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The Impact of PLTL in Four Introductory Engineering Courses: Improving Access and Opportunity for Students Underrepresented in STEM Disciplines

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Abstract

The performance assessment was a major component of the overall National Science Foundation-funded research project, Engagement in Engineering Pathways. The study examined underrepresented and female students' abilities to translate cognitive knowledge into demonstrable performance-based proficiencies through engagement in Peer-Led Team Learning (PLTL) labs in post-secondary, undergraduate introductory engineering courses. Evidence from the study comes from 518 students enrolled in four engineering courses and PLTL labs. The research protocols, implementation process, and assessment of academic achievement of project participants are discussed. Data are analyzed across student demographics to identify performance indicators within PLTL activities that influenced students' commitment and retention in engineering pathways. This study found evidence to suggest the incorporation of PLTL in introductory engineering courses had a positive effect on the academic achievement, persistence, and commitment to engineering of students historically underrepresented in engineering. Implementation and support for PLTL that incorporates active learning can promote high academic performance, increased participation in class as well as persistence and retention in engineering pathways.

Keywords: Engineering Education, STEM Education, Diversity in STEM, Collaborative Learning, Peer-Led Learning, STEM learning

Introduction

Peer-Led Team Learning (PLTL) and engagement in active learning exercises have been shown to be effective in increasing student academic performance (Loui et al., 2013) and early interest in STEM pathways (Drane et al., 2014). Since these interventional methods have largely been implemented at four-year institutions, less is known about their motivational implications in a two-year college setting with students who are historically underrepresented in STEM fields. Fewer than 30% of students enrolled in undergraduate engineering programs across the US complete them within four years and over 46% of students enrolled take six years or more to complete their programs (Yoder, 2012). Although STEM-oriented programmatic initiatives are available to support student persistence in engineering, issues with retention and persistence in STEM programs still exist and are specifically problematic in courses that require students to apply mathematical concepts to real-life situations. As a discipline, introductory STEM courses within engineering programs such as statics, dynamics, and electrical networking courses are fundamental components of degree pathways for students who are interested in pursuing a STEM or engineering degree after completing their general studies' Associate of Arts (AA) degree.

Learning strategies embedded in introductory courses offer an opportunity to reach a diverse population of students, particularly underrepresented and female students. The project is situated in an engineering context potentially to affect higher numbers of underrepresented students compared to other domains within STEM.

This paper examines findings from one campus of a multi-institution interventional pilot study sponsored through a three-year project, "Engagement in Engineering Pathways: An Initiative to Retain Non-Traditional Students in Engineering" funded by the National Science Foundation's Improving Undergraduate STEM Education (NSF IUSE) grant program. The pilot study was conducted at a two-year college, one of the several institutions piloting the intervention of Peer-Led Team Learning (PLTL), comparing the same interventions across institutional types. The authors' aim is to explore the effects of PLTL on improved academic outcomes and non-cognitive factors related to demonstrated performance-based proficiency of knowledge and persistence in engineering education. The findings support best practices for the development, implementation, and refinement of PLTL labs, and guidelines for instructors to follow to engage students fully.

Summary of Literature

It is important to note that the broader research to which this study pertains discusses active learning in relation to persistence in engineering education; however, the assessment presented here measures the impact of PLTL within the four introductory engineering courses. To address this, we rely on prior research that demonstrated that performance indicators found in these engineering courses, in general, also exist and are consistent within all of engineering as well as across STEM disciplines (Drane et al., 2014).

Female students in engineering pathways tend to have lower self-efficacy levels that often underpin the students' unwillingness to persist in STEM disciplines (Marra et al., 2009). The results indicate that although female students scored significantly higher on academic achievement measures, they reported lower levels of inclusion and sense of belonging, especially females from minority groups. This is consistent with engineering education, as was the percentage of students' final grade variance that we believe was a reflection of lower levels of self-efficacy.

According to Bandura's (1986) social cognitive theory, individuals possess a self-system that enables them to exercise a measure of comparison over their thoughts, feelings, motivation, and actions. Self-efficacy is a component of social cognitive theory. Bandura (1997) defines self-efficacy as the belief in one's capability to organize and execute the courses of action required to achieve specific results. Self-efficacy beliefs differ from other theories related to personal competence because self-efficacy focuses on an individual's perceived capabilities to achieve results and attain designated types of performance,

Specifically, self-efficacy judgments are task- and situation-specific (Bandura, 1977). Therefore, one critical component identified by the researchers was to use PLTL to improve commitments and confidence by providing students with real-world engineering applications through activities that were grounded in situated learning and social cognitive, specifically engineering and mathematics self-efficacy. The authors found this was an important aspect of the PLTL model so that students saw the connections between theoretical coursework and their future career goals in engineering.

Bumann and Younkin (2012) characterize the effects of high self-efficacy on an individual's willingness to address shortcomings by applying problem-solving strategies and by developing effectiveness in teamwork. Students with little self-efficacy may view setbacks as a lack of ability and personal flaws, while students with high self-efficacy are more likely to use interpersonal skills and shared experiences to overcome challenges (Bumann & Younkin, 2012, p.11). Characteristics related to high self-efficacy are noted in engineering students who are more likely to engage with a network of peers to address academic concerns.

Although the study is focused on engineering courses the findings can be generalized to STEM education.

PLTL strategies offer a solution to improve overall student performance and academic achievement in engineering and further support underrepresented and female students (Loui et al., 2013). The theoretical framework guiding the current study builds on educational theories and prior research studies pertaining to self-efficacy for learning and an individual's willingness to utilize academic support resources. For example, often students grabbing academic learning support opportunities can gain self-efficacy as their beliefs about accepting help may change as a result of the confidence they experience once receiving support. Improved self-efficacy has been shown to help students persist longer on tasks, set attainable goals, engage in teamwork, and respond creatively to failure (Bumann & Younkin 2012).

Therefore, the purpose of this study was to investigate inputs such as increased peer interactions and leadership opportunities that have the potential to increase self-efficacy. This current study shows that learning support interventions such as active learning strategies introduced during PLTL labs improve students' performance and build confidence, determination, and commitment to engineering pathways. Freeman et al. (2014) found that active learning increased average examination scores when compared to traditional lecturing in STEM disciplines. Furthermore, active learning strategies appeared to be most effective in small class sizes. Therefore, this study used group discussions and integrated specific learning strategies that are based on best practices from successful PLTL in STEM courses and small group learning sessions (Chan & Bauer, 2015; Hennessy & Evans, 2006). Since a student's self-perceived abilities may vary depending on their level of self-efficacy, students may impulsively misjudge their ability to perform before completing a particular skill in a small group setting.

Following a similar structure, the study examines the effects of student-centered models of engagement and facilitation techniques such as think-pair-share to measure changes in students' levels of confidence and competence in engaging in the traditional course setting. Institutional measures such as graded assignments and overall course grades were evaluated along with the students' attitudes and behaviors in class such as willingness to ask questions in class. The results were compared against students' self-efficacy perceptions using a pre-and post-course survey design.

Based on previous studies, the Peer Leaders were not expected to be content experts or surrogate instructors, but rather students who have successfully completed the courses and trained in small group facilitation (Gafney & Varma-Nelson, 2008) and active learning concepts (Blaz, 2018). The peer-led activities served as a supplement to the traditional lecture. Due to the large nontraditional and underrepresented minority student demographics, the researchers considered the findings from Rodriguez-Falcon et al. (2011) to inform the peer collaboration process specifically by employing an ethnically diverse group of engineering students as leaders. The Peer Leaders participated in eight-week, online training based on best practices in peer-led STEM learning (Drane, 2014; Lewis, 2011). The training included how to facilitate weekly small group discussions to engage diverse student groups (Gafney et al., 2008), such as underrepresented populations, in active-learning activities (Felder & Brent, 2009).

The peer-led activities were heterogeneous in makeup and were structured so both weaker and stronger students gain from the interaction in a setting that allowed for increased interaction between academic peers such as freshman or sophomore undergraduate students (Gafney et al., 2008). The environment offered students opportunities to socially negotiate and problem-solve through group learning and construct individual meaning to topics in the engineering curriculum. The development of this social learning structure helps Peer Leaders learn how to appropriately work within groups. The Peer Leaders can then help their students obtain meaning through a deeper conceptual understanding of the problems in active learning exercises.

Students were sub-divided into groups of three to read background information on a concept individually and then share their understanding of the content with their peers. Then, the team of three-five students generated a concept map of the content to present to all the students in the course. These methods of instruction have demonstrated success in helping students learning STEM principles at the undergraduate level (Ochsner & Robinson, 2017). Peer Leaders also used strategies including writing unclear concepts, finding mistakes, and sharing concept maps to assess students' pre- and post-knowledge. This was done by allowing students to write on whiteboards or use large post-it notes to discuss their steps and the conclusions they had reached.

Peer learning techniques have become a broadly used strategy to engage students in active learning across STEM education (Loui-Mark et al., 2010; Felder & Brent, 2009; Gafney & Varma-Nelson, 2008). Therefore, the model used in this study, which falls under the larger umbrella of collaborative learning, was structured so small groups of students met weekly for a minimum of one hour in a PLTL lab with an assigned Peer Leader outside of the traditional large classroom environment (Loui et al., 2013). Students engaged in best practices such as working collaboratively on complex problems that required conceptual understanding (Hennessy & Evans, 2006), and were asked to share their own ideas, practice giving explanations, listen to other students, and appreciate other students' problem-solving processes (Loui et al., 2013). The peer-led engagement required students to problem-solve more conceptually rather than simply regurgitating and memorizing course materials to pass an exam.

The PLTL activities were broken down by course assignments and represented themes common to engineering courses. The researchers prepared activities that applied mathematical concepts to real-life situations; the problems were completed through team engagement. These activities had high indicators for support by giving students access to peers who had gone through leadership training and training on how to motivate students through active learning. The additional support led to students' increased academic achievement and confidence related to their abilities and experiences in the classroom.

Methods

Participants and context. Participants (*N*=518) were undergraduate students with a STEM or engineering interest enrolled in an Associate of Arts (AA) or an Associate of Science (AS) degree program at a multi-campus, two-year college within the southwest U.S. The study included participants who primarily held a freshman and sophomore status and enrolled in four face-to-face introductory engineering courses required by engineering majors: 1) Statics, 2) Dynamics, 3) Principals of Electrical Engineering and 4) Electrical Networks.

This study is part of a broader NSF grant-supported research project that examines the effect of the use of PLTL on both cognitive and non-cognitive factors related to performance and persistence such as self-efficacy, motivation, grades, and interview responses. The data were collected from May 2018 through May 2020, for both Fall and Spring terms. Students were given surveys during class time. Quantitative survey data were collected and analyzed to determine whether there was any difference between pre-and post-responses. Pass and fail grades for students in engineering courses with and without the PLTL labs were analyzed as well as institutional data on persistence in engineering pathways. Qualitative data were collected through observations of students in the PLTL labs and focus group activities

Over the grant period, data were collected on participants enrolled in statics courses in Year One, statics and dynamics courses in Year Two, and statics, dynamics, engineering networks, and principles of electrical engineering courses in Year Three. The courses followed a face-to-face format with class time primarily reserved for lecture, and a one-hour per week PLTL lab practice session. The PLTL lab sessions consisted of active learning activities as well as academic learning support tools including online quizzes based on the textbook and lecture notes, and real-life, project-based engineering situations for longer-term team assignments.

Peer Leaders and faculty involved in the project engaged in training on how PLTL supported science learning and education and builds a solid engineering foundation and curiosity for STEM. Faculty members teaching the courses completed an *Active Teaching in Engineering Workshop* to learn how to employ the Peer Leaders and develop better comprehension and familiarity with specific active-based instructional strategies for peer-led labs, such as 3-minute review, mnemonics and analogies, and round-robin brainstorming activities (Blaz, 2018). The activities required students to work collaboratively towards a common goal to solve a problem that mirrored problems faced in the industry (Bransford, 2007).

Demographics. The majority of the students participating in the study identified with a group underrepresented in STEM and engineering, specifically Hispanic student groups. Further, female student participants represented 20.8% (108/518) of the overall student headcount enrolled at the beginning of the courses. Table 1 displays the demographics of the 518 participants in the study.

Table 1. Demographics of participants in the Three Years' Pilot Study (N=518)

Demographics	Percentage (Number)
Hispanic	41.31% (214)
Caucasian	26.06% (135)
Asian	7.14% (37)
African American	9.85% (51)
Others	15.64% (81)

As shown in Table 1, a significant number of individuals in the four courses identified as Hispanic, a group significantly underrepresented in engineering (NCSES, 2017).

<u>Data Collection</u>

Grades. The researchers 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). The female student pass rate was 58.49% (62/106) compared to the male students' pass rate 63.83% (263/412). Table 2 shows the breakdown of the overall student performance across all four courses.

Table 2. Overall student academic performance in four courses (N = 518)

Course	Semesters of implement-tation	Number of Students without PLTL Labs	Number of Students in PLTL labs	Students in Courses without PLTL Labs Pass Rate	PLTL labs Pass Rate
Statics	5 semesters: Sum18, Fall18, Sp19, Fall19, Sp 20	1141	380	Pass: 61% (691)	Pass: 62% (236)
Dynamics	3 semesters: Sp19, Fall19, Sp20	321	100	Pass: 66% (212)	Pass: 60% (60)
Electrical Networks	2 semesters: Fall19 and Sp20	24	24	Pass: 58% (14)	Pass: 71% (17)
Electrical Engineering	1 semester: Sp20	14	14	Pass: 71% (10)	Pass: 86% (12)

The researchers noted an overall increase in pass rates with the PLTL labs. Although the study included institutional measures on students engaged in all four courses across the three-year grant period, the researchers found the findings from the statics course of particular interest due to the content of material covered and the higher percentage of students (73%) enrolled. The results of the grade distribution per course from Fall 2014 to Spring 2020 provided insight into overall performance after participating in PLTL labs. The highest pass rates in the statics courses were seen in the Hispanic male students in the PLTL lab students at 79.61% followed by Hispanic female students at 73.58%. The next highest pass rates for the statics course were seen in the Caucasian male in the PLTL group. Although the overall grade distribution pass rate was lower for those enrolled in the PLTL labs in the dynamics course, female Hispanic students had the second highest pass rate of those who participated in PLTL. Additionally, female Hispanic students had the highest pass rates in both electrical engineering and electrical networks courses.

Commitment to Engineering Pathways. One of the project goals was to increase commitment to engineering pathways. A student's academic major was used to evaluate commitment level after participating in the PLTL labs. The data collected represents students enrolled in the statics courses and PLTL labs that were primarily the first course taken prior to dynamics, electrical engineering, and electrical networking courses. The researchers were not able to obtain institutional transfer data on all participants in the PLTL labs; however, the data were collected on the students whose information was reported to the National Student Clearing House.

Out of the students who enrolled in and successfully passed the statics course, 88% (208 of the 264) of the students in the PLTL labs remained in an engineering pathway at the institution and/or declared an engineering major upon transfer to a four-year institution. Ten percent (10%) (23 out of 264) left engineering but remained in a STEM pathway. Additionally, data were collected on students who took dynamics and electrical networks but did not enroll in statics for an academic reason such as transfer credit was awarded from a previous institution. Out of these students, 84% (71 of 85) of the students who took dynamics stayed in engineering and 12% (10 of 85) left engineering but remained in a STEM pathway. All of the students (18 of 18; 100%) who took electrical networks remained in engineering. The totals represent the student headcount and not the registrations per course since some students enrolled in each sequential course and not all students enrolled in statics.

Pre- and Post-Course Survey Results. Students were given a pre-and a post-survey. The survey included a Likert-like assessment to gauge motivation and commitment to engineering pathways as well as demographic information. Several demographic and background data points were collected through the instrument to compare the effect of the use of PLTL among different sub-groups. These demographics and background data points included gender, age, race, grade level, major, and current GPA. The survey was administered before and after the course to gauge the change that occurred as a result of participation in the PLTL labs. The questions were used to determine a student's commitment to engineering pathways and levels of self-efficacy as stated in the theoretical framework guiding the study. Table 3 shows the survey results from students in the PLTL labs from Summer 2018, Fall 2018 and Spring 2019. The number of students was reduced from 390 (pre-survey questions) to 295 (post-survey questions) due to attrition over the duration of the courses.

Table 3. Pre/Post Survey Results (Summer 2018, Fall 2018 and Spring 2019 Semesters)

Questions	Number of students	Percentage
Pre-Survey Q1: How committed are you in getting an engineering degree and achieving career goals?	390	
Yes, Great Extent	300	76.92%
Yes, Moderate Extent	85	21.79%
Yes, Small Extent	5	1.28%
No	0	0.00%
Post-Survey Q1: As a result of this class, do you feel more committed to getting an engineering degree and achieving career goals?	295	
More than before	148	50.17%
Same as before	139	47.12%
Worse than before	8	2.71%
Pre-Survey Q2: Do you agree that the mandatory labs will improve your understanding?	390	
Strongly Agree	115	29.49%
Agree	140	35.90%
Neither	108	27.69%
Disagree	21	5.38%
Strongly Disagree	6	1.54%
Post-Survey Q2: Do you agree that the activities in the mandatory labs helped to improve your understanding?	295	
Strongly Agree	105	35.59%
Agree	129	43.73%
Neither	31	10.51%
Disagree	18	6.10%
Strongly Disagree	12	4.07%
Pre-Survey Q3: Do you feel comfortable in applying mathematical and physical concepts to real-world problems?	390	
Very Comfortable	103	26.41%
Comfortable	210	53.85%
Neither	63	16.15%
Uncomfortable	12	3.08%
Very Uncomfortable	2	0.63%

Questions	Number of students	Percentage
Post-Survey Q3: Do you feel comfortable in applying mathematical and physical concepts to real-world problems?	295	
Very Comfortable	103	34.92%
Comfortable	157	53.22%
Neither	32	10.85%
Uncomfortable	3	1.02%
Very Uncomfortable	0	0%
Pre-Survey Q4: Do you feel that you need to improve your analytical and critical thinking skills?	390	
Yes, Great Extent	93	23.85%
Yes, Moderate Extent	184	47.18%
Yes, Small Extent	93	23.85%
No	20	5.13%

Based on the responses to Question 1, in the post-survey 97% of the students who participated in the PLTL labs remained as committed or felt more committed to the engineering pathway. Based on the responses to Question 2, in the post-survey 79% of the students felt that the activities helped improve their understanding of the material covered in the traditional course.

Results

Prior to participation in the PLTL labs, less than 80% of the students were comfortable applying mathematical and physical concepts to real-world problems. The percentage increased by 8% as shown in the post-survey responses. As a result of participation in the activities, 86% of the students felt that their analytical and critical thinking skills had improved by a great or moderate extent.

In addition to the pre-and post-survey, students were provided a mid-term survey that measured the extent to which the activities helped improve class performance. Over 80% of the students surveyed agreed that the activities helped improve their class performance. Additional information was collected on average student responses. The female students' average response was higher. This could indicate those female students were more comfortable or comfortable in applying mathematical and physical concepts to real-world problems compared to their male counterparts.

In October 2019, seven (7) students who participated in PLTL labs completed an experiences questionnaire that allowed students to report current experiences and experiences they wished to have more of in the engineering program as well as STEM programs in general. Although the sample size that completed the questionnaire is small, the results offer a reflection of participants' experiences, and which experiences the students felt were most important. The five most often reported experiences were: (a) feel comfortable using the tools needed for studies; (b) staff/faculty members making connections between course content and the real-world (i.e., community); (c) access to the tools needed for studies; (d) learned steps necessary for safety in the class or in labs; (e) learned ways to make a difference through a career in STEM. Almost all of these items showed a positive increase in the students who participated in the PLTL labs compared to the students who did not. Most students indicated they experienced using hands-on equipment and technology and have worked in pairs or small groups to discuss information and ideas. The students wished they had activities that encourage 'risk-taking' or that allow them to be more creative; opportunities to talk about their own STEM work; and opportunities to reflect on a problem and discuss the problem with a partner using the active-based learning strategy think-pair-share.

As a result of the participation in the PLTL sessions, post-survey Response 3 shows 80% of the students were comfortable applying mathematical and physical concepts to real-world problems and 96% of the students felt that their analytical and critical thinking skills had improved. The average post-survey response to the question asking whether students felt comfortable applying mathematical and physical concepts to real-world problems showed females had the highest averages. Their responses indicated that they felt nearly 'very comfortable' applying mathematical and physical concepts to real-world problems. This finding suggests that females who have a greater network to peers have higher levels of commitment to engineering pathways and confidence in their ability to apply the course material to their future career fields.

High self-efficacy relates to resolution, confidence, persistence, and in this study, increased academic performance. One of the limitations of the study was obtaining an accurate number of the students who remained in engineering pathways. For example, the number of students in engineering pathways may have increased with better institutional data on the students in PLTL labs who transferred between departments or data on the students who did not matriculate at the same pace as other students in the PLTL labs. However, overall, the majority of students who participated in the study remained committed to engineering as shown in their choice of major.

In addition to desiring an increased connection to peers and individuals that they identify with in engineering, the students reported that they wished for more experiences with hands-on instruction to learn STEM. The participants in the study also appreciated opportunities with faculty and peers to make connections between course content and the real world. The increased levels of self-efficacy, academic success and commitment to engineering can also be contributed to the experiences that the participants reported such as learning ways to make a difference through a career in STEM and the ability to work in pairs or small groups to discuss information or ideas.

These PLTL experiences have demonstrated success and are strategies that other instructors can use in engineering courses. The Peer Leaders were provided with professional development to incorporate active learning strategies into the PLTL labs. These active learning strategies included small collaborative groups, inquiry and questionning techniques, and demonstration of problem-solving strategies. The Peer Leaders incorporated other active learning strategies to increase students' confidence and decrease their nervousness (or anxiety). The researchers found that these strategies improved students' performance on both content-based exams and overall course grades.

Although significant differences exist between the pre-and post-test scores, we acknowledge that the number and opinion of students may vary in the different types of engineering courses completed before the surveys. However, the findings provide evidence that the PLTL labs significantly improve the scores of the majority of the students enrolled. Additionally, many of the subgroups historically considered at-risk for persistence in engineering demonstrate greater gains than those sub-groups historically overrepresented in engineering, specifically white males.

The analysis of quantitative survey data from students in the four courses revealed that there was an effect of race/ethnicity for 1) comfort asking questions in class, 2) collaborating with peers outside the classroom, and 3) applying mathematical concepts. Gender differences were significant for comfort in communicating with professors and peers and applying mathematical and physical concepts to real-world problems. Overall, females reported less comfort communicating with their professors than males.

Discussion and Conclusion

The study was designed to address barriers to underrepresented minority students' persistence and retention in engineering. The researchers noted that based on findings in the literature female and underrepresented students are more likely to persist if they have higher levels of self-efficacy for learning and a network of peers and faculty as role models that they can identify with in engineering disciplines (Stewart et al., 2007). Within this study, female and underrepresented minority students who were characterized as at-risk for leaving engineering pathways had collectively higher self-efficacy for learning than other students. Based on the study findings and results, it appears that academic performance of the students in the engineering courses who participated in the PLTL labs had greater performance than the comparison group. This finding supports Streitwieser and Light's (2010) findings that show peers who facilitated small group work with other peers had a higher success rate and increased academic performance.

The Peer Leaders were provided with professional development to facilitate active learning strategies and increase the engagement of diverse student groups. The leaders incorporated several learning strategies into the labs as best practices for teaching and learning (Prince & Felder, 2007). These strategies included small collaborative groups, inquiry and questionning techniques, and problem-solving strategies. The findings from this study show that while the students did benefit from engagement in PLTL as a means for improving student performance, we acknowledge that the Peer Leaders leading the labs are not a homogenous group, each having unique undergraduate experiences. This can impact the Peer Leader's ability to share relevant experiences and adequately facilitate meaningful discussions around the engineering concepts being explored.

Although this study did not examine the influence of PLTL on individual test scores, its influence in engineering courses may increase underrepresented and female students' critical thinking and problem-solving skills, especially if PLTL is coupled with activities related to real-world situations. This study found evidence to suggest the incorporation of PLTL had a profound effect on the students historically underrepresented in engineering. Although the results vary in strength, this study found support for all forms of PLTL that incorporated the active learning exercises.

Other challenges to traditional assumptions about engineering education are noteworthy such as whether or not the students will be more likely to be engaged in the lecture when they participate in PLTL labs. Contrary to the prevalent content-driven engineering course structures, the study supports the call for collaborative and cooperative learning environments compared to individual work to promote high performance as well as persistence and retention in engineering pathways.

The authors also noted and hypothesized that when underrepresented and non-traditional female students failed to connect to their peers, they miss opportunities for peer-facilitated studying and discussion of course material outside of the classroom. The literature supports this observation revealing that underrepresented students who are not established in a STEM community developed through PLTL have little incentive to continue in engineering once they start to experience difficulties in engineering courses like statics and dynamics. This evidence suggests that students, specifically underrepresented minority groups and non-traditional female students in engineering, will benefit from participation in PLTL through a non-traditional model to promote academic achievement and influence students' identity as aspiring engineers.

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