Confidence and Sense of Belonging: Undergraduate Mathematics Student Experiences with Calculus Support Course

Colin McGrane
San Diego State University

Chris Rasmussen
San Diego State University

Studying student experiences in undergraduate mathematics education serves as a fundamental aspect of understanding how mathematics departments can best serve the most at-risk populations of students who are often harmed by racial and gender inequities present in student success rates in undergraduate mathematics courses. In this study, we focus on support courses for Precalculus and Calculus I, where students engage in frequent Supplemental Instruction (SI) sessions and an online course run by the university Math Equity Coordinator. In analysis of a mixed-methods approach consisting of interviews and a survey, we examine the impact of these supports on students' sense of belonging and confidence in mathematics. Preliminary results from survey analysis show that students in the support course report higher levels of belonging and confidence in mathematics. Furthermore, interviews highlight the importance of instructor mentorship in enhancing students' confidence and sense of belonging.

Keywords: identity, belonging, calculus, student success

Introductory undergraduate mathematics, particularly the study of Calculus, often functions as a filtering and access-controlling mechanism that either impedes students' progress in STEM degrees or discourages them from continuing altogether (PCAST, 2012; Weston et al., 2019). A comprehensive examination conducted by Koch and Drake (2018) encompassing 36 higher education institutions throughout the U.S. revealed that a substantial 34.3% of students received a D, F, Withdraw, or Incomplete (DFWI) in Calculus. Even more unsettling were the statistics for Black or African American students and Hispanic or Latinx students, who faced even higher DFWI rates of 47.8% and 47.9% respectively. Furthermore, women are known to leave STEM fields 1.5 times more often than their male counterparts (Ellis et al., 2016). If the rightfully due pressure put on mathematics departments to close these racial and gender equity gaps is to be taken seriously, mathematics educators must dedicate time, money, and labor towards listening to student voices and understanding how we can support them through these historically difficult and harmful experiences.

The large, Southwestern University (SWU) that is the setting for our study has not been immune to the sustained racial and gender equity gaps in Calculus success observed across the U.S. In response, we are implementing a 2-year holistic approach to closing equity gaps present in our precalculus through calculus courses. One of the arms of this multi-faceted approach was to create support courses for Precalculus and Calculus I. The unique features of these courses are the nature of instruction and student engagement in that students opt-in to a 1-unit course that requires frequent attendance to university-provided Supplemental Instruction (SI) sessions and regular engagement with an online Canvas course hub run by a coordinator for the Math Equity Initiative. We see this definition of support course as fitting somewhere between a corequisite course that takes place in a classroom with a dedicated instructor and the regularly offered SI sessions.

In this preliminary report, we focus on the voices and experiences of students who opted-in to the new SI sessions in Precalculus and Calculus I through a mixed-methods study that utilizes semi-structured interviews and a comprehensive survey sent to all students enrolled in the

precalculus and calculus courses in the spring semester of 2023. These experiences include their perception of the inclusivity of teaching practices, their praise of and suggestions for improvement to the SI sessions, and the impact on their confidence, enjoyment, interest, and sense of belonging in mathematics. Focusing on the experiences of the students who enrolled in the support course, this study is guided by the following research question: How has enrollment in the support course impacted students' sense of belonging in the math community and their confidence in mathematics courses?

Relevant Literature and Theoretical Perspective

Investigating the experiences of students in our courses requires an acknowledgment of the unique identities and voices they offer to our research. Understanding that student's identities are potentially redefined and reshaped every day, we view identities as dynamically designed by a variety of factors and constantly in flux (Collinson, 2006). More specifically focused on their identities within a mathematics context, Martin (2012) defines mathematical identity as the ways that students enact their own identities as "doers" and "learners" of mathematics. We extend mathematical identity to include students' self-reported interest, enjoyment, and confidence in mathematics. Since a sense of belonging is so closely tied with the inclusivity a student perceives, students' multiple identities, including their mathematical identity, are intertwined with their sense of belonging in mathematics. We believe that with a focus on identity and sense of belonging in mathematics we may begin to understand one of the myriad reasons why in the U.S. roughly half of the students who pursue a degree in science, technology, engineering, or mathematics (STEM) never complete it (National Center for Education Statistics, 2018).

Supplemental Instruction originated at the University of Missouri-Kansas City in 1973 and has since evolved into a widely adopted pedagogical approach practiced at over 1,500 education institutions across 29 countries. As explained by Arendale (1994), SI is designed to address historically challenging academic courses by providing free, voluntary sessions to all students. These sessions held several times throughout the week are led by SI Leaders, students who have previously excelled in the targeted course. The hallmark of SI is its collaborative nature, where students actively engage with course content and hone essential study skills. SI Leaders draw upon insights gained from attending all class lectures to facilitate active learning techniques, which include interactive board diagramming and group work.

While active pedagogical strategies have been found to be effective for learning and narrowing opportunity gaps (Freeman et al., 2014; Theobald, 2020), research has also demonstrated that the situations that transpire in active learning classrooms put students at most risk for marginalizing and anxiety-producing experiences (Aguillon et al., 2020; Cooper et al., 2018; Cooper & Brownell, 2018; Shah et al., 2020). Since our students experience a mostly traditional large lecture atmosphere when they meet with their instructors, we acknowledge that the effect of an active learning classroom only applies when students are in their twice-weekly discussion sections run by graduate teaching assistants and the SI sessions. It is important to note that the participants of our study experienced a variety of classroom atmospheres that all impact their overall experience in mathematics and more specifically their own sense of self as they interact, problem solve, and learn with groups of their peers.

Methods

SWU is a large, public 4-year HSI research university. The focus of this study are 26 students (gender and race/ethnicity shown in Table 1) who opted-in to enroll in the newly developed

Precalculus and Calculus I SI-based support course that also responded to a survey sent at the end of spring 2023 semester. Acknowledging our own identities of two cisgender, white, male researchers (one heterosexual and one gay) at this institution is important to note, because we aim to push back against and rectify the long history of the dominant race and gender performing studies that have often taken from underrepresented communities and not given back.

Table 1. Students self-reported identity. This table shows a count of each gender present by race/ethnicity.

Support Course Student Demographics						
Gender	Alaskan Native or Native American	Black or African American	Hispanic/ Latinx	Middle Eastern or North African	East Asian	White
Man	1	1	7	1	1	3
Woman	0	1	4	0	0	2

Three of these 26 students participated in a one-hour long, semi-structured individual interview that focused on a variety of topics related to their experiences in their current mathematics courses as well as their own histories of experiences with mathematics in general. Topics that were discussed included how their identity has impacted their learning of mathematics, how their confidence in their mathematics ability has changed, and the extent to which they have utilized university-offered support structures such as SI.

In order to develop a broader sense of experiences across all precalculus and calculus courses, the survey we administered was an amalgamation of items built from subsets of two existing surveys. One of these surveys is the student postsecondary instructional practice survey (SPIPS-M), which specifically targets students' interpretations of instructional practices, changes in attitudes towards learning and doing mathematics, and their perceptions of the climate in the classroom (Apkarian et al., 2019). Supplemental to the focus of this survey, the second survey developed by Brown and colleagues at Penn State University called the Inclusive Instructor Behaviors (IIB) survey was included to leverage student experience to determine various aspects of the perceived inclusivity of teaching behaviors and sense of belonging in mathematics.

Results

Comparing the 26 students who enrolled in the support course and the 700 students enrolled in Precalculus and Calculus I combined, the most notable statistical differences emerged among the questions that focus on a sense of belonging. In order to compare two independent groups with such variance in population size, a non-parametric statistical test called the Mann-Whitney U test was performed to determine effect size of agreement to a variety of statements. The resulting U statistic was then transformed into Cohen's d, which is a real number between 0 and 1 that has been stratified and defined by Cohen (1985) into categories of strength. An effect size less than 0.2 is "little-to-no effect", between 0.2 and 0.5 is a "small effect", between 0.5 and 0.7 is a "medium effect", and greater than 0.7 is a "large effect".

Students in the support course agreed with the statement, "I feel like I fit in" more than students who did not take the support course with an effect size of d=0.301 ($p<0.001$). More specifically attending to their sense of belonging in mathematics, students in these students also agreed more with the statements, "I feel like I am part of the math community" and, "I consider myself a member of the math world" more than students who did not take the support course with effect sizes of d=0.246 ($p<0.001$) and d=0.242 ($p<0.001$) respectively. Furthermore, these students also agreed with the statements, "I feel a connection with the math community" and, "I

feel that I belong to the math community" more than students who did not take the support course with effect sizes of d=0.237 ($p<0.001$) and d=0.221 ($p<0.001$) respectively. Finally, students in the support course agreed with the statement "I feel valued" more than students who did not take the support course with an effect size of d=0.219 ($p=0.002$).

Regarding students' confidence in their mathematical ability, students who enrolled in the support course overall were more confident entering the course. When prompted to consider their confidence at the beginning of the semester, students who enrolled in the support course agreed with the statement, "I am confident in my mathematics ability" more than students who did not enroll in the support course with an effect size of d=0.26 ($p<0.001$). However, students were actually not confident in their mathematics ability, so the difference between the groups can be translated as the students who enrolled in the support course disagreed less with the statement, "I am confident in my mathematics ability" than the students who were not enrolled with the support course. In terms of the Likert scale range on the survey, students who enrolled in the support course "slightly disagreed" on average while the students who did not enroll in the support course "disagreed". This question was paired with a follow-up question that asked about their confidence in mathematics at the time of taking the survey, which was in the last 3 weeks of the semester. While both groups showed a statistically equivalent increase in confidence in mathematics ability between the beginning and end of the semester, the students who were enrolled in the support course felt a higher confidence overall.

Acknowledging that responses to a survey do not provide a complete picture of students' experiences and reasoning for their responses, three students interviewed near the end of the semester supplemented these findings with their own lived experience. The first student, Silvia, is an Italian female immigrant who went to primary and secondary schools in Italy before coming to SWU as a Biology major. She plans to attend medical school to become a doctor, with a passion for helping people. Before she attended SWU, she was not confident in her mathematics ability because of the teaching practices of her high school instructors. Specifically, she was made to feel that women do not belong in the mathematics community, which she attributed to a cultural difference between the old-time ways of her hometown and the liberal feeling of California. However, she speaks to how her confidence has changed since she came here:

> So I feel that I feel like more confident after taking this class. Probably in my math abilities. I work for the math department because I do like tutoring for college algebra. So I kind of start liking the math environment way more since I came here. So I think it has like changed my way to like see math and the fact that if I really understand I can like help other people to have success in the class.

Another student interviewed named Santiago is a male Mexican immigrant with the goal of becoming a computer scientist. He is a first-generation college student whose parents completed schooling through primaria, which is equivalent to 6th grade in the U.S. Due to the teaching practices he experienced in secundaria and preparatoria, equivalent to 7-9th grade and 10-12th grade in the U.S. respectively, he felt at a disadvantage to his peers at SWU. Not only because of the way mathematics was taught, but also the general lack of resources he found there to support him in his educational goals. When he approached his lecture instructor during office hours to comment on how he felt, he expressed his relief in their response by claiming, "I entered the room with insecurity, and I left the room feeling more confident about myself."

The third student who was interviewed named Bianca is a female Mexican immigrant who is a first-generation college student with the goal of going to medical school. She also spoke to the

lack of resources she had going to school in Mexico, particularly in the teaching practices that left her feeling inadequately prepared for higher education. However, she felt that instruction at SWU changed her confidence in mathematics when she said, "the instructor knew how to explain it better. Like, I felt more confident here in college than in high school, with the problems."

All three of these students felt that their confidence was increased due to experiences with their instructors at SWU. While these experiences were not directly related to enrollment in the support course specifically, their experiences impacted their mathematical identities. Specific to the support course, Silvia and Santiago spoke to the canvas course instructor that served as a mentor to them and the benefits they gained from her being in that role. Silvia said,

> The professor that led the course, she was like, not like a math professor, but she worked more as a mentor… so [the support course] was more like a class to support myself, like 360 degree, like a total thing. Not just within my math, but also like enrolling into classes, understanding what to do next, what classes to take. So, I think it was really good.

Santiago also felt that a having this person in the role of a mentor was beneficial to his experience:

> So, it isn't like she's only the instructor of the class, but she's also like a huge mentor for me. And I think that it is very connected with the [support course] programs. So they've been super helpful.

In summary, we have found that well-guided mentorship and engagement from instructors are two emergent themes from the interviews that stand to bring some reason as to why students in the support course had higher confidence and more sense of belonging in mathematics. Experiencing support from the SI instructors, their GTA's and their course instructors that form the mathematical community on campus and one key instructor that assumed the role of a mentor for them made a powerful difference in their experience in introductory undergraduate mathematics courses. Future research and effort are necessary to understand how we may broaden our reach to the many students who are often failed by our institutional systems. However, one key take-away is that support courses like the one we implemented are a cost-effective way to provide much-needed support for our most at-risk students.

Acknowledgement

The authors wish to express their sincere appreciation to The Learning Lab of California for the financial support provided through Grant Number 00005931. This research was made possible through their commitment to advancing educational initiatives. All views and opinions expressed in this paper are solely those of the authors and do not necessarily reflect the perspectives of The Learning Lab of California.

References

Aguillon, S. M., Siegmund, G. F., Petipas, R. H., Drake, A. G., Cotner, S., & Ballen, C. J. (2020). Gender differences in student participation in an active-learning classroom. *CBE—Life Sciences Education*, 19(2), 1-10.

Apkarian, N., Smith, W., Vroom, K., Voigt, M., Gehrtz, J., PtC Project Team, & SEMINAL project team. (2019). X-PIPS-M survey suite. Retrieved from: https://www.maa.org/sites/default/files/XPIPSM%20Summary%20Document.pdf

Arendale, D. R. (1994). *Understanding the supplemental instruction model*. Josey-Bass.

Collinson, J. A. (2006). Just 'non-academics'? Research administrators and contested occupational identity. *Work, Employment and Society*, *20*(2), 267-288.

Cooper, K. M., Downing, V. R., & Brownell, S. E. (2018). The influence of active learning practices on student anxiety in large-enrollment college science classrooms. *International Journal of STEM Education*, 5(1), 1-18.

Cooper, K. M., & Brownell, S. E. (2016). Coming out in class: Challenges and benefits of active learning in a biology classroom for LGBTQIA students. *CBE—Life Sciences Education*, 15(3), 1-19.

Ellis, J., Fosdick, B. K., & Rasmussen, C. (2016). Women 1.5 times more likely to leave STEM pipeline after calculus compared to men: Lack of mathematical confidence a potential culprit. *PloS one*, *11*(7), e0157447.Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the national academy of sciences, 111*(23), 8410-8415.

Koch, A. K., & Drake, B. (2018). Digging into the disciplines: The impact of gateway courses in accounting, calculus, and chemistry on student success. *Chemistry*, *34*, 29-4.

Martin, D. B. (2012). Learning mathematics while Black. *Educational Foundations*, 26, 47-66.

McFarland, J., Hussar, B., Wang, X., Zhang, J., Wang, K., Rathbun, A., ... & Mann, F. B. (2018). The condition of education 2018. NCES 2018-144. *National Center for Education Statistics*.

President's Council of Advisors on Science and Technology (PCAST) (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. The White House.

Shah, N., Christensen, J. A., Ortiz, N. A., Nguyen, A. K., Byun, S., Stroupe, D., & Reinholz, D. L. (2020). Racial hierarchy and masculine space: Participatory in/equity in computational physics classrooms. *Computer Science Education*, *30*(3), 254-278.

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., ... & Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences, 117*(12), 6476-6483.

Weston, T. J., Seymour, E., Koch, A. K., & Drake, B. M. (2019). Weed-out classes and their consequences. *Talking about leaving revisited: Persistence, relocation, and loss in undergraduate STEM education*, 197-243.