

The Road Not Taken: A Comparison of Precalculus Pathways

Zaher Kmail

University of Washington Tacoma

Ander Erickson

University of Washington Tacoma

Bonnie Becker

University of Washington Tacoma

Abstract: Precalculus can operate as a gatekeeper for STEM majors, and for minoritized and first-generation students. One way to address this challenge at an institutional level is to offer multiple pathways to Calculus so students can choose the course that best supports their needs. We examine the success of this approach by comparing precalculus sequences offered at three college campuses. The first offers a two-quarter precalculus sequence along with a compressed one-quarter sequence, whereas the second and third offer only one pathway. We contrast the performance of the pathways at the campuses to study which pathway leads to greater student success. Results suggest that offering multiple precalculus pathways is one way that an institution can move toward more equitable STEM outcomes.

Keywords: STEM majors, precalculus pathways, student success, first-generation students, minoritized students

1. INTRODUCTION

Lower-division mathematics courses often operate as gatekeepers for students who wish to pursue a STEM major (Martin et al., 2010) with students disproportionately withdrawing from or receiving a below-passing grade. This leads students to make a choice between taking the course again with an uncertain outcome or switching to a major that does not require the same mathematics prerequisite. In the United States, this phenomenon is particularly pronounced for minoritized and first-generation students, particularly with those students who are not from a high socioeconomic status (SES) background (Douglas & Attewell, 2017). Precalculus can play this gatekeeping role for calculus and, accordingly, for entry into most STEM majors (Zeidenberg & Collins, 2012). Indeed, precalculus is generally the first mathematics course that

college students in the United States take for credit and plays an outsized role for those students who did not already have an opportunity to fulfill that requirement in secondary school. In this paper, we explore the question of how best to present precalculus – whether as a single accelerated course or as a multi-quarter sequence – and explore whether offering multiple options mitigates the courses’ gatekeeper effects. We take advantage of the fact that one of the three United States’ universities involved in this project, Ambo University¹ (AU) offers precalculus in both one and two-quarter formats to assess whether students benefit from either format or whether the existence of a choice contributes to student achievement in and of itself. We are also able to use the fact that two other campuses in the same system and in the same metropolitan area, Simplex University (SU) and Duplex University (DU), use only a single precalculus pathway – a single quarter pathway at SU and a two-quarter pathway at DU -- to compare the effects of having options versus only having a single precalculus pathway.

Currently, AU, an institution with a high proportion of first-generation and minoritized students, offers a two-quarter precalculus sequence and a compressed one-quarter sequence to provide greater flexibility for students, but it is important for us to know whether the two different sequences are supporting student success for students of different backgrounds. To this end, we use ANOVA and multiple comparison t-tests to compare the performance of the precalculus pathways within and across campuses to study which pathway leads to greater student success and under which conditions. We also compare campus demographics to the demographics in these courses to better describe existing inequities related to enrollment in these courses.

¹ Names are pseudonyms

It is our hope that beyond contributing to the higher education research base, this research will provide insights to administrators in universities who wish to modify their course offerings in precalculus to increase enrollment into the calculus sequence. Our work may also appeal to mathematics departments who seek to improve persistence and retention. The broader impact of our work may also extend to administrators and mathematics departments at 2-year and professional colleges to modify their own precalculus course offerings to better serve their student population. Finally, we hope that academic advisors find our research relevant to help empower students as advocates in their own educational journeys through providing choice in precalculus pathways.

2. LITERATURE REVIEW

2.1 Precalculus as a Gatekeeper Course

Lower-division mathematics courses are often a prerequisite for STEM degrees, but they unfortunately also have a disproportionately high failure rate which leads to their label as ‘gatekeeper courses’ (Gainen, 1995; Eagan & Jaeger, 2008; Martin et al., 2010). There is no definitive account of why these courses serve this role – Eagan and Jaeger (2008) posit that these courses are often led by part-time instructors with less experience which may lead to the observed outcomes while Gainen (1995) suggested earlier that a lack of student mathematical preparation may be the cause. Martin, Gholson, and Leonard (2010) argue that the sorting resulting from this process has the effect of reproducing the inequities found in the current sociopolitical system. This argument was supported empirically by the analysis of school and workplace data from the Organization for Economic Cooperation and Development (OECD) conducted by Douglas and Attewell (2017) that led them to make three important conclusions: a) better math performance is associated with positive school outcomes in STEM fields, b) students

from higher-SES students disproportionately benefit from these classes, and c) students do not actually need the bulk of these mathematics skills in their subsequent careers. A recent interview study (Leyva et al., 2021) found that marginalized students perceived instruction in precalculus as exclusionary due to inequitable opportunities for participation, racial and gendered stereotyping, and a lack of opportunity for same-race and/or same-gender peer support. Taken together, these conclusions suggest that precalculus is in danger of serving a social sorting function rather than as genuine preparation for professional success.

2.2 Supporting Student Success in Precalculus

The well-documented high attrition rates in precalculus courses have historically been addressed using non-credit bearing mathematics courses (usually labeled remedial or developmental) that are intended to provide the necessary algebraic understanding to succeed in precalculus (Brusi et al., 2013). Unfortunately, the evidence for efficacy of these courses is mixed, suggesting that they may have limited to no effect on student mathematical outcomes (Jenkins & Boswell, 2002; Kurlaender & Howell, 2012). Another common approach is the introduction of student support courses that run concurrently with precalculus. This was most famously adopted by the California State University (CSU) system where they stopped offering developmental math courses and allowed students to enter precalculus directly without having to meet any placement criteria (Goyer et al., 2021). Jones and Lanaghan (2020) document how this transition worked at one of the CSU institutions, describing how the introduction of standards-based grading and a greater focus on a growth mindset was associated with a significant increase in the passing rate for the course.

2.3 Purpose of the Study

In what follows, we will explore the student body characteristics of the three campuses of AU, SU, and DU and discuss the question of whether the availability of a choice in precalculus pathway supports success in future math classes. Therefore, the purpose of this observational study is to explore the effect of the different precalculus pathways on Calculus I performance. Specifically, we compare Calculus I outcomes based on precalculus pathway, gender, race, and first-generation status. The study addresses the following research questions:

1. How does the existence of multiple precalculus pathways affect the demographics of the students' taking Calculus I and how does this compare to institutions without multiple pathways?
2. How do Calculus I outcomes differ based on students' choice of precalculus pathway?

Additionally, we study the importance of the precalculus pathway options by comparing the disparity of the results when only one precalculus pathway is available on a campus. Here, we compare outcomes in Calculus I between students who took precalculus at the institute studied and those who took precalculus elsewhere, such as at another four-year institution, community college or secondary school, or those who were placed into Calculus I via assessment testing. This study also discusses the importance of the two-quarter option for underrepresented minority (URM) and first-generation students.

3. METHODS AND MATERIALS

3.1 Description of the Precalculus Pathways

There are two pathways that students can take through precalculus at AU. There is a two-quarter sequence in which the first quarter (MATH 110)² covers the general concept of function, function operations, and algebraic functions such as polynomials and rational functions. Students learn about transcendental functions (exponential functions and trigonometric functions) in the second quarter (MATH 111) of this sequence. Faculty intends for this two-quarter sequence to serve students who have either not encountered precalculus before or who are not comfortable with precalculus concepts for any other reason. The other option is a compressed one-quarter (MATH 112) sequence in which all the material is covered at an accelerated rate. This sequence is intended for students who have seen the relevant material before and who only need a relatively fast review to be prepared for Calculus I. Students may choose which sequence to take at AU with guidance from advisors and higher scores in the placement test for the one-quarter sequence. Some students also choose to only take MATH 111 if they feel that they only need to review transcendental functions.

The precalculus options at SU and DU are both more limited. At SU, students are only given the option of the one-quarter compressed course. DU, on the other hand, only provides students with a two-quarter option. Like the two-quarter sequence at AU, students may take both precalculus classes while others will only take MATH 111 if they only need to review transcendental functions to be prepared for Calculus I.

² Course names are pseudonyms

3.2 Data Collection and Analysis

The data set includes the students from SU, DU, and AU from Autumn 2015 through Summer 2019. The data includes 62,890 students in that period where 8,958 were at AU; 9,736 at DU; and 44,196 at SU. The data includes race, gender, first-generation status, and the grades of the student on a numerical scale with grades ranging from 0.0 to 4.0 in increments of 0.1. We use the grade given to the students as a proxy of whether the course outcomes were different with respect to race, gender, and first-generation status.

The data were analyzed in two stages using SAS[®] University Edition software (SAS Institute Inc., 2021; 2017) and Microsoft Excel. Both descriptive and inferential statistical analysis were computed using the Proc Mixed and Proc Freq procedures in SAS. In the first stage, the Proc Freq procedure was used to study the overall demographics of the three campuses in addition to the demographics of precalculus and Calculus I students. Microsoft Excel was then used to visualize the SAS output by producing charts. In the second stage, the Proc Mixed procedure was used for inferential statistics involving Analysis of Variance (ANOVA) and multiple comparison t-tests to compare Calculus I grades based on the precalculus pathway across race, gender, and first-generation status.

4. RESULTS

4.1 Demographics of Precalculus Pathways

When given a choice, over two-thirds of students taking precalculus chose the compressed option at AU (Table 1). However, there was still a sizable group of students who decided to take the two-quarter sequence.

Notably, a much larger proportion of students (73%) had already taken precalculus prior to their studies at SU as compared to their peers at AU or DU. The large disparity in pre-calculus

preparation reflects SU's greater selectivity through the admissions process than either AU or DU. For example, in Fall 2021, the acceptance rate at SU was 53% while the acceptance rate at both AU and DU was 83% (Institute of Education Statistics, National Center for Education Statistics, n.d.).

While DU has a single precalculus sequence, students at DU are given the option of taking only the second course of the sequence (MATH 111) if they place into it and almost half the Calculus I students took that option. The determination of whether MATH 110 is needed is made either through Math assessment exams, observation that a student is struggling with the content of MATH 111 to the point where they are unable to be successful, or a combination of the two approaches.

Table 1: Percentage of Calculus I students based on precalculus pathways.

Precalculus	AU	DU	SU
MATH 112	43%	—	27%
MATH 110/111	14%	14%	—
MATH 111 Only	6%	46%	—
Precalculus Elsewhere	37%	39%	73%

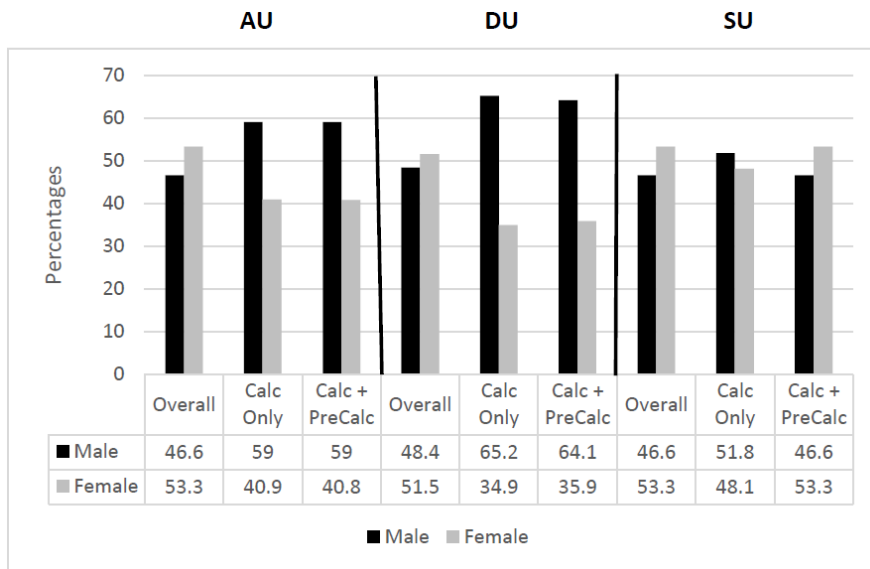
4.2 Precalculus Pathway by Gender

When looking at the entire student body, there were more female students than male students (Figure 1). This result holds true for all three campuses, with SU and AU having an approximately 53% female student body. DU had a slightly smaller proportion of female students at around 51%. However, there were more male students who took Calculus I without precalculus. This result was consistent across the three campuses in direction, but not degree.

Although there were more male than female students, SU campus came closer to parity with 51.8% male students and 48.1% female students. There was a greater disparity between genders of students who took Calculus I but also did not take precalculus at the other two campuses. The greatest disparity appeared at the DU campus with 65.2% of male students who only took Calculus I versus 34.9% of female students.

Similarly, there were more male students than female students who took Calculus I with the precalculus prerequisite. Even though there were more female students on all three campuses, there were more male students who took Calculus I with the precalculus prerequisite at rates of 59.0% and 40.8% male to female at AU, and 64.1% of male students and 35.9% of female students at DU took both Calculus I and precalculus on their campus. However, there was a greater balance at SU with rates which are more consistent with the overall percentages of enrolled students: 46.6% of male students and 53.3% of female students took Calculus I with the precalculus prerequisite as compared to 46.6% to 53.3% male to female ratio in the entire student body at SU.

Figure 1: Gender of students, students who only took Calculus I, and students who took precalculus and Calculus I.



4.3 Precalculus Pathway by Race and Ethnicity

There are more white students at AU than at DU and SU at 43.2% versus 40.0% and 40.9%, respectively (Figure 2). AU had the lowest percentage of Asian American students amongst the three campuses with a rate of 16.4% versus 24.75% at DU and 24.1% at SU. AU had the most diverse population of students amongst the three campuses with percentages of students who belong to groups identified by the NSF (2019) as under-represented in STEM (i.e., Hispanic, Multiracial, African American, American Indian, or Hawaiian/Pacific Islander) exceeding both other campuses. However, both SU and DU had a higher percentage of international students enrolled on campus at 14.0% and 9.8%, respectively, as compared to 4.8% at AU.

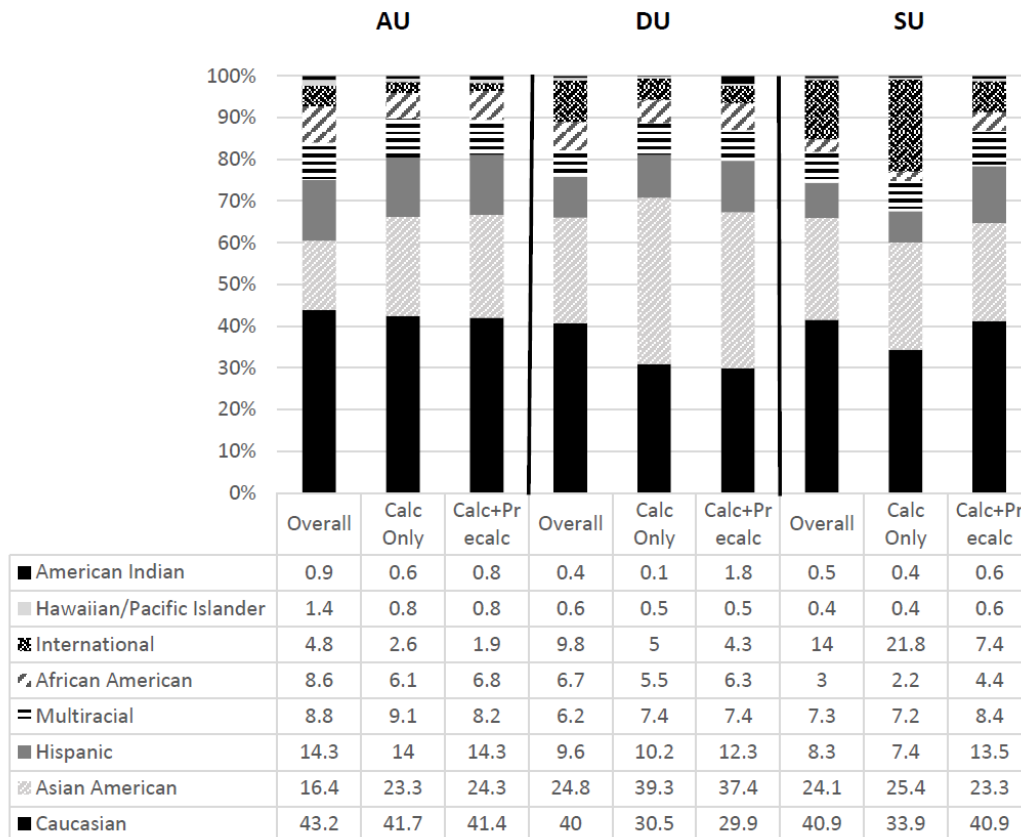
At DU and SU, looking at the students from groups under-represented in STEM, the percentage of students that took Calculus I with the precalculus prerequisite was higher than the percentage of students that only took Calculus I. The same pattern was seen at AU for students who identify as Hispanic, African American, and American Indian, where the percentage of students who took Calculus I and precalculus was higher than the percentage of students who took only Calculus I. The pattern was different at AU for students who identified as multiracial or Hawaiian/Pacific Islander, where the percentage of students who took only Calculus I was higher than the percentage of students who took Calculus I with the precalculus prerequisite.

International students were under-enrolled as compared to their campus representation at AU and DU. To be specific, at AU 4.8% of students were international students, but only 2.6% and 1.9% of them had taken Calculus I or Calculus I with the precalculus prerequisite, respectively. At DU, 9.8% of the student population were international students, but only 5.0% of them had taken Calculus I and 4.3% of them had taken Calculus I with the precalculus prerequisite. At SU, we saw a similar result with 14.0% of the student population being international students while

only 7.4% took Calculus I with the precalculus prerequisite. Interestingly, at SU there was a nearly 36% percent increase of international students who took Calculus I without precalculus.

Finally, students who identified as Asian American took both Calculus I and Calculus I with the precalculus prerequisite at the highest rate with respect to overall demographics across all three campuses with only one exception, which was Calculus I with the precalculus prerequisite at SU. The greatest difference between demographic representation and the rate at which Asian American students took Calculus I was nearly 15% at DU.

Figure 2: Race of students, students who only took Calculus I, and students who took precalculus and Calculus.



4.4 Pre-calculus Pathway by First-Generation Status

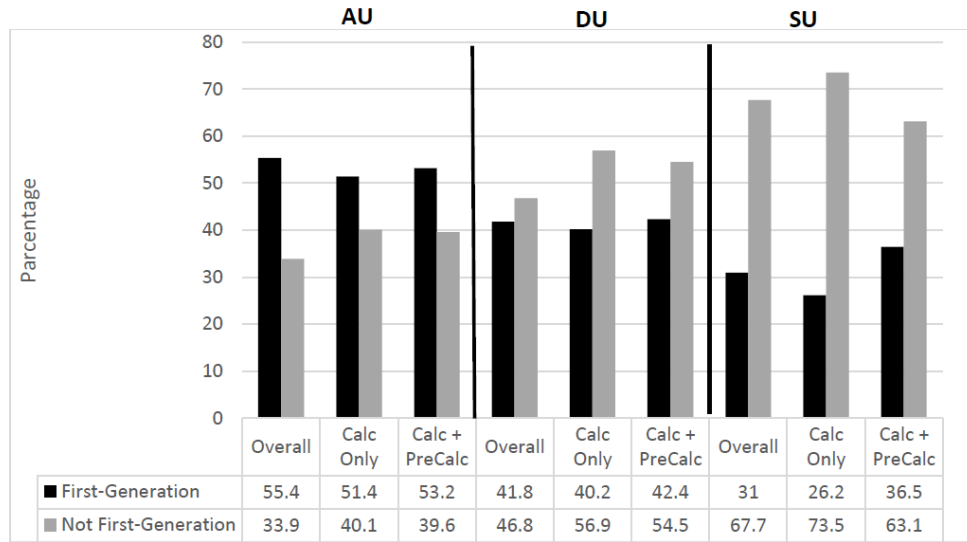
Most students (55.4%) at AU were first-generation students (Figure 3). By comparison, 41.8% and 31.0% of students at DU and SU identified as first-generation, respectively. Non-

first-generation students took Calculus I at a higher rate than their proportional campus representation both with and without the precalculus prerequisite at AU and DU. But at SU, the results were mixed. The rate of the non-first-generation students who took Calculus I without having taken precalculus as a prerequisite was higher than the overall rate of non-first-generation students at SU by 5.7%. But the rate of non-first-generation students that took Calculus I and precalculus at SU was less than the overall rate by 4.6%.

Additionally, results showed that first-generation students were underrepresented in Calculus I across all three campuses. The percentage of students who were first-generation and took Calculus I without precalculus as a prerequisite at AU was 51.4%, which was 4.0% below the overall percentage of first-generation students who were enrolled across campus over the period that was studied. The disparity was greater on the SU campus where 26.2% of first-generation students took Calculus I without having taken precalculus, which is 4.8% below the overall percentage of first-generation students on that campus. The smallest disparity between the percentage of first-generation students and the percentage of students who took Calculus I without also taking precalculus occurred DU at 41.8% and 40.2%, respectively, a difference of 1.6%.

Finally, there was a higher rate of first-generation students that took Calculus I and precalculus as a prerequisite compared to first-generation students who took only Calculus I across all three campuses. At SU, 10.3% more first-generation students took Calculus I with precalculus as a prerequisite than those who only took Calculus I. The differences between the same two groups of first-generation students were smaller at DU and AU, with differences of 2.2% and 1.8%, respectively. It can be inferred from these results the importance of precalculus pathways for first-generation students, especially at SU.

Figure 3: First-Generation status of students, students who only took Calculus I, and students who took precalculus and Calculus I.



4.5 Outcomes in Calculus I

We seek to examine Calculus I outcomes, using grade as a proxy, depending on student pathway through precalculus. Precalculus pathway was the most significant factor in Calculus I outcomes, with the largest significant differences at DU and SU (Table 2). On both campuses, students who placed directly into Calculus I performed significantly better than students who took precalculus first (Table 3). At DU, the estimated grade in Calculus I for students who took the two-course sequence was 0.48 lower than those students who placed directly into Calculus I (Table 4). For students who only took MATH 111 at DU, their estimated grade in Calculus I was 0.31 lower. The smallest significant difference was at SU where the estimated grade in Calculus I of students who took precalculus on campus was 0.29 lower than students who took it elsewhere. Conversely, there were no significant differences in outcome in Calculus I of students who took precalculus at AU and those who did not.

There were no significant differences in outcome in Calculus I among gender and precalculus levels at AU. However, there were significant differences at DU and SU. At both institutions, the

average grade of male students in Calculus I exceeded the average grade of female students by 0.13 at DU and 0.03 at SU.

Race was not a significant factor at AU and DU but was a significant factor at SU.

International students experienced significantly better outcomes in Calculus I as compared to domestic students across all race categories with an average estimated grade of 3.12. Minoritized students at SU, which includes those who identify as African American, Hispanic, American Indian, and Hawaiian/Pacific Islander earned significantly lower grades on average in Calculus I than those students who identify as Caucasian and Asian American.

Looking across all three institutions, non-first-generation students had significantly better outcomes in Calculus I than first-generation students. On average, the grades of non-first-generation students in Calculus I exceeded the grades of first-generation students by 0.16, 0.19, and 0.17 at AU, DU, and SU, respectively.

Table 2: The overall ANOVA to determine whether there are significant differences in Calculus I grades among the levels of precalculus, gender, and first-generation status.

Type 3 Tests of Fixed Effects			
	AU	DU	SU
Effect	Pr > F	Pr > F	Pr > F
Precalculus	0.3336	<.0001	<.0001
Gender	0.096	0.0096	0.0392
First-Generation Status	0.0178	0.0007	<.0001
Race	0.0879	0.1857	<.0001

Table 3: The estimate of the average grade on a numerical scale from 0.0 to 4.0 in Calculus I at AU, DU, and SU among the levels of gender, race, first-generation status, and precalculus pathway with significant differences.

Least Squares Means				
Effect	Levels	Estimated Grade in Calculus I at AU	Estimated Grade in Calculus I at DU	Estimated Grade in Calculus I at SU
Precalculus	MATH 110/111	No significant differences	2.75	-
	MATH 111		2.93	-
	MATH 112		-	2.55
	Precalculus Elsewhere		3.23	2.84
Gender	Female	No significant differences	2.90	2.68
	Male		3.04	2.71
First-Generation Status	First-Generation	2.62	2.84	2.68
	Not First-Generation	2.79	3.04	2.85
Race	Caucasian	No significant differences	No significant differences	2.74
	Asian American			2.76
	Hispanic			2.63
	Multiracial			2.71
	African American			2.52
	International			3.12
	American Indian			2.47
	Hawaiian/Pacific Islander			2.51

Table 4: Contrasting the performance of the average grade in Calculus I at AU, DU, and SU between the levels of gender, race, first-generation status, and precalculus pathway with significant differences.

Differences of Least Squares Means (Contrast 1 - Contrast 2)			
Institution	Contrast 1	Contrast 2	Estimate
AU	First-Generation	Not First-Generation	-0.16*
DU	Not at DU	MATH 110/111	0.48**
DU	Not at DU	MATH 111	0.31**
DU	MATH 110/111	MATH 111	-0.17*
DU	Female	Male	-0.13**
DU	First Generation	Not First-Generation	-0.19**
SU	At SU	Not at SU	-0.29**
SU	Female	Male	-0.03*
SU	First Generation	Not First-Generation	-0.17**
SU	African American	Asian American	-0.25**
SU	African American	Caucasian	-0.22**
SU	African American	Hispanic	-0.11*
SU	African American	International	-0.59**
SU	African American	Multiracial	-0.19**
SU	American Indian	Asian American	-0.29*
SU	American Indian	Caucasian	-0.27*
SU	American Indian	International	-0.64**
SU	American Indian	Multiracial	-0.24*
SU	Asian American	Hawaiian/Pacific Islander	0.25*
SU	Asian American	Hispanic	0.14**
SU	Asian American	International	-0.34**
SU	Caucasian	Hawaiian/Pacific Islander	0.23*
SU	Caucasian	Hispanic	0.11**
SU	Caucasian	International	-0.37**
SU	Hawaiian/Pacific Islander	International	-0.59**
SU	Hispanic	International	-0.48**
SU	Hispanic	Multiracial	-0.08*
SU	International	Multiracial	0.40**

** Indicates $0 \leq P\text{-value} \leq 0.01$

* Indicates $0.01 \leq P\text{-value} \leq 0.05$

5. DISCUSSION

We use the analysis reported above to revisit our original research questions: (1) How does the existence of multiple precalculus pathways affect the demographics of the students' taking Calculus I and how does this compare to institutions without multiple pathways? (2) Is there a difference in Calculus I performance based on students' choice of precalculus pathway? Taking into consideration the diversity of the students among the campuses, the fundamental question is whether the pathways to Calculus I on each campus succeed in bringing a representative set of students to the Calculus sequence and whether these pathways are associated with equitable outcomes. Lower-division mathematics courses like precalculus can often act as gatekeeper courses and can be obstacles for students who are pursuing a STEM major, particularly for first-generation and minoritized students. Our findings provide evidence of this effect at multiple institutions while demonstrating how the consequences can vary according to student population and the institutions' curricular choices. Though there are many studies about success rates in precalculus (Voigt et al., 2020; Ferguson, 2020) as well as studies about precalculus as an obstacle to STEM majors (Chen, 2013), we were able to look at how several different mediating variables, such as race, gender, and first-generation status interact with the types of precalculus classes offered at different institutions.

First-generation students were underrepresented in Calculus I across all three campuses, a finding which is consistent with previous reporting (Chen, 2005). Notably, there was a higher rate of first-generation students that took Calculus I after the precalculus prerequisite compared to those who took only Calculus I across all three campuses suggesting that a robust selection of precalculus options supports first-generation student representation. This was further supported

by our finding that the smallest significant differences in representation could be seen at AU where two precalculus pathways are available.

As seen in other studies (NSF, 2019), female students and URM students were under-enrolled in Calculus I at all three institutions relative to their overall campus level enrollment. This was even though all three campuses are consistent with the nationwide trend of greater female enrollment than male enrollment. The campus that had the least gender disparity was SU which is also the largest and most selective of the three institutions through its admissions process. Unlike the case of first-generation students, we did not find evidence that multiple precalculus pathways significantly reduced these enrollment disparities.

On average, there were no significant differences in the performance in Calculus I between gender categories, precalculus pathways, and race categories among the students of AU, which offers two precalculus pathways into Calculus I. By contrast, DU and SU offer only one pathway, but students that took precalculus on both respective campuses were given significantly lower grades in Calculus I on average than students who took precalculus elsewhere. However, this is not a criticism of precalculus offerings in the university system being studied. Rather, we speculate that the outcomes are related to the level of preparation prior to their enrollment in the university system. For example, students may have taken more math classes and for longer durations such as secondary students who have the benefit of taking a course over an entire school year instead of over one or two quarters. Students may have also developed an early interest in STEM and therefore taken more classes that would have prepared them for their college academic career.

Additionally, at DU, we observed that students who only took the second course in the two-course sequence experienced significantly better outcomes than those students who took both

courses in the sequence. But, again, we do not associate the outcomes to the precalculus offerings at DU. Instead, it is likely that students who took only the second course in the two-course sequence benefitted from advanced preparation before attending DU for the same reasons as discussed above.

More generally, female students received significantly lower grades in Calculus I than male students, on average, when presented with only one precalculus pathway. At SU, URM students experienced significantly worse outcomes in Calculus I than students who identify as Caucasian and Asian American. The finding that race was only a significant factor at SU does not discount the presence of racial bias at the other institutions, but it does suggest the existence of important interactions between the opportunity to take different types of precalculus classes and more equitable outcomes. While this suggests that the opportunity to take a two quarter precalculus sequence provides students with a better opportunity to succeed in Calculus I, we currently only speculate about the mechanism that is producing this result.

Our analysis of the demographic data reported above prevents us from making inferences about some subcategories of URM students. Specifically, those students who identified as Native American or Hawai'ian/Pacific Islander represented less than 1.5% of the student population on all three campuses. Thus, these categories were too small to display a precise estimate of the average grade in Calculus I since a multiple comparison t-test is necessary to discuss the differences among the categories.

The observed differences in outcome at AU, where students have multiple precalculus options, suggests that the existence of a choice is beneficial. Some reasons for this effect could be the existence of a self-sorting mechanism for students and/or the additional peer support furnished by a two-quarter precalculus sequence. It may be that students are better able to pick a

path most appropriate for their comfort with precalculus content when they can take a one quarter or two quarter sequence. However, this would not entirely explain the observed difference between AU and DU, when many students at DU chose the second quarter of the two-quarter sequence to cut short their time in precalculus. It may be that having the option of precalculus pathways creates a sort of cohort effect for students who choose to move through the 2-course sequence. That is to say that students can progress through the sequence with other students who are at academically similar levels. The cohort effect could create an opportunity for collaborative learning and confidence-building that is not as supported by a system that does not afford the students the opportunity to choose the path they prefer. We know that a lack of confidence can be a setback for students, especially in a math classroom (Hall & Ponton, 2005). Negative experiences in precalculus and Calculus I could be the difference between pursuing a STEM major and being repelled from STEM. The importance of creating a viable pathway through precalculus is further highlighted by the fact that students from historically minoritized groups are placed in developmental mathematics courses disproportionately often (Ngo & Kwon, 2015). Instilling confidence and creating a sense of community through maintaining access to extended versions of courses that allow for continuity of peer cohorts has the potential to be impactful for URM students.

6. CONCLUSION

Our research demonstrates the importance of providing students with multiple precalculus pathways into Calculus I to accommodate the diversity of the student population. Our results suggest that providing multiple precalculus pathways mitigates the gatekeeper effect and might create a kind of cohort effect by allowing groups of students at similar academic levels to proceed through precalculus courses together. Crucially, the choice of pathways is particularly

advantageous for historically minoritized and first-generation students who are disproportionately at risk for receiving a below-passing grade or withdrawing from lower-division mathematics courses. Given that precalculus courses frequently play an important role in entry into STEM majors, these findings suggest that offering multiple pathways is one way that an institution can move toward more equitable STEM outcomes.

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