Supplemental Instruction to Decrease Equity Gaps in Gate-Keeper Engineering Courses (ERM)

ABSTRACT

This study explores the impact of Technology-Assisted Supplemental Instruction (TASI) on the sense of belonging and academic achievement of URM identified students in Statics courses at a large public HSI university. TASI is a peer-led tutoring service in partnership with faculty support that targets high failure rate STEM courses, in this case, three different iterations of Statics. Students completed four surveys that measured demographics, sense of belonging in their field of study, and confidence in their ability to do well in their courses. In addition, TASI attendance, students' academic and enrollment data were collected. Preliminary belonging data at the beginning of the term showed the nearly 80% of Latinx students agreed with the statements: "I sometimes feel like other students in my field of study have skills that I do not," and "When I struggle in a class I feel that I don't belong in the field". Linear regression also shows that the main predictor of student grades in Statics are identifying as a URM student or Pell recipient. TASI has the goal of increasing academic support and therefore performance to alleviate these feelings and ensure student persistence. Using matched pairs analysis, the data shows a statistically significant increase of 0.4 to 0.5 in course grade on a 4-point scale. These results were most apparent in URM students. The rate of failing grades for URM students decreased up to twenty percent (depending on the section). The impact of the TASI is more evident for students of color during the COVID pandemic and virtual learning. The use of an anti-deficit lens highlights how imperative it is to have meaningful, useful, and accessible interventions. Student facilitators, access, and awareness of programs are noted as crucial to success.

OVERVIEW

Work has been done across many fields of education, including engineering around student success and a sense of belonging. Unfortunately, while very well intentioned, the efforts have been surface level- not focusing on student's ownership of their learning and what practices really increase academic performance and sense of belonging, especially in a virtual environment. This study examines a modified University of Missouri Kansas City model is foundational in Supplemental Instruction (SI). This peer support is a non-remedial way to use near-peers to increase success in traditionally difficult academic, gate-keeper, courses. Typically, these courses are chosen because about 30% of students earn a D, F, or W. In this study the support is Technology Assisted Supplemental Instruction (TASI) in Statics courses and its impact on Latinx students. Students' sense of belonging and self-efficacy indicators were gathered and paired with final course grade as an academic marker of effectiveness of the intervention. This study is also notable, as it uses anti-deficit lens to understand not only the literature but the effectiveness of the intervention.

LITERATURE

Despite being equally likely to pursue careers in STEM [1] and narrowing rates of degree attainment for BIPOC students in STEM, disparities are still evident in academic achievement and rates of degree attainment [2]. Differences in graduation rates, grades, and time to degree have historically been explained by a host of factors [3]. A number of models have been developed. However, traditional models, such as pipeline models [4], have done little except

narrow the qualifications for participation in the field [5], and, despite attempts to reduce disparities, they remain. The increase in STEM degree attainment has jumped from 8.6% in 2009 to 12.7% in 2017 [6], but Latinx STEM degrees greatly trail their non-URM counterparts. While the notion of an HSI designation should call attention to the unique needs of universities, they receive 68 cents for every dollar going to other universities [6]. Simply looking towards traditional makers for success like grades and high school factors, is not enough to understand the lack of degree attainment- other factors must be considered.

Sense of Belonging:

Sense of belonging has been identified as a key social-emotional variable impacting student success. Students' sense of belonging is a composite of perceived social support, connectedness, and feeling respected and valued by others on campus, including faculty and peers [7]. This is similarly true of specific majors. Sense of belonging is associated with academic achievement, motivation, and student well-being, yet underrepresented minority students consistently report low sense of belonging compared to their non-URM peers [8-10]. For STEM majors specifically, a sense of belonging is linked with perceived competence and retention in college major [11]. Hence it appears, low sense of belonging contributes to lower degree completion rates for URM students in STEM [11]. Interventions that address sense of belonging, in addition to competencies, are more likely to foster student success.

Addressing the Consequences of Barriers Faced by URM Students in Engineering:

Different interventions have been implemented to mitigate the consequences of the barriers URM students typically face. One academic support intervention is supplemental instruction (SI). Supplemental instruction is a type of tutoring led by peers who have taken difficult courses and assist others taking the same courses [12]. Studies done on the effectiveness of supplemental instruction suggest that this form of peer-assisted tutoring leads to higher final grades and higher pass rates for URM students, especially in roadblock classes, and higher graduation rates in STEM [13,14] Although supplemental instruction interventions have shown to be effective in improving academic outcomes for URM students, gaps in graduation rates persist in STEM majors [12].

Latinx students in the Stem Field: The Gap; Challenges; and Change

The university in this study is a Hispanic Serving Institution (HSI) with enrollment in the Latinx enrollment in the university being 50% (52% all URM), with the college of Engineering having 41% Latinx enrollment (43% URM). Currently, there is an equity gap for graduation rates in the college of engineering of 15%, meaning URM students graduate at a rate 15% lower than their non-URM counterparts. Despite explicit attempts to reduce equity gaps, many universities face problems retaining students in the STEM field, especially Latinx students [15]. According to Fifolt and Searby, inadequate academic preparation, low self-confidence, social economic status, and institutional factors conspire to reduce Latinx student success in STEM majors [15]. A shortage of mentors with adequate cultural competencies [16,17], high school educational experiences with a focus on success on standardized exams and language competencies [18], and a dearth of adequate tutoring programs [17] are excluding Latinx students and impinging on student success.

The Anti-deficit Lens

The Anti-deficit Lens is a framework that focuses on removing the stigma and accountability from underserved communities and placing the onus on the larger culture [19]. Mejia et al, defines the asset-based approach in engineering to be one that acknowledges the embodied knowledge of students of color [20]. This study uses the critical lens to understand the integration of reflection and praxis to help students grow in the ownership of their learning and be liberated from the constraints of the university barriers to achievement [20].

CURRENT STUDY

The current study examined the impact of different teaching strategies in Statics, more specifically, the impact of technology-assisted supplemental instruction (TASI) on engineering students' academic achievement and sense of belonging. The TASI program is designed to assist students in gatekeeper courses at the second- and third-year level which are known to have low completion rates. These low completion rates create frustration, slow student time to degree, and impact student sense of belonging. This study in particular examines three different versions of Statics courses (one in mechanical engineering, one in civil engineering and one in engineering technology). The historic D,F, and W grade distribution and enrollment data are below in table 1.

Table 1: Academic Year 2018 data- prior to TASI

Course	D,F,W %	Average Course grade	Non-URM	URM
Engineering Statics (CE)	16%	2.54	2.72	2.39
Applied Statics (ET)	7% (2017) 19% (2016)	2.85 (2017) 2.3 (2016)	3.07 (2017) 2.6 (2016)	2.8 (2017) 2.2 (2016)
Vector Statics & Strength of Materials (ME)	24%	2.24	2.36	2.06

Predictive analysis of final course grade in statics showed the strongest predictor of course grade is race. Even high school GPA, gender and Pell did not enter the model See below.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27.865	1	27.865	15.806	.000[b]
	Residual	3125.653	1773	1.763		
	Total	3153.519	1774			

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2.231	.048		46.051	.000
	URM Status	.254	.064	.094	3.976	.000

To counteract this, TASI provides academic support in the form of 50-minute peer-to-peer sessions for all students in the engineering field, conducted by students who have been successful in the course. This model differs from the traditional SI model as it uses technology to capture session to make them available to students, has one facilitator for all sections of a class (instead of a one section one facilitator model) and student facilitators work with a faculty mentor to develop techniques and receive needed guidance. The purpose of the study was to measure explore the efficacy of TASI for URM students in statics. The efficacy of TASI was considered along the dimensions of improved sense of belonging, and student performance in the course.

Materials and Methods:

Four surveys, two pre-surveys and two post-surveys, were administered from spring 2019 through the following academic semesters. Pre-existing measures for belonging were used, along with students' demographic information, student course performance data, their perceptions of their field of study, and confidence in their abilities within the field. Students were given space to express any concerns or challenges the students faced in final surveys. Pre-surveys were administered after the add-drop period had closed at the beginning of the semester and post-surveys were administered the last two weeks of the semester. In addition to the surveys, the students' enrollment and academic data from SP2019 to SP2021 was available. A quasi-experimental approach was used. While a larger project explores the efficacy of TASI for a range of engineering courses, this paper focuses on Statics courses: Engineering Statics (CE), Applied Statics (ET), and Vector Statics (ME).

RESULTS

Overall, we found sense of belonging was improved by TASI participation, and TASI participation did improve course performance. Analyses of course GPA data revealed that URM students' final course grades were consistently lower than that of their non-URM counterparts, as identified by previous research [15]. This pattern was evident each semester from SP2019 to SP2020 for all three courses with the exception of Spring 2020, in ET when the grades were equivalent. See tables 2-4 below.

Table 2 course grades and enrollment in Mechanical Engineering Statics:

	Spring 19	Fall 19	Spring 20	F 20	Sp 21
Non-URM course grade	2.38	2.15	2.78	2.63	2.68
Non-URM enrollment	102	118	83	96	100
URM course grade	2.04	1.9	2.46	2.36	2.63
URM enrollment	57	59	42	54	54

Table 3 course grades in Civil Engineering Statics:

	Spring 19	Fall 19	Spring 20	F 20	Sp 21
Non-URM course grade	2.7	2.6	3.05	3.25	3.23
Non-URM enrollment	85	110	92	113	93
URM course grade	2.26	2.24	2.85	2.99	2.84
URM Enrollment	67	106	080	115	81

Table 4 course grades in Engineering Technology Statics:

	Spring 19	Fall 19	Spring 20	F 20	Sp 21
Non-URM course grade	3	3.26	3.15	3.32	2.72**
Non-URM enrollment	15	23	26	22	15
URM Course grade	2.98	3.05	3.15	2.79	2.19**
URM enrollment	14	13	12	18	10

** TASI not offered this semester

Anti-deficit lens provides a frame that suggests we investigate differences in URM success in the program. Targeted programs are required to redress on-going institutional failure. In this study, the three courses were selected for analysis because of their traditionally low passing rates which typically hinders students from advancing in their degrees, as they are part of sequences.
For instance, the average percentage of students who received a D, F, W in ME between SP2019 and SP2021 was 16.8% (*SD* = 3.834).

TASI: Current data reflects that during the semesters TASI was offered, D, F, W rates improved for all courses. In Mechanical Engineering, the D, F, W rate dropped from 23% in F2019 to 14% in F2020. In Civil Engineering and in Engineering Technology, the DFW rate dropped to 8%. Additionally, grade data was analyzed for students who did and did not attend TASI. Between the two groups and regardless of URM status, students who attended TASI saw improvements in their grades compared to students in the same course who did not attend TASI. A matched pairs analysis was conducted, matching by prior GPA and URM status. Gender, Pell and other factors were considered; however, the analysis became too limited and appropriate pairs were not found. This finding was significant for two of the three courses included in this study, that is, Applied Statics and Vector Statics. Students in ME who attended TASI performed better in the course as they earned a grade of 2.3 while non-TASI students earned a grade of 1.9. This highlights a significant an increase by 0.4 on a 4-point scale (p = .003). Moreover, for students in ET, grades significantly increased by 0.5 for students who attended TASI (p = .003). TASI students in ET earned an average course grade of 2.9 whereas non-TASI students earned an average grade of 2.4. In CE, students also received a higher average course grade of 2.5 compared to non-TASI

students' 2.1, however this difference was not significant. Even though the results for CE were not significant, the overall group points to a significant improvement in student performance. The overall results are below in Table 5.

Table 5 Course grades for students by attend TASI or not

Course	TASI GPA	Non-TASI GPA	Significance
Engineering Statics (CE)	2.5	2.1	.219
Applied Statics (ET)	2.9	2.4	.003**
Vector Statics & Strength of Materials (ME)	2.3	1.9	.003**

TASI for URM Students: In Mechanical Engineering Statics, there were 264 URM students, or 34.6%, and 498 non-URM, 65.4%, students in the course. Out of the 264 URM students, there was a high frequency of students receiving F grades (n = 72). The second closest frequency (n=30) for URM students was a C- both of these scores mean students must repeat the course. 194 URM students did not attend TASI while 70 did. Matched-pairs analysis indicated that URM students who attended TASI received a higher course grade than URM students who did not (M = 2.91, n = 66, t = 2.39, p = 0.03). URM students who attended TASI had a higher course grade (M = 2.06, SD = 1.21) than URMs who did not (M = 1.69, SD = 1.41). In this case, the difference for students attending TASI and those not attending TASI reflects the difference between needing to retake the class, and continuing in the sequence. During the COVID-19 pandemic these results were even more apparent with students earning a course GPA of 2.55 pre-COVID and 2.66 during the pandemic with a significance of p=0.002.

Sense of Belonging: There were several surveys administered during this research that focused on a sense of belonging, and that allow us to compare data for Latino/x students at Cal Poly Pomona. Participants indicated they felt like they belonged at the University (M=5.52, SD=1.089) yet, when the students evaluated their ability skills against their classmates, many felt their skills weren't up to par. For example, when asked a question regarding ability uncertainty, "I sometimes feel like other students in my field of study have skills that I do not," about 76% of students indicated within the range of agree for that statement (M=5.35, SD=1.448). When observing Latino/x students' perception, 79.4% of Latino/x participants responded that they somewhat, moderately or strongly agreed with the previous statement (M=5.43, SD=1.603). Thus, many students were concerned with their abilities compared to others in their field, suggesting that the students believe others have stronger capabilities. Increasing student performance, and sense of belonging, especially by students of color removes this barrier to degree completion.

Barriers to Education: Many Latino/x students reported difficulties in the F2020 post-survey. It is important to note that this might not be representative for all Latino/x students yet, it hints that there are challenges faced throughout the semester. One challenge was of 26.9% of Latino/x participants, responded that they were unable to put the time needed to do well in the course. Finally, students had challenges with balancing course expectations with their personal and work

life. Given our high proportion of working students, and student parents, this is not surprising. Prioritizing financial and familial relief could reduce student time pressures.
Similar to the F2020 post-survey, Latino/x participants in the SP2020 post-survey faced challenges during the semester. Eighty-seven percent Latino/x participants reported having difficulties balancing course expectations with personal life and work; 60%, had challenges with taking exams and 1/3 reported difficulties completing course assignments. These reported challenges suggest that many had problems with their courses during the COVID 19 pandemic. TASI worked to alleviate these challenges.

Discussion: The results of the current study highlight the impact of TASI on reducing educational equity gaps for URM students and enhancing their experiences as they obtain their degree. These findings suggest that TASI is a helpful institution-provided resource for students struggling in their courses which makes a difference in whether students must retake a course or if they can progress toward graduation. Interventions such as TASI serve a key role in buffering these negative experiences that Latino/x and other URM students face. As mentioned previously, the TASI program is informed by the Anti-deficit framework allows us to understand when a student takes ownership of their learning and creates a space for reflection, TASI works to diminish institutional barriers. TASI is an example of an equitable resource that merges critical theory and reflection with action to engage and empower URM students in engineering. By attending TASI, URM students can deepen their understanding of course material and become empowered to persist and overcome institutional barriers to their success. This is highlighted by the performance of students who attended TASI in Applied Statics and Vector Statics. After matching students based on URM status and previous GPA, t-tests revealed a significant improvement in students' final grades for those who attended TASI compared to those who do not. The findings of this study are especially important for students progressing through their course sequence as attending TASI sessions made the difference in whether students had to retake a course to move forward in their academic program. Students attended TASI and earned passing grades that allowed them to move forward despite institutional barriers or challenges they faced. As a result, they also became more persistent when faced with challenges in their course and felt a greater sense of belonging to their university. Understanding Latino/x students' experiences in their courses and in their university offers institutions the opportunity for intervention and support for the students that represent a large demographic of the school. The findings of the current study reflect meaningful progress in supporting URM students and helping them become successful, but limitations exist and prevent further conclusions.

Recommendations: There are two factors that might have hindered students' availability for attending TASI. One factor is the TASI schedule. As mentioned earlier, TASI sessions are usually scheduled during U-Hour which is a university-wide hour of break. U-Hour occurs every Tuesday and Thursday from 12:00PM to 1:00PM. Engineering courses have different scheduled days of meetings; some might take place on Tuesday/Thursday and others on Monday/Wednesday. Thus, not every student will have U-Hour free to attend TASI due to student unions or clubs recurring at the same time. As well as not being on campus during the days they don't attend class and have other duties such as work or no childcare. There are other TASI sessions available to students on different days and times throughout the week to assist students who couldn't come to U-Hour sessions. However, each TASI session is catered to a specific course and there is only one additional session per course. A total of three sessions per

course is a limited selection for students. Thus, it is recommended that TASI sessions should be adaptable to the course it caters for. For example, if there is a course on a Wednesday and Friday, TASI sessions should occur before, after, or generally the day of to accommodate to student's needs and time. High attended TASI sessions, observed in SP2021, occurred before a course; thus, students had availability to attend the session and then attend class after. Another factor could be that students weren't aware of TASI sessions. Professors should persuade students weekly to attend, especially if they need extra support or are having difficulties understanding certain topics. Publicizing TASI sessions will be beneficial to all students as seen in the data. Retention of faculty is also a critical part of the program with specific training in education. This could provide a unifying voice for student success and move progress forward.

Future Directions: To fit the anti-deficit framework, TASI leaders will attempt to increase attendance by making TASI sessions more accessible and setting times that better suit students' schedules. Faculty will also be asked to promote TASI as a support system to students earlier on in their academic career. By providing more information on these resources many students will have accessibility to help in hopes of passing the class or finding a support system on campus in which they can identify with. This can eventually help with retention rates and sense of belonging in their field of study to feel comfortable and strive. Additionally, student facilitators will be given support and training from faculty who are teaching the class to give better understanding to the students when asking for help. Creating a mutual network of help to better benefit the students. We are also looking into the impact of TASI during the COVID 19 pandemic and developing a course of action for the return to face-to-face instruction.

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