experimenting with a co-requisite model (Bertrand et al., 2021; Ran & Lin, 2022). In this model, students that would traditionally be placed in remedial courses are mainstreamed into college-level math courses and provided with additional concurrent supports, such as tutoring services or extra lessons that review prerequisite skills just before they are required in the college-level course.

This need to reconsider 'remedial' or 'developmental' mathematics education for first-semester college students motivates our study. Having tried the co-requisite model, a computer-based self-paced emporium-style model, and other support systems with little success, our department proposed the development of a new course that acknowledges the unique (and varied) needs of this student population. The research team agreed that the overarching focus driving all of our efforts was to prepare students for Precalculus, and that this preparation must necessarily encompass more than just mathematical knowledge and skills. Given that, we eventually landed on two major goals: to enhance students' understanding of mathematics content that is considered prerequisite for Precalculus (math objectives) and to help them acclimate to being a college student (growth objectives). The team met weekly over the summer to develop these objectives and to design tasks that aimed to have students explore familiar mathematics using novel approaches.

Methods

The study took place at a mid-sized state university in the northeastern United States that has experienced substantial growth in the last two decades. Most of the students at this university come through local school districts or community colleges, and the current acceptance rate is roughly 87%. Precalculus is a required course for all STEM (science, technology, engineering, and mathematics) majors. Students take an internally developed placement test before their first semester, and are placed in ACM if their score is below 60%. In Fall 2024, approximately 30% of students were placed into ACM, with the remainder taking either Precalculus or Calculus. The

average class size of each ACM section was 23 students. Of the 343 students enrolled in the course in Fall 2024, 118 consented to participate in the study. Data was collected from both students and instructors. Students completed a survey at the beginning of the Fall 2024 semester in ACM and at the beginning of the next semester, Spring 2025, in Precalculus. This survey included several short-answer questions asking them, for example, why they were studying mathematics, their perception about what it means to be a 'math person,' and whether or not they thought ACM was the right course for them. The survey also included 14 Likert scale questions taken from the Attitudes Towards Mathematics Inventory Short Form (Lin & Huang, 2016).

At the end of the Fall 2024 semester, the seven ACM instructors were asked to report each student's grade (as a percentage), attendance (as a percentage), as well as their subjective assessment of each student with respect to seven categories: content knowledge; readiness for college; academic integrity; classroom presence; mathematical dispositions; and mathematical confidence. These assessments of each student were reported as scores of 1 (low), 2 (moderate), or 3 (high). Additionally, instructors were asked to predict each student's letter grade for Precalculus. Final letter grades for consenting students in ACM in Fall 2024 and Precalculus in Spring 2025 were collected from our institution.

Results

We report on three key findings: the percentage of students receiving either a D, F, or W grade (the DFW rate) in Precalculus, students' perceptions of their placement in ACM (both before and after having taken ACM), and a regression model predicting students' letter grades in Precalculus. In the semester prior to the implementation of ACM, the DFW rate in Precalculus was 34.7% (a rate that has historically been between 30% and 50% at our institution). This rate is significant because STEM students who receive a D grade or lower are unable to take the next required mathematics course. The Precalculus DFW rate in the first semester we held ACM (Fall 2024) was 18.4%, notably (and predictably) lower than the previous semester, due to placing the less-prepared students into ACM. When the ACM students took Precalculus in Spring 2025 (accounting for 61.3% of Precalculus students), the overall DFW rate increased slightly to 20.3%, but was well below the historical average of 30% to 50%. The DFW rate in Precalculus for students who had taken ACM was also comparable to that of those who had placed directly into Precalculus (20.5% and 19.5%, respectively). This last result indicates that students who took ACM were able to earn their required Precalculus credit at rates roughly similar to their peers.

Another notable result had to do with students' sense of whether or not they felt that taking ACM before Precalculus was the right course of action for them. Students were asked to answer the following open-ended question at the beginning of their ACM semester and at the beginning of Precalculus: *Do you believe ACM is/was the right course for you?* Students' responses to this question included straightforward 'yes' or 'no' responses, with some responses being more nuanced (e.g., "I feel like I should've been placed in [Precalculus] instead of [ACM], but it was a nice refresher."). However, we categorized all responses as either 'yes' or 'no,' based on our understanding of the intent behind the more nuanced responses. In the pre-ACM survey, 91.5% were coded as a 'yes' response; by the start of their Precalculus semester, this percentage had dropped somewhat to 80.5%. Despite this decrease, it was clear that the overwhelming majority of students felt as though their placement in ACM had been appropriate.

Finally, in order to investigate whether some of the data we collected about the ACM students might have predicted their subsequent success in Precalculus, we ran a multiple linear

regression model using SPSS. Students' Spring 2025 Precalculus grades[1] were used as the dependent variable; predictor variables included students' ACM final letter grades[1], ACM attendance, the ACM instructors' seven subjective assessments, and the instructors' predicted Precalculus letter grade[1] for each student. The model of best fit ($p < .001$) included only two statistically significant predictors for students' Precalculus letter grades: their final letter grade in ACM ($p = .024$) and their mathematical confidence as assessed by their instructor ($p = .001$). However, this model left much of the variance in students' Precalculus grades unexplained ($R^2 = .187$; see Figure 1).

Model Summary[c]

					Change Statistics					Selection Criteria			
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Akaike Information Criterion	Amemiya Prediction Criterion	Mallows' Prediction Criterion	Schwarz Bayesian Criterion
1	.405[a]	.164	.157	1.1516	.164	22.592	1	115	<.001	35.008	.865	7.106	40.532
2	.448[b]	.201	.187	1.1310	.037	5.218	1	114	.024	31.771	.841	3.849	40.058

a. Predictors: (Constant), InstrConf
b. Predictors: (Constant), InstrConf, ACMLetter
c. Dependent Variable: PrecalcLetter

Figure 1. SPSS output for the multiple linear regression showing students' ACM letter grade and instructors' assessments of students' mathematical confidence as significant predictors of their Precalculus letter grades.

Discussion

In our preliminary investigation of the impact of the ACM course on students' preparedness for Precalculus, we found some encouraging evidence that this new course was associated with improved outcomes for these students. There was a marked decrease in the DFW rate in Precalculus after the ACM course was implemented, from 34.7% in Spring 2024 to 20.3% in Spring 2025. We also found that the vast majority of students placed in ACM in Fall 2024 believed that this placement was appropriate, both before and after they had taken the course. Finally, our multiple linear regression found that students' ACM course grades were significant predictors of their success in Precalculus. Taken together, these results suggest that our implementation of a reimagined prerequisite course for Precalculus had a positive impact on students' success.

Perhaps the most surprising finding in our preliminary analysis was the emergence of only one of the ACM instructors' subjective student ratings as a significant predictor of their Precalculus grade, namely their ratings of students' mathematical confidence. This finding merits further investigation because the term *mathematical confidence* likely meant something different to each instructor. In future iterations of the course and data collection, we intend to clarify the meaning of this term to help determine whether this rating is truly a significant predictor of students' eventual success in Precalculus. We are also interested in investigating the relationship between instructors' ratings of students' mathematical confidence and students' assessment of their own self-confidence in mathematics.

Other institutions have found success in supporting students who are not yet ready for college-level mathematics with, for example, just-in-time teaching (e.g., Bertrand et al., 2021) and co-requisite course enrollment (e.g., Ran & Lin, 2022) models; what seems to have worked at our institution has been a return to a standalone prerequisite course for Precalculus. We

[1] All letter grades (ACM/Precalculus letter grades and instructors' letter grade predictions) were converted to numerical GPA equivalents as follows: A=4, A-=3.7, B+=3.3, B=3, B-=2.7, C+=2.3, C=2, C-=1.7, D=1.

reimagined a traditional 'remedial' mathematics course by focusing on both presenting familiar mathematics content in novel ways and by focusing on growth objectives. The mathematics content was often explored through integrated STEM problems, gamified lessons, student collaboration in different forms (e.g., pairs, small groups, whole group) and an emphasis on creativity and connection-making. Our inclusion of growth objectives recognized the transitional nature of the students' lives and addressed skills that are essential to learning mathematics at the college level that go beyond understanding content, such as seeking out resources, study skills, and stress management. Not only are these unique aspects of our course design likely responsible for the improvements observed in students' performance in Precalculus, but we believe that they also serve as contributions to the research on supporting mathematically-underprepared STEM majors.

We have only reported on three major findings of our study in this report, but anticipate the emergence of additional, notable results as our analysis continues. As mentioned previously, we collected survey data with respect to students' attitudes towards the ACM course and mathematics in general, as well as several open-ended questions addressing their views of mathematics as a discipline. We intend to analyze this data to identify any attitudinal shifts students experienced from ACM to Precalculus, as well as to determine whether the ACM students' attitudes were significant predictors of their eventual Precalculus performance. Additionally, because the ACM course was developed in response to the high DFW rates for Precalculus at our institution, and because we saw a marked decrease in this rate following the implementation of ACM, we will investigate whether this trend of lower DFW rates persists for the cohorts of ACM students as they progress further through the calculus sequence. Furthermore, we continue to collect data from ACM courses. We have begun our Fall 2025 academic year with a new round of data collection for our incoming (approximately 900) ACM students.

There is a continuing need to find new ways to support STEM majors that arrive on college campuses in need of additional preparation to study mathematics at the college level. We look forward to adding our preliminary results to ongoing discussions in the RUME community about addressing this need. Furthermore, we hope that by describing the development of ACM, sharing its design, and presenting these preliminary results, we will inspire others to reimagine 'remedial' mathematics and consider implementing a similar course at their institutions.

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