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Peer-Led-Team Learning in Introductory Engineering Courses: An Analysis of an Interventional Method of Support for Underrepresented Students at a Two-year, Hispanic-serving Public Institution

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Abstract

The three-year project entitled Engagement in Engineering Pathways funded by the National Science Foundation Improving Undergraduate STEM education grant explored the conditions that led to increased academic outcomes and non-cognitive factors related to persistence of non-traditional undergraduate students in engineering education. The study was conducted at a multi-campus, federally-designated, Hispanic-serving, public, two-year college in the southeast United States. This paper presents one aspect of the effects of peer-led team learning (PLTL) on academic success through the inclusion of active learning modules in introductory undergraduate engineering course. The researchers found that PLTL introduced in engineering courses, to include statics and dynamics, closed a gap between majority and minority students, populations historically underrepresented in engineering. Although the study is limited to a single institution, the results support that the inclusion of active learning modules introduced through peer-led exercises are an important learning support construct known to be a factor in academic success and persistence in engineering education.

Introduction

The Engagement in Engineering Pathways "E-path" project took place at a large, two-year college in Central Florida that serves a high percentage of low-income students and minority students that are traditionally underrepresented in engineering pathways. Many of the students at the institution enter STEM programs, specifically engineering programs, with poor mathematical preparation. As a result, the students experience delays in their time to graduation and are required to begin in remedial mathematics. The target population struggles to integrate applied mathematical concepts within their introductory engineering classes. As a result, the attrition rates are higher after students take statics and dynamics courses. These students with poor mathematical preparation were identified as at-risk for leaving engineering and STEM pathways entirely once they faced difficulties in their early coursework due to applied mathematics. This paper highlights the best practices in implementing peer-led team learning strategies as part of engineering recitation courses to achieve student persistence and retention.

As part of the activities for the NSF Improving Undergraduate STEM Education grant, the investigative team implemented recitation labs, fifteen per course taught by a peer, who met the recitation leader eligibility criteria. The courses followed a face-to-face instructional model with class primarily reserved for lecture and the one-hour a week recitation lab reserved for peer-led practice of applied mathematics within real-world engineering concepts. Over the three-year period, the project moved toward the goal of increasing student success and provided support structures so that underrepresented students, particularly minority female students, can progress in engineering and engineering technology disciplines.

The team relied on best practices based on the literature for small-group learning offered through PLTL exercises in which teams of students review subject matter through group interactions that help them learn from each other [4]. The strategies are successful across multiple STEM disciplines and found to be particularly salient in engineering education as a benefit to both instructors and students [7]. The learning strategies work well in the context of engineering as most students and instructors understand the stark dichotomy between regurgitation of an observed process versus internalization of foundational principle. In first-year, math-based, engineering courses, students advance by repeating observed processes and rotating application of the engineering methods. Repetition and practice are critical habits to engrain, however rigor and complexities build when applying these skills to core principles to new areas in upper level engineering courses. Through peer-connections, students can employ both a disciplined approach and scientific intuition. This requires principled internalization and understanding. As such, peer leaders will practice devising individualize context for students who already possess practical understanding with engineering theory and integrate cooperative learning outcomes for engaging non-traditional students in peer-led small group work [3], [5]. Based on findings in the literature on PLTL, the investigative team structured the activities and small group sizes based on best practices for small group discussions and engagement of minority student groups [6], [8], [9].

Overall, 518 students participated in seven introductory engineering courses to include statics, dynamics, electric networks and principles of electrical engineering from July 2018 through December 2020. This paper offers an overview of the activities that took place during this time, the survey tools used in the courses, and the results of the surveys with a comparison between courses. The mixed-method study includes results from both qualitative and quantitative research findings to include academic performance-based tracking data and focus group interview responses.

Prior Work

The study addressed institutional concerns with low success rate and high attrition rate in introductory engineering courses with a high enrollment of non-traditional students, specifically Hispanic females. In developing the intervention activities, the investigative team considered best practices from a large body of literature on improving the retention and graduation rates of underrepresented minority students in STEM to address the following research question:

<u>Research Question.</u> Does peer-led team learning through recitation labs in engineering courses increase students' mathematics confidence, mathematics efficacy, engineering identity, and persistence in engineering pathways?

The team constructed the activities based on studies that highlighted the need for active and collaborative learning environments to engage underrepresented minorities, specifically female students, in engineering fields. These activities had high indicators for support to assist students' academic achievement and confidence related to their abilities and experiences in the classroom. Situated learning and social cognitive abilities, and self-efficacy specifically in engineering and mathematics serve as the theoretical base for E-path's conceptual framework. Self-efficacy is a component of social cognitive theory; a self-system that allows individuals to exercise control over their thoughts, feelings, motivation, and actions. Self-efficacy is an individual's belief in oneself to achieve specific results and perceived capabilities to attain specific types of performance [1], [2].

Specifically, self-efficacy judgments are task and situation-specific. One critical component identified by the investigative team was to use PLTL to improve commitments and confidence by providing students with real-world applications of engineering through recitation activities. The team found this was an important aspect of the PLTL model so that students can see the connections between theoretical coursework and careers in engineering. Similarly, the investigative team found that offering PLTL early in the engineering pathways improved student's understanding of the major, confidence in their abilities and commitment in their field of study.

Peer Leader Training and Recitation Labs

Students were introduced to additional course components through discipline-specific engineer advisors who were well-versed on the purpose of the recitation labs taught by peers that were linked to each course section. New faculty members shadowed a course with the recitation lab as part of the training. The peer leaders had to meet the eligibility criteria identified by the investigative team prior to selection and employment. The recitation leaders participated in two professional development courses and an online training on incorporating active-learning activities and project-based scenarios to enhance curriculum; learning styles, teaching techniques, working with students from diverse ethnic and cultural backgrounds, improve listening, question and study skills. The recitation leaders were also informed on the purpose of the PLTL exercises in relation to STEM and the broader goals of the NSF Improving Undergraduate STEM Education project. For example, the recitation leaders and faculty involved in the project were showed how the PLTL supported learning and education in science and builds a solid engineering foundation and curiosity for STEM and engineering through peer engagement.

Survey Tools

Quantitative survey data was collected through pre-surveys and post-surveys. The tools were designed to assess the effects on the PLTL activities on student commitment to engineering and non-cognitive factors such as confidence in class. The surveys contained a set of matched questions. On both surveys, a 5-point Likert-like scale was used. The pre-survey was given to students before the course and the post-survey was administered on the last week of the course.

Qualitative data was collected through classroom observations and focus group sessions with peer leaders and the students who participated in the labs.

Results and Analysis

An overview of the findings from the student surveys, institutional research tracking-data on retention and academic progress, and student interviews are detailed below.

Demographics of Participants

The study included 518 participants enrolled in seven introductory engineering courses.

Female student participants were 20.8% (108/518) of the overall student headcount at the beginning of the course.

Table 1: Demographics of participants in the 3 Years Pilot Study

Demographics	%
Hispanic	41.31%
Caucasian	26.06%
Asian	7.14%
African American	9.85%
Others	15.64%

<u>Trends from Surveys</u>

One of the problems identified by the investigative team was that female and underrepresented minority students do not have a network of peers and faculty as role models that they can identify with in engineering disciplines. More specifically, underrepresented minority students at the institution may have an interest in engineering lack a support network and leave STEM pathways after initial setbacks in introductory engineering and mathematics courses.

To solve some the known experiences of students, the E-path program incorporated methods of collaborative learning with upper division peer mentors who served as role models and had the formal title of recitation leaders. An analysis of survey data from collected from students in the introductory engineering courses revealed that there was a significant effect of race/ethnicity for the following items: comfort asking questions in class, collaborating with peers outside the classroom, and applying mathematical concepts. For race/ethnicity, there was a significant difference for the question relating to feeling excluded or devalued in the classroom. Gender differences were significant for comfort communicating with professors and peers. Overall, females reported less comfort communicating with their professors than males.

The pre- and post- survey responses indicated that 97% of the students who participated in the PLTL labs remained as committed or felt more committed to the engineering pathway. Additionally, 79% of the students felt that the peer-led activities helped improve their understanding of the course material covered in the traditional course.

The investigative team found that overall, most students stated they felt comfortable with asking questions in class as shown by the higher average post response compared to the pre-survey response. Furthermore, a comparison of pre-post average responses to this question shows that students' comfort about applying mathematical and physical concepts to real-world problems increased by eight after they participated in recitation labs. Most students reported a higher level of support and reported having access to tools for studying and felt comfortable using the necessary tools for studying in the post-test compared to the pre-test. They also reported they experienced faculty members who helped them make connections from the course content to real world scenarios.

Quantitative Performance Indicators

The investigative team used grades and pass rates as part of the quantitative performance indicators. The student pass rate was 62.74% (325 of the 518 students passed the courses). 58.49% of the female students passed the course (62/106) compared to 63.83% male students' pass rate (263/ 412). The following table shows the breakdown of the overall student performance:

Table 2: Overall student academic performance

Course	Student Count	Semesters	Pass rate without PLTL	Pass rate with PLTL	Difference
Statistics	380 students	SU 18, FA 18, SR 19, FA 19, SR 20	60.56% (691)	62.11% (236)	2%
Dynamics	100 students	SR 19, FA 19, SR 20	66% (212)	60% (60)	-6%
Electrical Networks	24 students	FA 19 and SR 20	59% (54)	71% (17)	11%
Electrical Engineering	14 students	SR 20	71% (62)	86% (12)	14%

As shown in the table above, the investigative team noted an overall increase in pass rates with the experimental group. Furthermore, the team noted a significant statistical difference when controlling for race and gender between the students who enrolled in the recitation labs with PLTL compared to students who only enrolled in the course without the lab. The highest pass rates were in the Hispanic male experimental group at 67%. In the students' academic performance in statics courses were particularly noteworthy due to the content of material covered and the higher percentage of students (73%) enrolled in the statics courses out of the three courses incorporated in the study.

In the statics courses, the highest pass rates were in the Hispanic male student population (79.61%) who enrolled in the labs with PLTL followed by Hispanic female students (73.58%). The next highest pass rates for the statics course were seen in the Caucasian male experimental group. The overall grade distribution pass rate was lower for students enrolled in the recitation labs in the dynamics course, however, female Hispanic students had the second highest pass rate of those who participated in the PLTL activities. Additionally, female Hispanic students had the highest pass rates in both Electrical Engineering and Electrical Networks.

Conclusion

Findings from this study are expected to advance the development of an equitable national engineering workforce that promotes the full participation of all women, specifically Hispanic women, at all levels within academia and the workforce. The findings provide insight into best practices including faculty guidance on implementing PLTL exercises within engineering courses that have potential to increase underrepresented students' commitment to the engineering pathways. The findings promote the integration of new evidenced-based practices across STEM fields through a practical and conceptual framework for current practitioners to inspire and transform new teaching initiatives. The survey results for both years show that PLTL has had a positive impact on students' commitment and attitude towards engineering major and careers.

The student participants were identified as at-risk due to the high attrition rate in the introductory engineering courses and poor mathematical preparation and placement of the majority of STEM students enrolled at the two-year college from the surrounding service areas. With the PLTL intervention, the investigative team documented positive changes in the students passing rates and satisfactory progress in completing the engineering sequence required for engineering majors.

Future Work

The investigative team expanded the activities to include two additional courses in year three of the project, however, additional research is needed to investigate the effects of PLTL in other STEM disciplines and at a new institution type serving a different student demographic. Although the study was limited to a single institution type, the use of PLTL in the introductory engineering courses showed significant change on survey results and participant feedback is overwhelmingly positive. The investigative team will continue to track participants' current major, mathematics progression, and overall academic progress during future terms and will disseminate the results for future researchers to adapt to new studies serving different student demographics.

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