

WIP: Pathways and Belonging for Incoming Engineering Students Placing into Precalculus

Dr. Leah Rineck, University of Wisconsin - Madison

Leah is the Director of Learning Success Services in the College of Engineering at UW Madison. Her focus is using whole student support to promote their success and well-being. She has been with the College of Engineering since February of 2023 and UW Madison since July of 2020. Before working at UW, she taught math at UW-Milwaukee since 2005.

Mira Rilee Potter, University of Wisconsin - Madison

WIP: Pathways and Belonging for Incoming Engineering Students Placing into Precalculus

Abstract

This work in progress explores the design and implementation of a program supporting incoming engineering students placing into precalculus. These students face many challenges, including the possibility of an extended graduation timeline, missed opportunity for taking coursework with their incoming cohort, and managing the stress of feeling behind. Typically, engineering students who are not calculus-ready are from at least one underrepresented background and thus face additional barriers. To combat these challenges and address underlying issues, we have developed a holistic mathematics bridge program. The program had two cohorts: the 2023 cohort comprised 33 students with 66% of the students underrepresented in engineering. The 2024 cohort comprised 42 students with 93% of the students underrepresented in engineering.

Our goals for the program included fostering community and creating a sense of belonging in the College of Engineering. The program began about ten days before classes started. A representative met with each student at summer orientation during fall class scheduling. We also hosted a welcome dinner for students and their families. A typical program day included math instruction, lunch-and-learn sessions, engineering activities, and community building activities.

The program then continued throughout the students' first year on campus, providing math and chemistry support for their first semester and math, chemistry, and statics/physics support for the second. Second year students still completing this coursework can also take part.

While our initial sample size is small with two cohorts of 77 students, we are excited to report promising initial results. In the 2023 cohort, one-third of the students progressed into their major in their first year, three more progressed into their major at the end of the Fall 2024 semester, and 5 students received progression extensions. In the 2024 cohort, all students maintained or increased their math placement. Forty-three percent placed into Calculus 1 and 10 students were able to start General Chemistry.

Introduction

Students entering an engineering program underprepared for calculus are less likely to persist in their engineering program [1], [2]. Additionally, these students are typically under-represented in the engineering fields either in terms of gender, race or socio-economic status. To address this issue, many colleges and universities have introduced summer bridge programs that aim to increase math placement. The programs vary in length from short programs of one to two weeks [3], [4], [5], [6] to long programs of four to six weeks [7], [8], [9], [10], [11], [12]. All programs showed an increase in math placement level for most of their students.

Students participating in these bridge programs were shown to perform like their peers who placed into the same math class on their first placement test [3], [7], [11]. The bridge programs also increased persistence in the engineering programs [4], [6], [13]. These studies found that increasing students' math placement was beneficial, but that providing a path for students to develop community and a sense of belonging was more important [4], [6], [10], [13].

Due to Covid-19, there are more students now entering university in precalculus classes[14]. Therefore, the College of Engineering at UW Madison decided to develop a bridge program to support incoming students that were placed into precalculus. There are five goals to the program.

1. Provide mathematics support for students that may be underprepared for calculus.
2. Provide study skills and academic support for students throughout their first year.
3. Foster a sense of belonging for students in the program.
4. Prepare students for the pace and rigor of STEM coursework.
5. Increase retention and persistence of students in their engineering programs.

Many similar bridge programs have been implemented in other institutions across the country. Below we discuss the considerations of these programs and the best practices of each.

Literature Review

Mathematics Bridge Programs

The math portions of these bridge programs varied from a week-long review to a full course for credit. The week-long reviews typically included algebra, trigonometry, graphing, solving equations, logic and application problems [3], [5], [15] and were taught by an instructor. However, the length of the program didn't contribute to a positive outcome for students; most increased their math placement scores regardless of program length.

Study Skill Support

Many of the bridge programs integrated study skill support [3], [7], [15], [16]. The skills they taught included test taking, time management, test preparation, and study and habits. While this is beneficial, without context for the students, many didn't transfer the skills when needed during the semester.

Community Building

Developing a sense of community and belonging is beneficial for students to persist in engineering. This is even more important for students who are historically underrepresented in engineering. Most of the programs had different forms of community building throughout their durations. These activities included evening social programming [12], engineering projects [9], [15], and a living learning community (LLC) [4], [10]. Interestingly, Nicklow, et. al., found that their LLC developed organically in the first year with people living together on their own, and they intentionally formed it the second year based on first year results [10].

Ongoing Support

Many of these programs only lasted through the summer and did not have ongoing support for the students into their first year. In one program, students were put into a forced cohort to help them stay motivated and earn a high GPA [7]. Some other programs did form study groups from their LLCs [4], [10]. While some programs offered support in other areas, many didn't offer any study support extending into the academic semester. This is a gap because many students may still struggle with their math class or other engineering classes that incorporate math concepts.

Methods

Because this is a work in progress, we can measure Goal 1, 3 and 4. Goal 2 is incorporated into the program design and discussed below. We will not know persistence and graduation completely until 2027 or later. Goals 1 and 4 are measured by students' performance on the placement test retake, math course GPA, cumulative GPA and progression into their major.

Sense of Belonging

Goal 3 is to promote a sense of belonging for the students. This was assessed through two different surveys. There are a few published scales for sense of belonging that have undergone the development process to ensure validity and reliability [17]. We were able to find and adapt the scale that was used by Imperial College of London [18]. Imperial College gave permission to adapt their scale to focus on specific needs. We chose this scale because it was research based, made for higher education, and concise.

Summer of 2024, we found a scale that was more student-centered [19] and adapted it to our use. This scale is more focused on the students' own feelings and perceptions compared to the previous scale that focused on perceptions of how people treat the student.

Population and Demographics

All students who placed into precalculus during the summer of 2023 and 2024 were invited to participate in the Badger Engineering Start (BEST) Program. The students had the option of participating in the program, studying and retaking the placement test on their own, or following their placement and enrolling in a precalculus course. Summer 2023 we had 33 students participate out of 266 invitations sent, Summer 2024 there were 42 participants out of 275 invitations sent. Both summers 2 students received AP Calculus results and credit after they enrolled in the program and decided to participate anyway.

In the Summer 2023 cohort, 14 students identified as female and 19 identified as male. There were 3 students that identified as African American, 8 Hispanic, 1 International and 21 White. Six students requested a scholarship to pay for the cost of the program.

In the Summer 2024 cohort, 25 of the students identified as female and 17 identified as male. There were 5 Asian students, 14 Hispanic, 1 African American, 1 that selected two or more races, 1 International, 17 White, and 3 students that did not select a race. Twenty-four of the students requested a scholarship to pay for the cost of the program.

Badger Engineering Start (BEST) Program Design

For students to persist in engineering they need to have a sense of self-efficacy and belonging [20]. To address these needs, as well as fill in gaps in students' mathematics knowledge, the BEST Program was created as a multi-faceted approach to a bridge program with the goals of math and study skills review, facilitating a sense of belonging, preparing students for university academics, and increasing persistence and graduation rates of precalculus students.

To accomplish these goals, we offered varying support mechanisms throughout the summer and first year of the student's college career. The program design was student-centered and reflected the rigors of engineering. The program design comprised these major components:

1. The director communicated early with the students who did not place into Calculus 1, which included an invitation to participate in the BEST Program.
2. The director met with students at summer advising and registration to talk about the BEST Program and answered any questions they had about their placement.
3. Students were encouraged to participate in an online asynchronous mathematics review over the summer.
4. Students were required to attend the Early Start part of the program 10 days before the semester started. This part of the program included math review, engineering activities, lunch-and-learn workshops, community building activities, welcome and end of summer celebrations, and a placement test retake.
5. Students were provided with ongoing support throughout the first year that included math, chemistry and statics study tables, community activities, peer advising during course registration time, and Study Jams for finals. This is the largest difference in design between our program and others that were reviewed in the literature. Most other programs offered the summer bridge with no ongoing support throughout the first year.

Results

The placement results for both cohorts were very encouraging. No student dropped to a lower course, but in the summer of 2024, our mathematics department did change their policy that they would accept the highest placement score instead of the most recent.

Results for 2023 Cohort

Twenty-two of the 33 students increased their placement scores, and 19 of those students placed into Calculus 1.

Eleven of the students in 2023 progressed into their major after 2 semesters. There were 2 students that transferred out of engineering, 1 student that withdrew, and 1 student was dropped from the university. At the end of the Fall 2024 semester, 3 additional students progressed into their major, 5 received extensions, 5 must leave the College of Engineering, 2 indicated plans to transfer out and 1 withdrew. Below is a table that summarizes the outcome from both decision periods.

Table 2: 2023 Cohort Progression Decisions

Progression Decision	Number of Students
Progressed to major	14
Non-placement extension	4
Placement extension	2

Plan to transfer out	2
Transfer out	2
Must leave College of Engineering	6
Withdrew/dropped from university	3

2023 Sense of Belonging

The students in the 2023 cohort averaged a 24.3 on the sense of belonging scale. The total score is 30, thus this shows that they did have a strong sense of belonging after the program. Since we did not have the students fill out a pre-survey, we are not able to attribute this to the program.

Results for the 2024 Cohort

Thirty-four students placed into a higher math course, and 17 of those placed into Calculus 1. One exciting result was that all the students that initially placed into beginning algebra ended up placing into a higher math class. By placing out of beginning algebra, students are taking a for-credit math class right away and they will only be increasing time to graduation by a year at most if they are successful in all their classes. The table below lists how the students initially placed and their first math course. Only 5 of the students maintained their placement level, and all others increased their placement level.

One student transferred out of engineering and one student was dropped from the university. There were 2 students who were on academic probation at the time of this writing.

We noticed that the students that regularly attended the study tables in the Fall 2023 and Spring 2024 were successful in progressing into their major after 2 semesters. Therefore, in the summer of 2024 we began encouraging students to sign up for the study tables as a zero-credit class that appears on their transcript. The table below shows the students that remained enrolled in the zero-credit class until the end of the semester and those that did not.

Table 4: 2024 Cohort Math GPA Comparison of Study Table Enrollment

	Enrolled in Zero-Credit Study Table		No Formal Study Table	
Math Course	Number of Students	Average Fall 2023 Math GPA	Number of Students	Average Fall 2023 Math GPA
CA	2	3.5	1	2
CA/T	6	2.75	2	4
Trig	8	3.375	1	4
Calc 1	8	3.06	11	2.09
Total	24	3.125	17	2.56

The three students in CA/T and Trig that did not enroll in the formal study table may have correctly determined they didn't need the extra support or found different support. We performed a simple t-test to determine if there was a significant difference between the Calc 1 performance of students that attended the study table compared to those that didn't. The t-test showed significant differences in the Calculus 1 grades for students that enrolled in the zero-credit study compared to those that did not with $p < .05$. Since the samples were so small for the other classes, we did not perform statistical analysis on those groups. The grade distribution for students who did enroll in the study table earned letter grades of A through C. Those that did not enroll in the study table earned letter grades of B through F. The requirements for students to progress into their major is dependent on them earning a specific GPA in certain classes, of which calculus is a fundamental course. It is important that students earn the best grade they can. Therefore, attending the study table may be beneficial to students' progression into their major.

2024 Sense of Belonging – The 2024 results were like the 2023 results even though we used a different survey. The range of scores on this survey was 5 to 35, with a lower score on the survey shows a stronger sense of belonging. The average score for the 2024 cohort was 16.9. This again shows a strong sense of belonging after the program. Again, we did not have the students fill out a pre-survey, thus we are not able to attribute this to the program itself.

Discussion

As institutions of higher education, we need to offer support to students who are admitted to our college and are underprepared for the coursework when they enter. This can be done in multiple ways. One way is offering underprepared students a math bridge program before their first semester. By incorporating activities that build community and support students' academics and well-being, these programs can support the whole student and increase retention. Unfortunately, there is an opportunity cost to take part in a summer program, such as students may be missing summer work, transportation to and from campus, housing and meals away from home, etc. This cost will disproportionately affect underrepresented students. Therefore, if there are ways to offer programs throughout the school year or somehow provide for the lost opportunity cost while students participate in a summer program.

Additionally, we can explore the implementation of success courses that supplement the zero-credit review courses. Helping the students learn how to be a student, take notes, and manage their time will set them up for success. Lastly, one area of research to explore in the future includes supported summer classes between the first and second year of school for students that came in underprepared in mathematics. There are different ways to support these students. We believe we have to give them the tools to succeed rather than lowering the bar for success.

Conclusion

Most of the students in the BEST program did increase their placement scores, but not all of them entered Calculus 1. Both summers we were able to help all but 2 students increase their placement out of Beginning Algebra. Beginning Algebra is a zero-credit class at UW Madison and will increase their time to graduation by at least one year, but more likely a year and a half, if they do well every semester.

To successfully progress into their major students must maintain a specific GPA based on their intended major and must take some specific core classes. If students meet the criteria, they are automatically admitted to their major. If they don't meet the criteria, they write an essay and are considered to be admitted, offered an extension to meet the criteria, or asked to leave the College of Engineering. There were 19 students that took Calculus 1, and 2 students that took Calculus 3. Eleven (58%) of these students progressed into their major after 2 semesters. This is a promising result for students that were originally placed into precalculus. Additionally, there are now 14 (42% of the total) students total that have progressed into their major. There are 13 students that have or will transfer out of engineering, have withdrawn, or were dropped from the university.

The students did show better performance when they attended study tables regularly in the Fall of 2023, thus we told the Fall 2024 students they were required to enroll in the zero-credit study table. Since there is no scholarship attached to the program, we could not require the students to participate/attend, so some students did not enroll or dropped the class. Looking at the difference in the Calculus 1 grades, attending the study table did make a difference in their performance in Calculus 1. It is difficult to compare the other courses due to the limited number of students who took the class.

The students in both cohorts had a strong sense of belonging at the conclusion of the program. At the events during the semester, they were all excited to see each other and many had contact throughout the semester. Additionally, from the 2023 cohort there were 5 students that came back to be peer mentors for the 2024 cohort. They shared their knowledge about the program and what they had learned about being at the university.

References

- [1] S. G. Brainard and L. Carlin, "A six-year longitudinal study of undergraduate women in engineering and science," *Journal of Engineering Education*, vol. 87, no. 4, pp. 369–375, 1998.
- [2] C. Papadopoulos, "DO STUDENTS IN SUMMER BRIDGE PROGRAMS SUCCESSFULLY IMPROVE MATH PLACEMENT AND PERSIST? A META-ANALYSIS. Do Students in Summer Bridge Programs Successfully Improve Math Placement and Persist? A Meta-Analysis," in *American Society for Engineering Education*, 1994, pp. 13–21.
- [3] D. Budny, "Mathematics Bridge Program," in *Frontiers in Education 1995 25th Annual Conference. Engineering Education for the 21st Century*, Nov. 1995, pp. 2a4-11.
- [4] J. Mathias, "IMPROVED RETENTION THROUGH INNOVATIVE ACADEMIC AND NON-ACADEMIC PROGRAMS," in *American Society for Engineering Education*, 1993, pp. 12–23.
- [5] T. Vercellino, D. Christenson, and A. N. Morse, "Implementation and Effects of a Bridge Program to Increase Student Learning and Retention in Engineering Programs Implementation and Effects of a Bridge Program to Increase Student Learning and

- Retention in Engineering Programs,” in *122nd ASEE Annual Conference & Exposition*, 2015.
- [6] A. Windsor *et al.*, “Increasing Retention in STEM: Results from a STEM Talent,” *Journal of STEM Education*, vol. 16, no. 2, pp. 11–17, 2008, [Online]. Available: www.memphis.edu/oir/retention/
 - [7] R. Alkhasawneh and R. Hobson, “PRE-COLLEGE MATHEMATICS PREPARATION: DOES IT WORK? Pre-College Mathematics Preparation: Does it work?,” in *American Society for Engineering Education*, 2010, pp. 15–25.
 - [8] J. M. Citty, J. Citty, and A. S. Lindner, “DUAL MODEL SUMMER BRIDGE PROGRAMS: A NEW CONSIDERATION FOR INCREASING RETENTION RATES,” in *American Society for Engineering Education*, 2012, pp. 25–48.
 - [9] J. Gleason *et al.*, “Integrated Engineering Math-Based Summer Bridge Program for Student Retention,” *Adv Eng Educ*, pp. 1–17, 2010.
 - [10] J. Nicklow, R. Kowalchuk, L. Gupta, J. Tezcan, and J. Mathias, “A short-term assessment of a multi-faceted engineering retention program,” in *2009 39th IEEE Frontiers in Education Conference*, Oct. 2009, pp. 1–6.
 - [11] J. R. Reisel, M. M. Jablonski, L. Rineck, and E. V Munson, “ANALYSIS OF MATH COURSE PLACEMENT IMPROVE-MENT AND SUSTAINABILITY ACHIEVED THROUGH A SUMMER BRIDGE PROGRAM in civil/environmental engineering from UWM in 2013,” in *American Society for Engineering Education*, 1994, pp. 25–41.
 - [12] T. L. Strayhorn, “Bridging the Pipeline: Increasing Underrepresented Students’ Preparation for College Through a Summer Bridge Program,” *American Behavioral Scientist*, vol. 55, no. 2, pp. 142–159, Feb. 2011, doi: 10.1177/0002764210381871.
 - [13] C. Moller-Wong and A. Eide, “An engineering student retention study,” *Journal of Engineering Education*, vol. 86, no. 1, pp. 7–15, 1997.
 - [14] E. Panagouli *et al.*, “School performance among children and adolescents during covid-19 pandemic: A systematic review,” Dec. 01, 2021, *MDPI*. doi: 10.3390/children8121134.
 - [15] A. Nagchaudhuri and G. Singh, “Summer Engineering Bridge Program at University of Maryland Eastern Shore: Objective and enrichment activities,” in *2001 American Society for Engineering Education Annual Conference & Exposition*, Jun. 2001.
 - [16] M. F. Summers and F. A. Hrabowski III, “Preparing minority scientists and engineers,” *Science (1979)*, vol. 311, no. 5769, pp. 1870–1871, 2006.
 - [17] H. Gehlbach and M. E. Brinkworth, “Measure Twice, Cut Down Error: A Process for Enhancing the Validity of Survey Scales,” *Review of General Psychology*, vol. 15, no. 4, pp. 380–387, 2011, doi: 10.1037/a0025704.

- [18] H. Gehlbach, "User Guide: Panorama Student Survey," Retrieved from <https://www.panoramaed.com/panorama-student-survey>.
- [19] X. Ma, "Sense of belonging to school: Can schools make a difference?," *J Educ Res*, vol. 96, no. 6, pp. 340–349, 2003.
- [20] V. Tinto, "From Retention to Persistence," Inside Higher Ed. Accessed: Mar. 13, 2023. [Online]. Available: <https://www.insidehighered.com/views/2016/09/26/how-improve-student-persistence-and-completion-essay>