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Integrating Peer-Led-Team Learning (PLTL) and Design Thinking to improve student success in Engineering Statics

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Session XXXX

Integrating Peer-Led-Team Learning (PLTL) and Design Thinking to Improve Student Success in Engineering Statics

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Abstract

This paper presents the integration of Peer-led-Team Learning (PLTL) and design thinking (DT) to improve student success in Engineering Statics, which is a gatekeeping class for mechanical and aerospace engineering (MAE) students. The MAE department at the University of Texas Arlington (UTA) offers multiple sections of Engineering Statics each semester with an average passing rate of around 70% in the past several years. In spring 2024, UTA Division of Student Success introduced PLTL to this course with a professor from the MAE department serving as the faculty liaison. The main task of the faculty liaison was to develop the weekly PLTL packages, which typically consist of a set of problems that the peer leaders (PLs) would guide the students to solve. In developing the weekly PLTL package, the faculty liaison intentionally incorporated a six-step problem-solving process following the DT pedagogy. The goal is to help students following the DT process in defining the problem and developing creative solutions. 30.5% of students enrolled in the course signed up for the PLTL sessions. A 19.3% increase in the passing rate was achieved for the students who participated in PLTL as compared to those who did not.

Introduction

Engineering Statics is a fundamental course for Mechanical, Aerospace, and Civil Engineering. It covers the fundamental concept of forces, moments, reactions, equilibrium, free-body diagram, etc. To successfully pass this course, the students need to have a strong grasp of mathematic concepts, such as trigonometry, vectors, etc., and the ability to apply these concepts to solve complex engineering problems. As such, Engineering Statics has long been a gatekeeping course that stops a sizable portion of students from advancing their engineering studies. The MAE department at UTA offers multiple sections of Engineering Statics each semester. The average enrollment in the past eleven semesters was around 150 students and the average passing rate was about 70%. The MAE department had made multiple changes to improve the passing rate of this course, including introducing a one-hour problem solving course to prepare students for Engineering Statics[1]. This intervention led to modest increase in the passing rate of Engineering Statics in the first semester, but a study on the long-term effect of this intervention has not been conducted.

PLTL is a pedagogical approach that emerged in the 1990s as an active learning approach to enhance student learning, especially in science, technology, engineering, and mathematics (STEM). Research have shown that PLTL improves student performance, retention, and commitment to engineering[2,3]. Contrary to traditional lecture-centric pedagogy, PLTL incorporates small-group sessions facilitated by peer leaders (PLs). These PLs are selected from students who have successfully completed the course with a grade B or above. They receive comprehensive training on active learning strategies, communication, leadership, etc., prior to leading PLTL sessions. The PLTL sessions are typically offered as a supplement to regular classroom teaching. Students voluntarily sign up for the PLTL sessions, but they are required to meet certain attendance threshold to remain in the program. The PLTL sessions focus on collaborative problem-solving and active learning strategies that help students engage deeply with the material and their peers. A faculty liaison develops a weekly PLTL package containing problems for students to solve during the PLTL sessions. He/she meets with the PLs weekly but does not attend the PLTL sessions. Even though the faculty liaison plays a crucial role in ensuring the success and effectiveness of the PLTL program, there is no training for the faculty liaisons. As such, the development of the PLTL packages relies solely on the faculty liaison's experience and knowledge of active learning strategies. Following a pedagogic framework could help the faculty liaison create packages that are more structured and more engaging to maximize the benefits of PLTL for all participants.

Design thinking (DT), as a pedagogical framework, offers a structured approach for creative problem-solving. Evolving from the practice of design, DT has been generalized as a human-centric problem-solving process consisting of five elements, i.e., emphasize, define, ideate, prototype, and test[4]. In education, researchers are exploring this mindset for curriculum design[5–7] and classroom interventions[7–10], with a goal to teach students how to think like a designer[5,11,12]. It was found that "intentional implementation, including organization and framing of design thinking pedagogy, was an essential foundation for fostering student interest."[10] While it is intuitive to implement DT in design focused courses, implementing the DT pedagogy in fundamental engineering courses like Engineering Statics remains to be explored.

This paper presents the integration of PLTL and DT to improve students' understanding of Engineering Statics concepts and the application of these concepts to solve complex problems. A modified DT process is first introduced, and its implementation is explained using an Engineering Statics problem as an example. The first semester implementation of this strategy led to a 19.3% increase in the passing rate for students who participated in the PLTL program, as compared to those who did not. A few observations from the faculty liaison on the benefits of this strategy are discussed.

Course Description

Engineering Statics is a critical gatekeeping courses that MAE students at UTA must receive a C or above grade to pass. Each spring and fall semester, multiple sections of Engineering Statics were offered. These sections have different instructors, but the lectures are held at the same time and the students take the same exam. The average enrollment per semester is about 150 with a passing rate of around 70%. In the past four long semesters, 35.3% of students taking Engineering Statics from the MAE department at UTA are identified as Latinos, the largest demographic group of this course.

PLTL Implementation

Overview

UTA's Office of Academic Student Success launched PLTL for Precalculus in Fall 2020. The results showed PLTL had a positive impact on pass rates for at-risk populations[13]. In spring 2024, UTA expanded PLTL to Engineering Statics. An experienced instructor who has taught Engineering Statics for many years volunteered as the faculty liaison. Two PLs were recruited to lead the PLTL sessions. 32 students signed up for the PLTL sessions, accounting for 30.5% of the total enrollments. The students met 80 minutes per week outside of regular class time and worked in groups of 8-10 to solve problems related to concepts taught in lectures. A total of 342 PLTL sessions was delivered.

Design Thinking Pedagogy

Convention DT process consists of five stages, namely empathize, define, ideate, prototype, and test. To tailor it for engineering problem solving, this convention framework is modified into a process consisting of six steps. The application of this six-step DT process to solve Engineering Statics problems is described in Table 1.

Table 1. Modified Design Thinking Process for Solving Engineering Statics Problems

Steps	Application to Engineering Statics problems
1. Identify goal & constraints	Visualize and rephrase the problem to gain a deeper understanding. Write done what needs to be solved and what are given.
2.Research principles & concepts	Identify relevant concepts, including the concepts covered in lectures & those learnt from previous courses, especially from math courses.
3. Visualize solutions, results & evaluation plan	Discuss the solution steps, alternative approaches, expected results, and evaluation plan. Using flow diagram, sketches, etc. are strongly encouraged. Reflect on the plan before proceed (break point #1).
4. Solve the problem	Follow the planned solution steps. Do not skip steps!
5. Evaluate the results	Follow the evaluation plan. Discuss the results with others (breakpoint #2). Re-visit the goal and constraints if necessary
6. Report methods & results	Write down detailed step-by-step solution following the homework format. Reflect on the insights gained from the problem-solving process.

To emphasize the iterative nature of the modified DT process, these six steps are arranged in a circle shown in Figure 1. It starts with identifying the goal and constraint of the problem and ends with reporting the methods and results. The PLTL activities emphasize the first three steps, namely identifying the problem, researching the concepts, and planning the solutions. The goal is to deepen students' understanding of fundamental concepts and stimulate their creativity in finding alternative ways to obtain the solutions. Typically, students are divided into two groups to work through the first three steps independently. The PL will then review the work of these two groups and lead the discussion to clarify concepts and/or explore different approaches. The students can only proceed to solve the problem after the plan has been reviewed and approved by the PL.

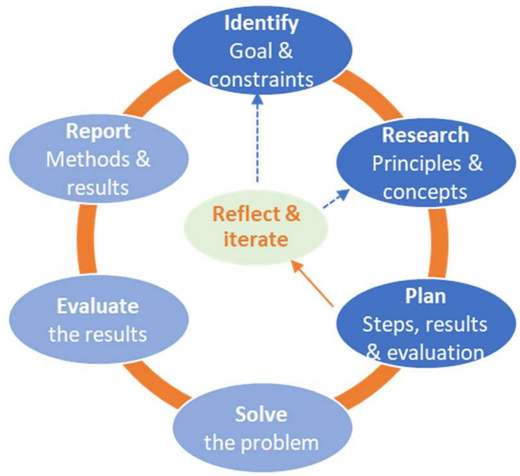

Figure 1. A Modified Design Thinking Process Tailored for Solving Engineering Statics Problem

Apply Design Thinking to Solve Engineering Statics Problems

To demonstrate the application of the six-step DT process for solving Engineering Statics problems, an example problem is shown in Figure 2. The problem is given as the following: "the component of a force ***F*** in the x-y plane is 100 lb, and the orientation of the force is shown in Figure 2. Find the magnitude and the direction angles of force ***F***." If the students were given the problem without any instructions, they would be most likely to solve the x, y, z components of force ***F*** first and then calculate the magnitude and the direction angles from these components, as taught in the textbook and in the lecture. The students probably would not give much deep thought about the problem or about how to verify the results they obtained. To help the students understand the problem and the concepts

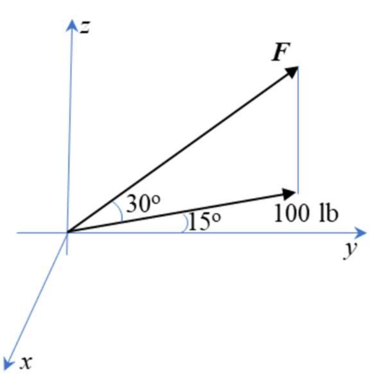

Figure 2. An Engineering Statics Example Problem for Demonstrating the Design Thinking Problem Solving Process

more deeply, the PLTL problem set provides a detailed instruction on the first three steps of the DT process. The first step, i.e., "identifying goal & constraints", starts with visualizing the problem. To help the students with this task, instructions for a paper folding exercise are given as the following.

1. Draw ***F*** and the 100 lb force on a piece of paper. Fold the paper into a triangle formed by the three lines shown in the figure.
2. Draw the x-y plane and the 100 lb force on another piece of paper. Lay the paper on the table.
3. Assemble the triangle from step 1 and the x-y plane from step 2 to demonstrate the force vector ***F*** in 3D space.

This exercise not only helps the students construct the force vector in 3D space but also helps them learn the process of breaking a complicated 3D problem into two simpler 2D problems. After visualizing the problem, the students are instructed to rephrase the problem using technical language and symbols, such as "the projection of force ***F*** on the x-y plan is ***F***'. The angle between ***F*** and ***F***' is $\phi = 30^{o}$. ***F***' lies in the second quadrant of the *x-y* plan and has an amplitude of 100 lb. The angle between ***F***' and the positive *y* axis is $\theta = 15^{o}$. Determine the magnitude and direction angles of ***F***". They can then move on to the second step of the DT process, which is to identify the Engineering Statics and Mathematics concepts that are needed to solve this problem. The third step, i.e., "visualizing solutions, results & evaluation plan", encourages the students to find different ways of solving the problem, even if it is just partially. For the problem given in Figure 2, the magnitude of force ***F*** can be found without knowing the *x* and *y* components of the force first, i.e., it can be solved directly from the 100 lb force and the 30^{o} angle using the triangle in the 1st step of the paper folding exercise. Moreover, the direction angle between force ***F*** and *z*-axis can be quickly found to be 60^{o}. The students can solve the problem using the conventional procedure taught in the lecture and validate their results with these two variables. Working through step #3 encourages the students to look for creative ways to solve the problem in different ways, making the exercise much more interesting and engaging.

Results and Observations

In Spring 2024, 69.6% of students who did not participate in the PLTL program passed Engineering Statics. In comparison, 88.9% of the 32 students who participated in the PLTL program passed the course. This 19.3% increase in the passing rate means PLTL helped 7 students who would otherwise fail the course advance to the next phase of their study. This preliminary result highlighted the benefit of integrating DT with PLTL for Engineering Statics.

In addition to the passing rate improvement, the faculty liaison observed a few additional benefits that have yet to be quantified. First, the students who participated in PLTL demonstrated problem-solving capability that is beyond what was taught in lectures. The PLTL problems are typically more complex than the homework problems assigned by the instructor. Moreover, the instructors used to spend one lecture teaching how to apply the concept of friction to solve wedge problems. In spring 2024, the instructors were not able to cover wedge problems because of time constraints. However, the students did not have any difficulty in solving a wedge problem at the PLTL session, even though it was not covered in lecture. Secondly, the DT process encouraged the PLs to “think out of the box”. There were numerous “aha” moments at the faculty liaison meetings, in which the PLs saw hidden connections between concepts that they were not aware of before. This led to a feeling of excitement and satisfaction. Thirdly, the faculty liaison learned a lot from the PLs about the students’ ways of thinking and the learning challenges students face. Better understanding of students’ capabilities and needs could lead to more effective teaching. Most importantly, the DT process made engineering problem-solving a fun experience for all participants, including the students, the PLs, and the faculty liaison.

Summary and Conclusions

This paper presents the integration of PLTL and DT to improve student success in Engineering Statics. A modified DT process was introduced and implemented in PLTL sessions to deepen the students’ engagement with the material and to stimulate their creativity. A 19.3% increase in the passing rate was demonstrated. Other benefits, including enabling students to solve more complex problems, catalyzing “aha” moments for the PLs, and enhancing the faculty liaison’s understanding of students’ capabilities and needs, were observed but not quantified. Overall, the PLTL experience contributed to a supportive, engaging, and fun environment for all participants.

References

1. Ewing DJ, Davidson P. Creating a first-year course to prepare Mechanical and Aerospace Engineering students for the path ahead. In: ASEE Gulf Southwest Annual Conference. ; 2022.
2. Luthi KT, Kar M, Macon L. The Impact of PLTL in four introductory engineering courses: improving access and opportunity for students underrepresented in STEM disciplines. Advances in Peer Led Learning. Published online December 19, 2022:55-71. doi:10.54935/apll2022-01-05-55
3. Guden JM, Bellen JA. A scoping review of the peer-led team learning to learner-participants and peer leaders in STEM courses. International Journal of Research Studies in Education. 2020;9(5). doi:10.5861/ijrse.2020.5008
4. Brown T. Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation. Harper Business; 2009.
5. Fila ND, Mckilligan S, Guerin K. Design Thinking in engineering course design. In: 2018 ASEE Annual Conference & Exposition. ; 2018.
6. Wrigley C, Straker K. Design Thinking pedagogy: the educational design ladder. Innovations in Education and Teaching International. 2017;54(4):374-385. doi:10.1080/14703297.2015.1108214
7. Lock J, Scott D. The future of Design Thinking in education: Challenges and possibilities. In: Teacher as Designer Design Thinking for Educational Change. Springer Singapore; 2021:151-153. doi:10.1007/978-981-15-9789-3_11
8. Welsh AA, Dehler GE. Combining critical reflection and Design Thinking to develop integrative learners. Journal of Management Education. 2013;37(6):771-802. doi:10.1177/1052562912470107
9. Deng MY. How to develop engineering students as design thinkers: A systematic review of Design Thinking implementations in Engineering Education. In: 2023 ASEE Annual Conference and Exposition. ; 2023:38923.
10. Rodriguez SL, Doran EE, Friedensen RE, Martinez-Podolsky E, Hengesteg PS. Inclusion & marginalization: How perceptions of design thinking pedagogy influence computer, electrical, and software engineering identity. International Journal of Education in Mathematics, Science and Technology. 2020;8(4). www.ijemst.com
11. Henriksen D, Richardson C, Mehta R. Design Thinking: A creative approach to educational problems of practice. Think Skills Creat. 2017;26:140-153. doi:10.1016/j.tsc.2017.10.001
12. Rauth I, Köppen E, Jobst B, Meinel C. Design Thinking: An educational model towards creative confidence. In: Proceedings of the 1st International Conference on Design. ; 2010.

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