Enhancing students' outcomes in gatekeeper engineering courses through Technology-Assisted Supplemental Instruction (TASI)

ABSTRACT

Tutoring is an intervention that universities implement to ease students' adjustment to college courses and reduce achievement disparities. Several studies indicate that tutoring helps students develop their identities as learners and provides a sense of belonging at their institutions. While many programs focus on freshman, this program focus on upper-division students, something essential at a university with a high proportion of transfer students. This program focused on assisting students in gate-keeper engineering courses with high failure rates as part of a larger institution-wide HSI grant. Technology-Assisted Supplemental Instruction (TASI) is a peer-led tutoring service with the goal of persistence of students and student facilitators as measured by their academic performance and sense of belonging. Instead of the traditional one-to-one (one section for one SI) this study looks at using technology to service all sections of a class with one facilitator.

Surveys were distributed to STEM students measuring their sense of belonging in their field and university, confidence in their abilities, and demographic information. In addition, data on academic outcomes and attendance for tutoring sessions were collected. Statistical analyses revealed that in three different versions of Statics courses, TASI was significant in impacting course grades between students who attended compared to those who did not attend. Also, when comparing TASI's impact before the transition to online and after, TASI was statistically significant in two courses while online, indicating more students used the service during the pandemic. In the surveys, students reported a high sense of belonging in both their field of study and at the university yet, many students indicated facing challenges such as balancing life obligations, studying for exams, and completing course assignments. Additionally, surveys revealed that while students are confident in their abilities, when compared to their peers, their confidence decreased. TASI helped students better comprehend course material and provided them more accessible support. Providing students with resources such as TASI will help students feel more motivated to persist and obtain better grades. This assistance can reduce the complex challenges students face with their courses.

I. OVERVIEW

The 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. This free and voluntary support for students is based on the following tenets: [1]

1. integrate how-to-learn with what-to-learn;
2. incorporate study skills;
3. provide peer-support;
4. reinforce classroom instruction; and

5. are free and informal.

While the academic markers are an easy way to measure success of students, they are often lagging and do not consider other measures of success such as sense of belonging. Developing a sense of belonging is critical, especially in a virtual learning environment, to retain students and develop an identity as an engineer. While sense of belonging is critical, it is often illusive and not measured directly by studies that look at academic achievement- even though it tends to develop prior to a shift in academic markers.

Moreover, much of the research on SI has been done from a perspective of supporting one section of one class, or focused on support classes for engineers like chemistry, math, or physics. This leaves little evidence on how SI can support students through the gate-keeper courses- where engineering identity is fully established.

The supplemental instruction program used in this study was based on Kansas Missouri model with key differences. 1- Student facilitators support all sections of a class instead of a one-to-one match. 2- Students use technology to deliver instruction and record sessions making them available for students to access at a later time. 3- A faculty member is a mentor to the supplemental instructor to plan, address concerns, and ensure content is delivered in a sound manner (they do not attend sessions). 4- The courses selected for support of SI are gatekeeper 2000 level courses with a higher rate of D, F, and W grades instead of introductory classes and are within the engineering content.

Student facilitators held three 50-minute sessions of Technology Assisted Supplemental Instruction (TASI) each week during the academic year. These sessions are based on student questions and if needed, concerns of the instructor, recorded and posted to a close website. Students were selected as supplemental instructors based on previous performance in the class and success in subsequent courses. When possible, the instructor was selected to best understand the students. For instance, in one department a student who was a transfer student was selected as the SI facilitator because over half of the department were transfer students.

II. Literature

A. Sense of Belonging

Students' sense of belonging is often defined as perceived social support, connectedness, and feeling respected and valued by others on campus including faculty and peers [2]. In the context of the Science, Technology, Engineering, and Mathematics (STEM) fields, more specifically in the engineering field, a sense of belonging can be defined as feeling respected, valued, and encouraged by engineering faculty and other students in the same major. Understanding a sense of belonging is necessary because it is associated with academic achievement, motivation, and student well-being, yet underrepresented minority (URM) students consistently report low sense of belonging compared to their non-URM peers [3,4]. For STEM majors specifically, a sense of

belonging is linked with perceived competence and retention in college, so the low sense of belonging that STEM students tend to report can be a factor contributing to the gap between URM and non-URM students who complete their STEM degrees [5]. It is important to understand URM students' sense of belonging in STEM because it is often tied to students' success in the academic setting. Knowing how much students feel they belong in their respective departments and fields can further inform interventions in higher education as this is linked to student success in the academic setting.

B. 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 [6]. Studies done on the effectiveness of supplemental instruction suggest that this form of peer-assisted tutoring leads to higher final grades and a higher percentage of URM students that pass the difficult courses. It also results in higher graduation rates for URM students in STEM majors as the students are better able to progress with their undergraduate degrees [7,8]. Although supplemental instruction interventions have shown to be effective in improving academic outcomes for URM students, the graduation gap between URM and non-URM students still exists with a higher graduation rate for non-URM students in STEM majors.

Past studies conducted on SI for engineering students have consistently found that SI is linked to greater self-efficacy, persistence, and subsequent success in students' academic programs [9,10,6]. important feature of SI is the supportive and collaborative learning environment shared between the individual leading the session or SI leader and the student seeking support. Not only does this deepen students' understanding of difficult course concepts, but the learning environment inherent in SI ultimately increases student persistence and retention rates thus reflecting students' success in their programs [1].

III. Technology Assisted Supplemental Instruction (TASI)

Methods

This study is part of a larger Hispanic-Serving Institution (HSI)-wide National Science Foundation (NSF) funded grant focused on developing a model for an inclusive polytechnic university that inspires creativity and innovation, embraces local and global challenges, and transforms lives. Specifically, the project is designed to support STEM faculty in creating an inclusive atmosphere within the classroom, especially in critical transition courses, by attending to students' motivation and other malleable social-psychological factors. This project examines students' sense of belonging and academic achievement in traditional engineering gate-keeping courses within the college of engineering (after Calculus and Physics) with the support of Technology-Assisted Supplemental Instruction (TASI).

Courses selected to be supported by TASI are those with historically high D,F,W rates and are pre-requisites for other courses in a sequence as shown in. The project began pre-pandemic and continued through the pandemic offering TASI over zoom.

Table 1- Historic D,F,W rates for TASI supported courses

Academic Year 2018 data- prior to grant				
Course	D,F,W %	Average Course grade	Non-URM	URM
Electrical Circuits 2 (EE)	27%	2.71	2.72	2.65
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
Fluid Mechanics (ME 3000 level course)	19%	2.30	2.36	2.21

Students were given an inventory that measured their sense of belonging in the field, the college of engineering, and the university. These indicators are used across the project and give a complete picture of how the university is serving students. Final course grade data was also obtained for each student in the sections of the target classes as well as demographic data including scores in physics and calculus (both pre-requisites for these classes).

Sense of belonging data was collected by student survey and analyzed mostly using cross-tabulation to see if differences emerged across, gender, ethnicity, major, or transfer status (see appendix for full survey). Grade data was analyzed using t-tests and matched pairs to accurately compare students who attended supplemental instruction with those who did not. Pairs were matched on previous GPA within a 0.2 margin, and ethnicity (URM and Non-URM as defined by the university). Other criteria were originally added such as gender and physics grades, however gender created a field too narrow to match (because there are too few students who identify as women in the courses) and physics grades were redundant to previous GPA.

When outcome grades were analyzed, a matched analysis was performed. Students who attended TASI were matched based on URM, Pell, and GPA to those counterparts who did not attend TASI. To understand the program's effectiveness, the course grade at the end of the term was compared in a 2 tailed t-test.

Findings

The sense of belonging data gave an informed place to proceed with analysis of the grade data. When examined, 79.4% of Latinx participants on the sense of belonging survey responded that they somewhat, moderately or strongly agreed with the statement “I sometimes feel like other students in my field of study have skills that I do not.” This was significantly higher than their non-Latinx counterparts. Creating an environment that is student-led and improved academic performance decreases this feeling and will increase sense of belonging and persistence in the field.

Students attended TASI at differing rates as shown below in Table 2. Some of the courses decided to pause TASI when we transitioned to remote learning in March of 2020 (some sections are reporting partial semester). In the Fall of 2020 and Spring of 2021, TASI was entirely remote as the university was entirely remote.

Course	Fall 2019	Spring 2020	Fall 2020	Spring 2021
	Began week of 9/10/19	Began week of 2/4/20 *COVID transition	Began week of 10/5/21	Began week of 2/15/21 *partial semester data
Electrical Circuits 2 (EE)	8	16	77	168
Engineering Statics (CE)	67	9	91	28
Applied Statics (ET)	185	45	78	*not offered
Vector Statics & Strength of Materials (ME)	288	269	259	508
Fluid Mechanics (ME 3000 level course)	195	54	77	14

At the macro level, a decrease in the percent of students receiving a grade of D,F, or W should decrease when TASI is instituted. There was not an overwhelming change in the D,F, W rate for these classes as shown below in Table 3.

Course	Spring 2019	Fall 2019	Spring 2020	Fall 2020	Spring 2021
	% D, F, W	% D, F, W	% D, F, W	% D, F, W	% D, F, W
Electrical Circuits 2 (EE)	9%	10%	7%	12%	4%
Engineering Statics (CE)	18%	23%	15%	14%	14%
Applied Statics (ET)	9%	5%	3%	8%	48% * SI not offered
Vector Statics & Strength of Materials (ME)	26%	27%	27%	41%	30%
Fluid Mechanics (ME 3000 level course)	16%	7%	3%	3%	5%

Grade data was analyzed for those who attended TASI and those who did not. Pairs were matched based on URM status (the university defines non-URM as white and Asian students excluding Southeast Asian and Pacific Islander) and prior GPA. These factors allowed us to answer the question- does TASI impact the performance of students attending TASI did see an improvement in their final course grade (see table 4 below). In Vector Statics, the largest enrollment of all the courses, the average age increased from 1.9 to 2.3, a grade increase of 0.4, on a 4-point scale and made the difference of having to repeat the course or not (a C- is not

passing for the next course). Not all the classes showed a significant difference on the two-tailed T-test. Applied Statics had a significant improvement of 0.5, however, Engineering Statics (CE) had a non-significant improvement of 0.4. In the same way, Electrical Circuits II improved 0.2 but the results were not significant. However, when these four classes are taken as an aggregate, they show that TASI improves student performance up to a half of a GPA point.

Unlike the other courses, Fluid Mechanics had a negative difference in GPA performance. Students who attended TASI earned a grade of 2.9 and those who did not earned a grade of 3.2. This is the only upper-division course in the group and has a had a change of facilitator and faculty mentor each semester and there are alternative academic supports offered.

Course	TASI GPA	Non-TASI GPA	Significance
Electrical Circuits 2 (EE)	3.4	3.2	.167
Engineering Statics (CE)	2.5	2.1	.219
Applied Statics	2.9	2.4	.003**
Vector Statics & Strength of Materials (ME)	2.3	1.9	.003**
Fluid Mechanics (ME 3000 level course)	2.9	3.2	.003**

Future Directions and Next Steps

As the grant reaches its complete date, we are continuing to analyze the data for those who attend TASI and those who do not. A complete analysis is underway to examine the results by semester to understand the impact of the COVID pandemic and virtual learning have on the results. We are also expanding the research to include courses offered throughout the college such as Vector Dynamics and Materials Processing to understand the impact TASI will have in those classes. We are also merging the three courses of statics (Applied Statics, Vector Statics, and Engineering Statics) to see if we can add criteria to match pairs in order to get a more precise indication of TASI effectiveness.

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