30 Inclusive Calculus: Active, Applied, and Inquiry-based Learning with Linked Workshop and First-Year Seminar

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Abstract: Augsburg University is a small, private university in Minneapolis, MN. Over the past decade we have intentionally substantially increased the diversity of our student body, especially students from minoritized and marginalized populations, first-generation students, and students with disabilities. For example, 56% of our students identify as people of color in 2020-21-20 compared to 34% in 2016-17. We took a comprehensive approach of rethinking calculus to create a student-ready program that welcomes and values all our students. In this

paper we discuss the rationale, implementation, and impact of five key elements of our program. 1) We partnered with science and Economics faculty, through the NSF-funded SUMMIT-P Project, to refocus calculus on authentic, applied, and contextualized problems relevant to students' lives and future studies. 2) We redesigned each class period to include small group, inquiry-based exploration and collaborative practice work at the boards; these activities now constitute the majority of class time. 3) In addition to standard tutoring, we developed a weekly Calculus Workshop where students work collaboratively on challenging calculus problems. The workshops are open to all, with an emphasis on building community among students from groups traditionally underrepresented in STEM. 4) We connected a section of first year seminar to Calculus I to provide students an opportunity to connect with alumni working in quantitative fields, learn about local STEM labs and companies, and to develop college navigation and learning skills. 5) We built robust transfer pathways for students who start at a community college (or other university), including securing scholarships for transfer students in STEM with support from the NSF-funded AugSTEM program. The collective effect of these changes – to the course content, pedagogy, and student support – is a lively, engaging, and welcoming calculus classroom.

Keywords: inquiry-based learning, calculus, first-year seminar, student success

1. *Introduction: Motivation*

Uri Treisman, founder of the Emerging Scholars Program and director of the Charles A. Dana Center at University of Texas Austin has long highlighted the role mathematics plays in equity. As quoted in a recent *Education Week* article,

> *'Math[ematics] is even more important to upward mobility now than it was 20 or 30 years ago, because ... it's seen as related to your general ability to solve problems quickly,' Treisman said, adding that as a result, 'there's general anxiety and panic about equity issues for anything new, even though the current [calculus] pathway is a burial ground for students of color.'*

We teach at Augsburg University in Minneapolis, MN. Originally established as a Lutheran Seminary for Norwegian immigrants, our programs and students have changed dramatically over the past 150 years. In the past decade Augsburg has intentionally substantially increased the diversity of our student body. In fall 2019 53% of our undergraduates were students of color (1141 students) and 37% were first-generation (807 students) (Augsburg University, 2020). During this time the population of students who identify as (a) Black or African American or (b) Hispanic or Latino grew 10% and 16% respectively each year. In addition, around one third of our new students each fall are transfer students, making Augsburg University a popular transfer destination for students at local community colleges. See Figures 1a and 1b which illustrate how rapidly we made this change as an institution.

As elsewhere, our Calculus I students at Augsburg arrive with aspirations for their future and dreams of making an impact on the world. They are often nervous about the course because of its reputation for being difficult – especially so if they needed to complete Precalculus or other mathematics courses first. Societal, economic, and racial systemic barriers amplify the challenges of the course itself. As well-intended faculty members who care about our students'

successes, we are disheartened to realize the extent to which we built barriers to student learning that had nothing to do with calculus itself. We imagined our classrooms as a place that supported everyone's learning and where all students felt comfortable (and safe) as they struggled to learn. We were already using active learning and tried to use relevant examples in class. We hoped that made us different, but even seemingly innocuous practices like allowing students to call out answers to questions we posed, frequently using examples from Physics, or expecting students to be quiet to learn reinforced the historically white, male culture of Mathematics. We discounted the impact of racial and financial stress on student learning. The department wanted to face the problem head-on, and embraced changes in our calculus courses that would open them up to students from all backgrounds.

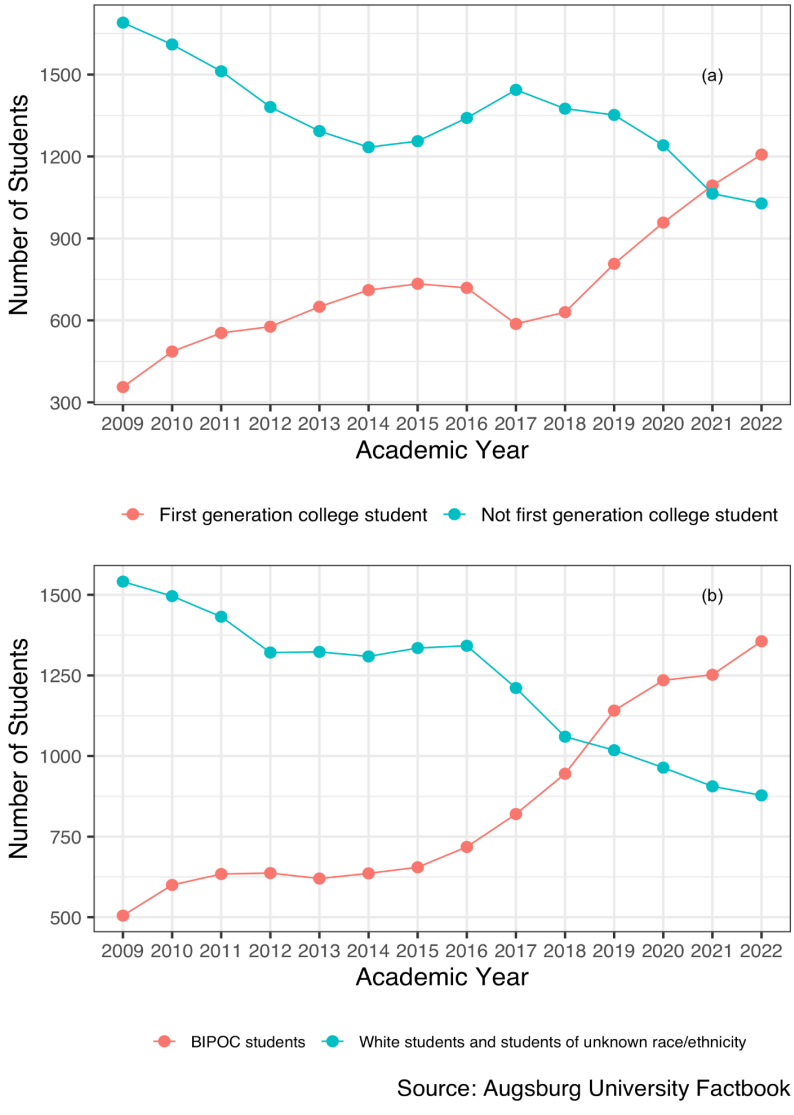

Figure 1: Panel (a): Enrollment trends of traditional undergraduate Augsburg University students, comparing between first-generation college students and not first-generation college students. Panel (b): Enrollment trends of traditional undergraduate Augsburg University students comparing between BIPOC students and white students or students of unknown race or ethnicity.

2. *A Multi-faceted Approach*

Description & Population targeted: We each began approaching our calculus sequence from different angles – active learning structures, rethinking the core topics, technology and labs, data-driven relevant examples, classroom practices attuned to different backgrounds and levels of preparation, and outside of classroom supports. Over several years of sharing and collaborating with faculty members across the department, these efforts coalesced.

We targeted our intervention to focus on students of color, first-generation college students, and transfer students. We define students of color as the aggregate of multiple ethnicity categories: American Indian or Alaska Native; Asian; Black or African American; Hispanic or Latino; Native Hawaiian or other Pacific Islander; or two or more races, as reported from the Integrated Postsecondary Education Data System (IPEDS) database.

Rationale: We are experienced mathematics faculty members accustomed to improving the curriculum. Change was needed; we took chances and wanted to be creative. In addition, we hold scholarship of teaching and learning in high regard, so curricular work is part of, rather than tangential to, our work as faculty- scholars. Many of us were engaged in on-going professional development around diversity, inclusion, and equity. Our group included the Director of STEM programs (Dupont) whose job centers on improving student success in STEM, particularly for students of color and first-generation students.

We also had the context to make the changes. Augsburg University has a long-standing commitment to social justice and equity, which is a lens through which we view curricular change. Our rapidly changing demographic has been a center of campus-wide discussions and calls to action for a more inclusive campus (Augsburg University, 2020).

The urgency of our changing context encouraged us to take a critical look at calculus with attention to the course's role as the entry gate to STEM majors where the representation of students of color anecdotally did not match the general student population at Augsburg. Our goal was, and remains, to create student-ready calculus courses that welcome and value our students.

In this paper we discuss the rationale, implementation, and impact of five key facets of our renovation of calculus: Curriculum, Pedagogy, Linked Workshop, Linked First-Year Seminar, and Transfer Path- ways/Scholarships.

3. *Five Facets*

We implemented five key changes to calculus that we believe increased inclusion and equity in *Calculus I* and in the Mathematics major.

3.1. *Collaborating with the Partner Disciplines to Rethink Calculus Content: The SUMMIT- P Project*

The NSF-sponsored Curriculum Foundations Project (CFP) brought together partner discipline faculty to discern what mathematics their majors needed to know. Their findings are summarized in Ganter & Barker (2004) and Ganter & Haver (2011). Augsburg is a member of subsequent collaborative NSF-funded research project SUMMIT-P: A National Consortium for

Synergistic Undergraduate Mathematics via Multi-institutional Interdisciplinary Teaching Partnerships (NSF Award #1625557; https://www.summit-p.com/; SUMMIT-P, 2020) that studies how mathematics and partner discipline faculty members can collaborate to improve mathematics courses in the first two years based on CFP findings.

At Augsburg, our team of three mathematicians, one chemist, and one economist are renovating our calculus curriculum. To start, we held listening sessions with additional faculty members from Biology, Physics, Chemistry, Environmental Studies, Economics, Finance, and Business to refine CFP recommendations for our local courses. We also reviewed textbooks from classes requiring calculus.

Based on this work we narrowed the content of our calculus courses to essential concepts, skills, and habits of mind. We wanted to be sure that everything we were teaching students would be useful and relevant. We also brought in a wider array of applications of calculus, especially from Biology and Economics, and committed to teaching calculus concepts in context rather than in the abstract. We switched textbooks to align with these changes (Briggs et al., 2018) and wrote daily exploratory activities and weekly labs which often start with data (not equations). These changes made the course more accessible to students from varied backgrounds, and increased interest in the course.

Results: Paring down the course to essential concepts and skills considerably reduced the need for rote algebraic manipulation which gave students with less algebraic facility greater access to the big ideas. This refocusing is especially important for students without extensive practice in rote algebraic manipulation from high school.

Using examples that are more familiar to students (e.g., Biology vs. Physics) made the courses more relevant and useful to students. In the 2018-2019 school year students completed an attitudinal survey. Of the 32 respondents, two-thirds reported they had already applied what they had learned in *Calculus I* in their non-mathematics courses. In addition, 80% of students believe that the things they learned in *Calculus I* will be useful to them after college. A similar percentage of these students stated what they learned in the course will be applicable to their futures.

3.2. *Consistent use of Active and Inquiry-based Learning: 20 + 20 + 20 = 70*

During class meetings, we spend the majority of time on active and inquiry-based learning (IBL) pedagogies that have positive effects on student learning (Conference Board of the Mathematical Sciences, 2016). Our calculus course meets four times per week: three 70-minute class periods and one 100-minute laboratory. We split the class into three 20-minute segments (with 10 minutes to use as needed). Students begin with an exploratory activity and work with classmates of their choosing. Next, the instructor recaps key ideas. Lastly, students work on practice problems with randomly assigned partners at the white boards.

We deliberately made the in-class activities carefully scaffolded - starting in a familiar place and then increasing in difficulty and sophistication. Students of all backgrounds can make a start and engage with the material - everyone has thoughts to share and questions to ask.

During these times, students support one another in learning and the instructor circulates to help. Studies by Freeman et al. (2014) and Laursen et al. (2014) have shown active learning has disproportionately positive effects for students from minoritized groups (Conference Board of the Mathematical Sciences, 2016). In Laursen et al. (2014) studying the impact of IBL by gender, women performed as well in IBL or non-IBL courses, but women's reported level of mastery was higher in IBL courses. According to Laursen, "IBL methods do not 'fix' women but fix an inequitable course."

Results: Using active and inquiry based learning pedagogies **every** student is talking in class, with each other and with the instructor. We see increased ownership ("When we did part (c),. . . " vs. "When you did Example 3, . . . ") and sense of belonging, particularly in the formation of outside-of-class study partners. Instructors are able to see and hear what students are doing and able to quickly identify where students might be struggling and support them.

3.3. *Developing Skills in Community: The Calculus Workshop*

For some students of color and first-generation students finding a home with a community of learners took additional support. This was especially true early on when in many cases there would only be one student of color in a given calculus section. In 2009 we (Dupont) began a Calculus Workshop where students work together to strengthen their mathematical and study skills. The workshop is open to all students, with targeted recruitment to first-year students of color or first-generation students.

The workshop sets high expectations for academic excellence. The goal of the collaborative activities is to develop student confidence in their ability to tackle difficult mathematical problems. The workshop problems contain a mix of previewing material to be presented in future classes, reviewing key concepts, or tackling challenging multi-step calculus problems.

A peer mentor assists the professor with student questions. The peer mentor also serves as a role model, helps students navigate the "hidden curriculum," and connect students with leadership, academic, and research opportunities such as study abroad, Fulbright awards, the McNair Scholars program.

Results: After the first year, workshop participants achieved a 0.6 higher grade point average (GPA) than the *Calculus I - II* students not in the workshop, despite having entered college with an overall lower average ACT score and GPA (Augsburg Now, 2011). Examining more recent data from 2016-2020 in the aggregate (25 different *Calculus I* sections) a higher percentage of workshop participants earned a grade of B- or better in *Calculus I* compared to students not in Workshop (Table 1). This pattern is consistent and higher for students of color or first-generation students.

Table 1
Comparison between students who receive a B- or better in Calculus I and participation in Work- shop, also separated between students of color and first-generation students. We report aggregated numbers from 2016-2020.

Population	B- or better	Less than B-
All students in Calculus I	209 (53%)	184 (47%)
Workshop students in Calculus I	65 (64%)	37 (36%)
Students of color in Calculus I	101 (50%)	103 (50%)
Students of color in Workshop & Calculus I	37 (65%)	20 (35%)
First-generation students in Calculus I	83 (54%)	71 (46%)
First-generation students in Workshop & Calculus I	36 (75%)	12 (25%)

The results in Table 1 indicate that for the intended Workshop population (students of color and first-generation students), participation in Workshop has a positive association in earning a B- or better in *Calculus I*. In addition, students sometimes enroll in the same section of subsequent courses with classmates from Workshop or continue study partnerships, strengthening community building.

3.4. *Envisioning a Career in STEM: The Augsburg Seminar*

Our students want to see a connection between their major and meaningful, financially-stable careers. Surprisingly, many of our students did not know that many of the top-ranked careers start with a major in mathematics, statistics, or computer science (U.S. News, 2020; Indeed, 2020). We wanted to help students of color and first-generation students see those connections to STEM and Business, but especially to Mathematics, Statistics, or Data Science.

We linked a section of Augsburg Seminar, our 1-credit first-year seminar, to *Calculus I* with a focus on career pathways in Mathematics, Statistics, Computer Science, or Data Science. Students register for Augsburg Seminar during summer orientation, and the course is open to all students.

We revised the Augsburg Seminar linked to *Calculus I* so students engage in a series of career planning and visioning exercises; explore profiles of BIPOC, LGBTQIA, and female mathematicians and computer scientists (Mathematically Gifted & Black, 2020; Lathisms, 2020; Project 5050, 2020; Sigma Pi Sigma, 2020; Henrich et al., 2019); and interview recent mathematics and computer science alumni for career advice. We also help students create an academic plan and mentor them through their coursework (often for all four years). The course also addresses inclusion and equity by discussing implicit bias (both in and outside mathematics) and intercultural communication. In addition, the seminar includes sessions on financial aid, study abroad, advising, and mental health to support student success.

Results: Students enjoy learning more about careers and, especially, interviewing alumni. Students appreciate that they can explore profiles of a variety of mathematicians, expanding

their view that mathematics is an exclusively white, male field (Stinson, 2013) . As a predominantly white faculty, we believe these connections help address the lament that "they can't be who they can't see."

Because the Augsburg Seminar is both major specific and linked to *Calculus I* we hoped the changes to the Seminar were associated with a positive outcome of B- or better in *Calculus I* for Mathematics and Computer Science (MSCS) majors. We examined data from 2016-2020 comparing the grades between students in Augsburg Seminar to students in *Calculus I* in the aggregate as well as based on populations of interest (students of color and first-generation students). We do not report percentages as in Table 1 because the number of students in this population is smaller.

Table 2

Comparison between Mathematics and Computer Science (MSCS) majors who receive a B- or better in Calculus I and participation in Augsburg Seminar, also separated between students of color and first-generation students. We report aggregated numbers from 2016-2020.

Population	B- or better	Less than B-
MSCS majors in *Calculus I*	83	63
MSCS majors and Augsburg Seminar students in *Calculus I*	23	12
MSCS majors and students of color in *Calculus I*	39	36
MSCS majors and students of color in Augsburg Seminar & *Calculus I*	13	5
MSCS majors and first-generation students in *Calculus I*	39	22
MSCS majors and first-generation students in Augsburg Seminar & *Calculus I*	14	2

The majority of MSCS majors who participated in Augsburg Seminar received a B- or better in *Calculus I*, and this pattern was consistent - and in some cases disproportionately larger - when controlling for a particular subset of the population. Anecdotally we know that students in the linked Augsburg Seminar have a higher-degree of self-selection to study mathematics than their peers, which may be a confounding variable in this association.

3.5. *Supporting Transfer Students: The AugSTEM Program*

Approximately one-third of our incoming class each year consists of transfer students. These students have additional needs, including building a connection to their new classmates and professors and learning to navigate a new institution with different expectations. Some transfer students also carry family and work obligations outside of school, which adds to their pressure to succeed. Many started at a community college or state university because it was more affordable than Augsburg.

We designed the AugSTEM Scholars Program to relieve some of their financial burden and to facilitate an easier transition for transfer students. Augsburg has received two awards under the NSF Scholarships for Science, Technology, Engineering and Mathematics (NSF S-STEM) program, Award #1154096 (2012-2016) and Award #1565060 (2016-2020).

Students in the AugSTEM Scholars Program receive personalized support for their needs, starting with an Individual Development Plan (IDP) as well as the CliftonStrengths assessment [20]. IDPs can take different forms and appear in many workplace and educational settings

(CIMER, 2020; My IDP, 2020; Bosch, 2017). We directly connect AugSTEM Scholars with recent alumni about navigating the transition to post-bachelor's opportunities.

To support students and advisors at Community Colleges, one of our staff members facilitated communications between department chairs, faculty members at Augsburg, and area Community Colleges to develop 32 STEM Transfer Guides at eight community colleges. The transfer guides are shared with community college advisors and to students at events targeting STEM transfers.

Results: Over the period 2012-2019, the two S-STEM grants supported 111 scholars of whom 92 graduated in STEM and 18 are continuing in STEM (99% retention). Of these scholars, 41% were transfers. Five students received Graduate Fellowships for their academic achievement – two of these students began at community colleges and two were NSF-identified underrepresented minorities. Table 3 shows a comparison of the number of STEM graduates overall and the number who started as transfers from prior to getting the first grant in 2012 to 2018. Three-year averages were used to compare the growth over this time period of all graduates (11%), STEM graduates overall (56%) and STEM graduates who began as transfers (115%).

Table 3
Three-year averages of Bachelor's Graduates by STEM and Transfer Status since AugSTEM Scholars began in 2012. Source: Augsburg Office of Planning and Effectiveness (Day program students only)

Year	2009	2010	2011	2016	2017	2018
All Graduates	356	382	426	456	385	448
All STEM Graduates	64	43	76	107	87	91
Transfer STEM Graduates	18	15	16	36	35	34

Even with the AugSTEM scholarships of up to $10,000 per year, many students still experience financial need. Mentors help students apply for additional scholarships or find employment with a higher hourly wage. We also established a new donor-funded scholarship specifically for 5th-year STEM transfers.

4. *Conclusions*

Our systematic changes addressed all dimensions of how students engage with calculus, inside and outside of class. Perhaps you may be wondering how you can make change at your institution. As a place to start we encourage you and your colleagues to reflect on the following questions:

- What motivates you to change your curriculum?
- What is the department experience in changing curriculum and pedagogy?
- Where is your department in terms of training for diversity, equity, inclusion, and anti-racism?
- What tools/resources/opportunities beyond the classroom could be part of the solution?
- What other partners across campus can help you in this work?

Discussion from these questions sparked ideas for changes we implemented at Augsburg University. Small, isolated changes alone might not be enough. We encourage you, too, to take a multi-faceted approach.

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