Converging Paths: A Survey of Calculus Students' Course Experiences

Joe Champion
Boise State University

Brinley Stringer
Boise State University

Amanda Willoughby
Boise State University

Rachael Welder
Boise State University

This preliminary study reports on a brief survey of students' course experiences in introductory university calculus. In particular, we compared the responses of students who took precalculus and calculus at the same institution with those who took precalculus in high school or other settings. Findings highlight significant differences in students' reported calculus experiences between the two groups of interest, which indicates areas for improved alignment of course structures in undergraduate precalculus and calculus, especially around academic support. Building on this initial study, the data are being used to inform efforts to improve instruction and curriculum of both precalculus and calculus courses at the research site, starting with a new pilot calculus course in Spring 2025.

Keywords: calculus, precalculus, affective experiences

Calculus is widely recognized as a challenging course in the undergraduate curriculum that often serves as a barrier for students pursuing STEM majors (e.g., Steen, 1988; Chen & Soldner, 2013). The combinations of barriers to STEM achievement are formidable, with only 35% of high school seniors who intended to pursue a STEM major earning an undergraduate STEM degree (Seymore & Hewitt, 1997). Yet, despite longtime efforts to improve retainment of students in the STEM pipeline, undergraduate programs continue to struggle with attrition. For example, Chen and Soldner (2013) found that 48% of students pursuing bachelor's degrees and 69% of those pursuing associate degrees in STEM switched to a non-STEM field or left college without a degree.

STEM attrition is particularly pronounced among students from historically marginalized and underrepresented groups, including students identifying as ethnic minorities and women. Treisman (1992) noted that ethnic minority students often face higher barriers in STEM courses, while Ellis and colleagues (2016) reported that women are one and a half times more likely to leave the STEM pipeline after experiencing Calculus I than their male peers. Additionally, Chen and Soldner (2013) found that students attending less selective colleges were more likely to leave STEM fields compared to their peers at highly selective institutions. Increasingly, undergraduate educators have focused on the role of early coursework and institutional support for high quality resources to support student success in calculus and precalculus courses.

Calls for improved student outcomes in calculus have led to many small and large reforms, including curriculum and assessment overhauls to focus more on student engagement and essential understandings, and the integration of innovative teaching methods, often including technology-enhancements, inquiry-based activities, and adaptive learning systems (Bressoud et al. 2015; Rassmussen et. al. 2019). The good news is that research indicates that the instructional methods used in calculus courses can have a significant impact on student outcomes. For example, a recent landmark randomized trial by Kramer and colleagues (2023) demonstrated that active learning techniques that involve students more directly in the learning process results in improved grades and a deeper student understanding of calculus concepts. Similarly, Freeman

and colleagues (2014) observed positive outcomes of active learning approaches in courses in other STEM disciplines. Yet, despite these advancements, traditional lecture-based instruction remains the primary mode of instruction in many undergraduate calculus classes (Rasmussen et al., 2019).

Sonnert and Sadler (2015) observed significant declines in students' attitudes and desire to continue in mathematics after completing an introductory college calculus course. While taking and excelling in advanced math courses in high school had a strong positive effect on students, completing a precalculus or calculus course in college did not show the same impact, highlighting a disconnect in the transition from high school to college mathematics. Students' experiences in college calculus courses seem to play a crucial role in declining affect (Sonnet & Sandler, 2015) and persistence in the subject (Rasmussen & Ellis, 2013). Notably, Rasmussen and Ellis (2013) reported that 31.4% of students who initially intended to progress from Calculus I to Calculus II, but chose not to do so, cited their experiences in Calculus I as a major factor in their decision. Similarly, Ellis and colleagues (2014) found that students' perceptions of their calculus courses, including the pedagogies they experienced, played a critical role in their decision to (dis)continue studying mathematics. Unfortunately, the characteristics of calculus courses that have been identified as most strongly correlated with maintaining confidence, enjoyment of mathematics, and desire to continue in STEM fields–such as slower pacing, smaller class sizes, more qualified instructors, and more student-centered pedagogies–are more prevalent in high school classrooms than in college settings (Bressoud, 2015).

Though calculus is a central junction in the STEM pipeline, it is necessary to investigate the (dis)continuous experience that students face while both preparing for, and enrolling in, calculus courses. Existing literature that has examined curricular and pedagogical aspects of precalculus to calculus transitions (e.g., Apkarian et al. 2018; Voigt et al. 2019; Wade et al. 2023) highlights a lack of consistency. However, there is a gap in the literature emphasizing the affective experiences of students as they navigate the precalculus-calculus corridor of the STEM pipeline.

In this preliminary report, we investigated student-reported survey data on their experiences in a Calculus I class and how it relates to their other class experiences. We pay special attention to the group of students who completed precalculus courses prior to enrolling at the university research site compared to those students who completed precalculus at the same university in which they took calculus. We hope results of the study can spark conversation about the importance of alignment between course structures in college-level precalculus and calculus courses with those of high school precalculus settings. The guiding question is, "**How can students' reported experiences in university calculus classes inform better alignment of curriculum and instruction of precalculus and calculus courses?**"

Methods

The institutional setting is important to this study. Mountain State University (pseudonym) is a large public university in the western United States. Students typically enroll shortly after graduating from high school in the local or nearby state. Admission is minimally selective (~85% acceptance rate). The undergraduate student body is typical of many mid-to-large U.S. public research universities, including many first generation students (~35%) and students eligible for federal financial aid (~50%). Calculus classes are typically taught by full-time lecturers and adjunct faculty who specialize in lower-level undergraduate mathematics teaching. The calculus curriculum has many of the features of reform calculus programs, including technology-assisted assessment, frequent low stakes individual and small-group assessments, and a focus on applications. Most applied tasks center around physical contexts typical of

introductory engineering and physics courses. Course coordination is moderate, with a schedule of topics, homework, and exams provided on an opt-in basis among instructors, but daily instructional methods vary. Success rates, as measured by the percentage of registered students who earn a letter grade of A, B, or C, have improved in recent years, averaging about 70%, with considerable variability across instructors.

A recent institutional emphasis on first year student experience and retention highlighted calculus as one of a small number of STEM courses targeted for improved equity in student outcomes, and a task force within the department was established to address potential improvements in the course. This study is part of those efforts.

Precalculus courses at MSU are designed for students who are admitted to the university without sufficient preparation for calculus, with very robust systems for supporting student success. The courses are taught by different faculty in a separate unit from the mathematics department using a hybrid of flipped-classroom and emporium formats centered around building students' mathematics self-efficacy (Bandura, 1997). Class sizes are similar to calculus (about 40 students each), but classes are much more coordinated. In all sections, students spend several hours per week in an online program that helps reinforce procedural knowledge, while class time is a mix of small group activities and individualized work time for students to reinforce conceptual knowledge with their instructor available to answer questions. The model has resulted in high success rates (consistently around 80%), and MSU has received two recent national awards highlighting the positive impacts of precalculus systems on student success and retention outcomes (APLU, 2023; NCCU, 2023).

The primary data source for this observational study was an abridged version of the end-of-course student survey from the large MAA National Study of College Calculus (Bressoud et al., 2015). We distributed the survey by email to all 905 students who registered for calculus at MSU during fall or spring of the 2023-2024 academic year, yielding a sample of N = 190 student responses (response rate = 21%). As a preliminary study focused on informing alignment of precalculus and calculus courses, the primary groups of interest were students who reported completing their precalculus courses at MSU (43%) versus those who reported completing precalculus in all "Other" (57%) settings (high school = 49%, two-year or community college = 6%, others = 2%). We computed comparative descriptive statistics of students' reported calculus course experiences in these two groups, emphasizing indications of similarities and differences.

Results

Overall, students who took precalculus at MSU tended to report lower letter grade attainment in their first calculus course (A = 37%, B = 37%, 19%, D/F/W = 13%) compared to those who took precalculus in Other settings (A = 53%, B = 23%, C = 17%, D/F/W = 7%), χ^2 (3) = 14.2, $p < .01$. Similarly, students who took precalculus at MSU tended to report lower levels of agreement on survey items about math enjoyment (MSU = 71%, Other = 86%), confidence (MSU = 61%, Other = 78%), and preparation for calculus (MSU = 53%, Other = 65%). Details are shown in Figure 1.

In questions about their experience of calculus course quality (see Figure 2), students who took precalculus at MSU tended to report lower agreement with survey items about the course increasing their interest in mathematics (MSU = 43%, Other = 55%), getting the support they needed to succeed (MSU = 54%, Other = 80%), and wishing more courses were taught like their calculus course (MSU = 51%, Other = 64%) In addition, students who took precalculus at MSU reported feeling more frequently "lost and unable to keep up" in calculus (MSU = 42%, Other = 26%), although they reported asking questions (MSU = 47%, Other = 35%) and learning through

peer interaction (MSU = 67%, Other = 65%) with similar distributions in their calculus courses (see Figure 3).

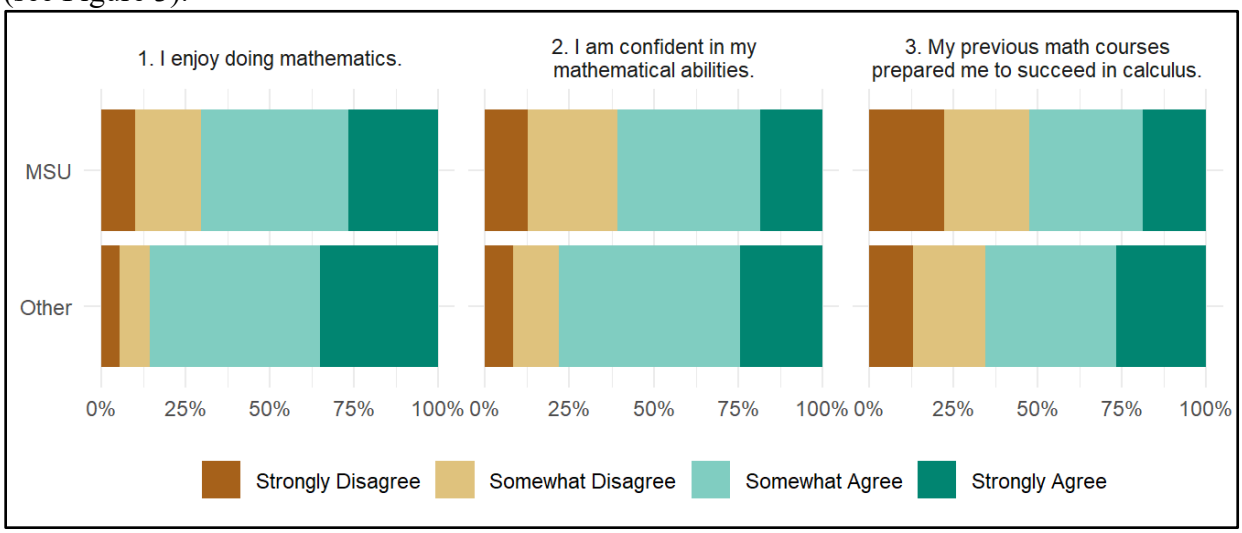

Figure 1. Indicators of calculus students' reported mathematics identity.

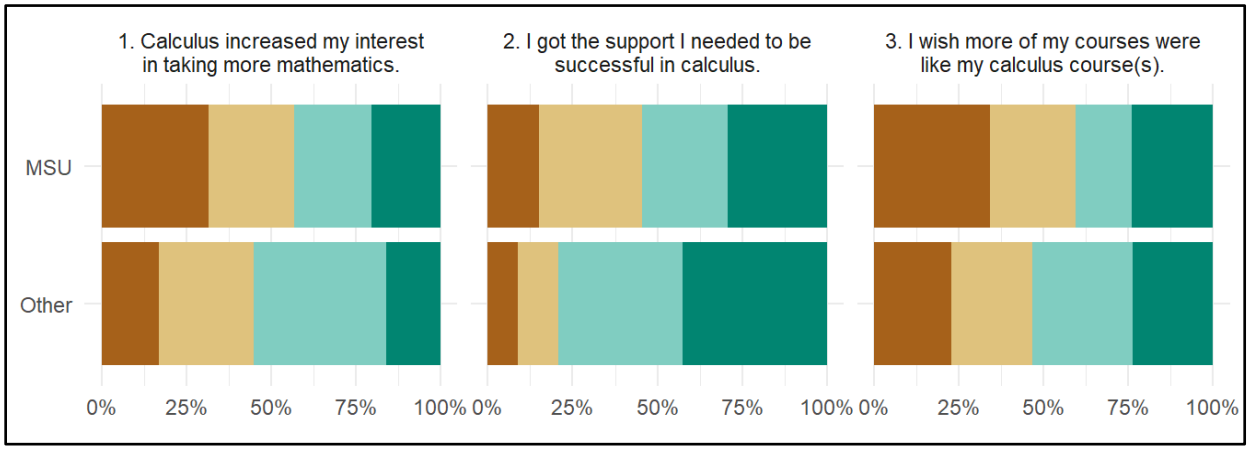

Figure 2. Indicators of calculus students' perceptions of calculus course quality.

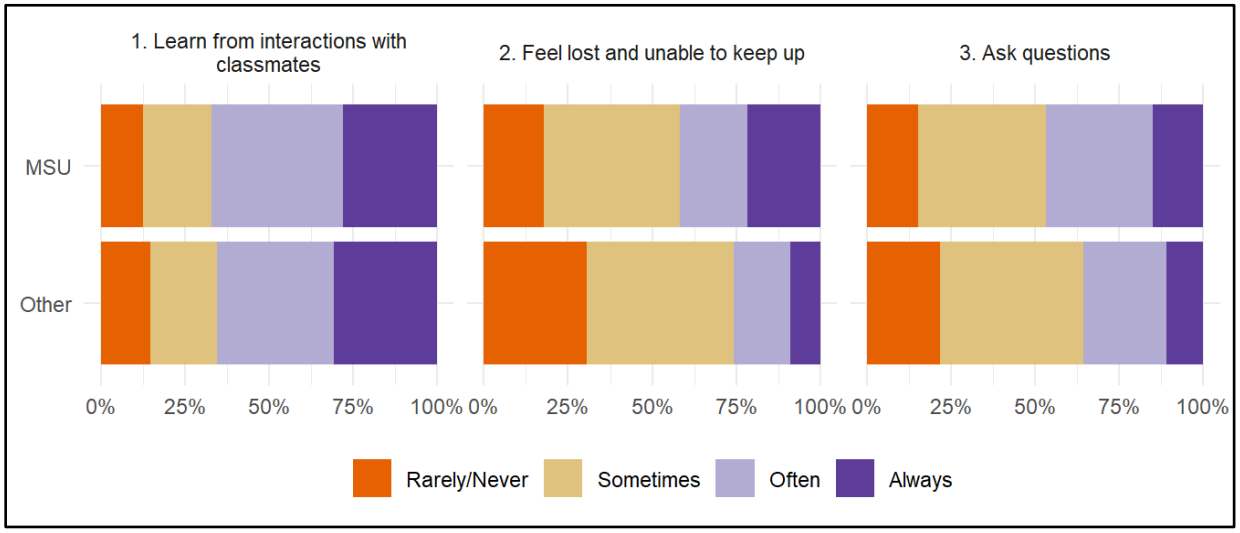

Figure 3. Indicators of calculus students' experiences of calculus instruction.

Discussion

The distributions observed in our survey of students' course experiences suggest substantial differences in the calculus experiences of students who completed precalculus at MSU compared to students who completed precalculus in another setting (typically high school). There is a consistent pattern of students who took precalculus at MSU reporting lower perceptions of instructional quality and support for their learning. This is particularly surprising given that the precalculus course at MSU has been designed to foster student self-efficacy and has garnered national attention for its impacts in supporting student success and retention efforts across the institution.

The results from this study are only observational, thus it is difficult to discern the cause(s) of the observed differences. Nonetheless, the disparities suggest room for improvement in better aligning precalculus and calculus transitions at the university level. More broadly, the results highlight a need for more research into localized, contextual factors which may impact students' affective experiences in calculus and other undergraduate mathematics courses which are taken in sequence at MSU, and all institutions of higher education.

We anticipate that attending to vertical alignment of sequenced courses, especially in terms of instructional methods, assessment strategies, and other course design features could positively affect students' perceptions of course quality. To test this idea, we are currently building a pilot calculus class that aligns with the structure of precalculus classes at MSU to see if there are any differences in student's reported experiences in such a course. This course will launch in the Spring 2025 semester. In addition to survey data, we hope to follow up with focus group interviews with students to better understand their experiences in transitioning from precalculus to calculus. This data will help inform cycles of design research to help improve the pilot calculus class, and other changes to create more consistency in this portion of the STEM pipeline.

Questions for Audience

As a preliminary study, we are particularly interested in the perspectives of other undergraduate mathematics education researchers and university teaching faculty. We want students to experience cohesive, well-designed undergraduate courses, and recognize that the challenges of offering high quality calculus course experiences are widespread. Thus, we welcome input from colleagues about interpreting the survey data, in the context of the scholarship of teaching and learning at the undergraduate level. In particular, we are interested in conversing about the following questions:

1. What changes to calculus might lead to better course experiences for both students who took precalculus at the same university and those who took precalculus in other settings?
2. Which aspects of course design are most important to align across university precalculus and calculus courses?
3. What other aspects of students' calculus course experiences are most important to consider in the context of precalculus?
4. How might we effectively facilitate cross-course collaboration about course design between undergraduate calculus and precalculus instructors? What are the barriers and drivers?

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