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Impact of Project-Based Assignments on Students' Learning Experience in Inclusive Courses

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Impact of Project Based Assignments on Students' Learning Experience in Inclusive Courses

Abstract

Project-based assignments help students enhance their learning experience and promote the application of engineering concepts to solve real-world problems. This paper discusses the implementation of three different project-based assignments in three different upper-level undergraduate civil engineering courses at the University of Connecticut. All these three courses, viz., Mechanics of Materials, Soil Mechanics, and Principles of Construction-I had large enrollments (n >75). These courses were offered as a part of the inclusive approach taken by the Civil and Environmental Engineering department. The students were allowed to make a choice regarding the mode of the final project deliverable – a written report, a PowerPoint presentation, or an oral video presentation. It enabled them to personalize their learning based on their unique strengths and challenges.

In Mechanics of Materials, the students were divided into two sections. The students in one section (the experimental group) completed the individual projects in which they had the choice to create a physical model or analyze an object from their areas of interest by using mechanics concepts. The students in the other section (the control group) were not assigned this project. A post-assessment test was administered in both sections. The purpose of this assessment was to investigate if the students in the experimental group benefited from completing the project.

In Soil Mechanics, the term group project was used to assess the students' ability to apply the knowledge gained from the first seven of the eight course modules to solve a real-life problem. The CATME tool - developed and licensed by Purdue University, was used to form teams based on different criteria such as GPA, preferred schedule, software skills, writing skills, leadership preferences, commitment level, and big-picture/detail-oriented thought process. The project had three phases. In the last phase, the groups had the option to submit the final deliverable in the form of a written report or an oral video presentation.

In Principles of Construction I, students were instructed to explore their creative strength in addition to their analytical skill in an optional strengths-based group project. They were allowed to choose their group members and assignment submission method. The project provided students opportunities to apply all major components of their learning throughout the semester. Students were provided with support from the instructor and the teaching assistants. Lastly, as part of the inclusive approach, they could choose an optional comprehensive final exam instead of the group project.

In each of these courses, the students were invited to participate in an anonymous survey to share their feedback. In this paper, the survey results will be discussed to demonstrate if these projects enhanced the students' learning experience as well as their overall learning outcomes.

Introduction and Background

Project-Based Learning (PBL) is a learner-centered pedagogical approach used to engage students in authentic projects [1]. In PBL, students work collaboratively or individually to accomplish the project tasks that require content knowledge and skills and produce a product to show their knowledge of the content [2]. The assignments in PBL require students to acquire and apply information, concepts, and principles and they have the potential to improve students' competence in thinking (learning and metacognition) [3]. Moreover, working on real-world projects helps students realize the impact of those projects, which in turn, gives them a sense of agency and purpose [4]. Although PBL benefits all types of learners, it helps particularly the neurodivergent ones, who struggle with traditional lectures/assignments.

To promote inclusive teaching best practices, the majority of the required courses in the undergraduate Civil and Environmental Engineering curriculum at the University of Connecticut were redesigned. The redesign effort was part of a project *Leveraging Neurodiversity for Engineering Innovation* sponsored by the National Science Foundation (NSF). Meaningful inclusion of neurodivergent students in engineering curriculum requires educators to move beyond a focus on accommodations and accessibility and embrace a strengths-based approach toward neurodiversity [5]. While teachers value engagement as a critical component of working with students, the strengths-based approach provides an easy roadmap that allows the students to promote the things that they are good at [6]. Despite the potential of neurodiverse individuals to contribute to innovation in science and engineering, neurodiverse students, such as those with attention deficit hyperactivity disorder (ADHD), autism, or dyslexia, remain highly underrepresented in engineering majors [7]. A study by Syharat et al. found that incorporating flexible scheduling, participants' interests, and choice into the program are key components of a successful program to support neurodivergent students [8]. The Universal Design for Learning (UDL) principles provide valuable guidance for course design in meeting the needs of the growing number of neurodiverse students in college classrooms [9-12] .The UDL standards are adequate to design courses to make them accessible to all learners. However, to cater to the needs of neurodivergent learners, additional standards are necessary to ensure that students can identify and use their unique strengths in an engineering context [6].

A set of inclusive teaching standards (I-standards) was developed collaboratively within the department, incorporating principles from the UDL framework, best practices for inclusive teaching from the literature, and the strengths-based approach on neurodiversity during the summer of 2020 and revised in the summer of 2021 [6]. To meet the I-standards, multiple means of engagement, representation, and action/expression were included throughout the course design, particularly in the individual and group project assignments [13]. These strengths-based project assignments were geared to cultivate students' ability to apply course materials to real world problems, foster collaboration among students, and provided opportunities to explore their creativity and strength.

This paper discusses the implementation of PBL along with the lessons learned in three such redesigned courses viz., Mechanics of Materials, Principles of Construction I, and Soil Mechanics. These courses had a common goal of engaging the students in authentic projects.

Course Descriptions and PBL Implementation

All three redesigned courses are upper-level courses in Civil Engineering with large enrollments ($n > 75$) and offer 3 credits. Although the purpose of the redesigned courses was to help students personalize their learning [13], it was not feasible for the instructors to tailor the assignments based on the strength of each student in these large courses. Instead, students were encouraged to reflect on their strengths and challenges and make choices based on their own understanding of their strengths. The individual course descriptions are provided below.

Mechanics of Materials (CE 3110): CE 3110 is a sophomore/junior-level class required for several engineering majors such as Civil, Mechanical, Biomedical, Material Science, and Manufacturing Engineering. The course has a typical enrollment of 100 students per section with a total of 400 students per academic year.

In this course, students learn about various methods of calculating the stresses and strains in structural members, such as beams, columns, and shafts. It is offered in a “flipped” modality. Each lecture is presented with a pair of videos - a lecture video that presents the concept and formulations followed by a sample solving video where 2 or 3 problems are solved in a step-by-step format. Each lecture is 50-minutes long and the class meets three times per week. The class activities include a short lecture by the instructor at the beginning discussing the topics of the day and relevant real-world examples followed by a problem-solving session by the students.

The Strengths-Based Project (SBP) was created as part of an effort to make the course more inclusive and promote a sense of belonging. SBPs prompted students to identify one or more areas of interest such as photography, filming, sports, game design, woodworking, cooking, planting, yoga, animals, or music instruments [14]. After the students identified their areas of interest, they were required to submit a draft of their project to indicate the topic and the relevant mechanics concepts that they would study. The instructor then reviewed the draft submissions and provided feedback within a few days. Thereafter, the students had two weeks to complete and submit their final projects. The instructor was available during this period to provide further instructions or correct misconceptions about the projects. Students were given another opportunity to address any errors or add missing information after they had received the feedback on their final project. They had the choice to present their project as a written report, poster, short video, PowerPoint Slides, or any other preferred format. The SBPs carried 15% of the final grade for the course.

Principles of Construction I (CE 3220): CE 3220 is an introductory course in construction engineering and management. It is a required course for students from Civil and a few other related engineering majors and Construction Engineering and Management minor. This course is taken by mostly juniors and seniors at undergraduate level. The total enrollment was 88 students in Fall 2022. The purpose of this course is to provide a basic understanding of the principles of construction, including construction process and procedures, contracts and delivery methods, scheduling, cost estimation, project control, project change management, dispute resolution, and safety management.

The content of this course was divided into three modules and students were expected to meet ten objectives after taking this course. The detailed learning outcomes from each module were described and a course map was created to verify them. Various types of assignments such as homework, class discussions, etc. and assessments such as quizzes, exams, and a group project were designed with weights from 5% to 15% of the total grade. Students were provided options either to take a comprehensive final exam or participate in the group project.

A strengths-based group project was assigned in the course curriculum to provide multiple means of engagement, representation, and action/expression as outlined in the Universal Design for Learning approach. The project was based on the construction of multiple Solar Trees on the university campus. It provided students with the opportunity to apply the major components of their learning throughout the semester. A rubric was provided to guide them with the project work. 64 students out of a total of 88 students decided to participate in the group project, while the remaining 24 students took the Final exam. Students were allowed to choose their group members for the project - each group consisted of 3 or 4 students. Most of the groups had students with diverse backgrounds.

Students were encouraged to explore their creative strengths in addition to their analytical skill for this strengths-based project. They were also allowed to choose the submission format of their project deliverable - either a written report, a PDF presentation, or a video presentation. A sign-up sheet with several timeslots was provided to students for visiting the construction of the Solar Tree and getting information related to the project. Students were also provided support from the instructor and the teaching assistants, if needed.

Soil Mechanics (CE 3510): CE 3510 is a lecture-based course and covers fundamentals of soil behavior with a focus on the effective stress principle, compaction, consolidation, and shear strength. It is taken primarily by juniors and seniors in Civil Engineering as their major requirement. Some Environmental Engineering students also take this course as an elective. The enrollment in the Fall 2022 semester was 80.

The content of this course was divided into eight learning modules and the students were expected to achieve seven course-level learning objectives by the end of the semester. Several low-stakes (ranging from 1.5% to 20% of the overall grade) assignments and assessments were administered throughout the semester to assess those learning objectives. The assignments included one homework assignment for each module and a term group project. The assessments included one online quiz for each module and three exams. The course also had a cumulative but optional final exam, which the students could take to replace the lowest exam grade and a participation grade. The redesign process of this course is delineated elsewhere [13].

The term group project was a part of the PBL implementation in the course and was spread throughout the semester. It was designed to assess the students' ability to apply the knowledge gained in the first seven of the eight course modules. The CATME [15] tool - developed and licensed by Purdue University, was used to form teams based on different criteria such as GPA, preferred schedule, software skills, writing skills, leadership preferences, commitment level, and big-picture/detail-oriented thought process. The overall goal of the project was to determine the differential settlement between the North side and the South side of the Tower of Pisa using some simplified assumptions appropriate for the class level. The groups were required to present their findings in the form of a) a written report or b) an oral video presentation. This flexibility built into the term project assignment allowed the groups to choose their preferred mode to best express their learning based on their unique strengths and challenges

Results and Discussions

Students in these three courses were invited to participate in an anonymous survey after completing their projects to share their feedback about different aspects of PBL practices implemented. The same survey was administered for all three courses. Approximately 91% (75 out of 83) of the invited students in CE 3110, 33% (21 out of 64) in CE 3220, and 37% (29 out of 80) in CE 3510 responded to the surveys.

Students responded to a series of questions to reflect on their learning experience such as if the projects enabled them to use their strengths/talents, enhanced the skill of applying their knowledge to real life examples, and if they used their creativity. It was investigated if the timeline, the instructions, and the feedback system were appropriate for the projects. Finally, a question on the accessibility and approachability of the instructors and teaching assistants was asked. The results of the surveys are described below.

Figure 1 shows that a majority of the respondents (69% in CE 3110, 81% in CE 3220, and 93% in CE 3510) agreed or strongly agreed that they were more confident applying the course materials to real-life situations.

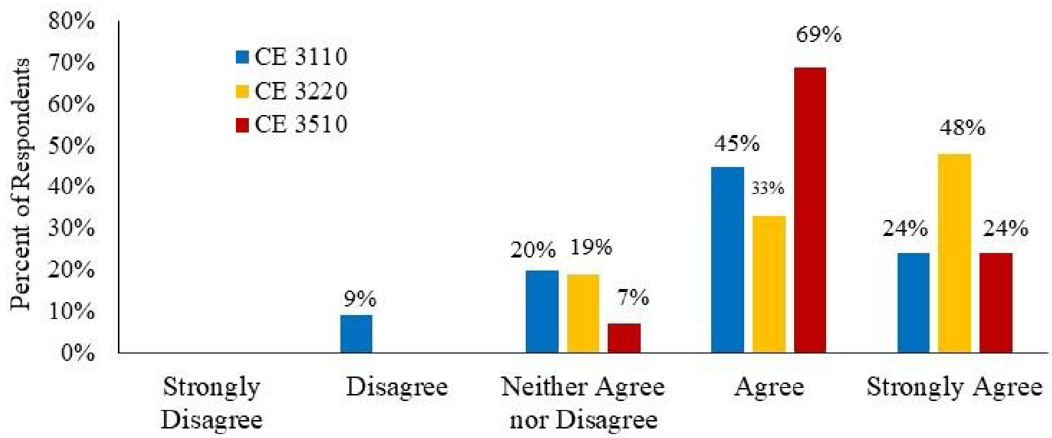

Figure 1. Students' feedback on application of course materials to real-life situations

Similarly, Figure 2 indicates that a majority of the respondents (79% in CE 3110, 91% in CE 3220, and 79% in CE 3510) agreed or strongly agreed that completing the project assignment helped them learn the course ideas and develop appropriate skills.

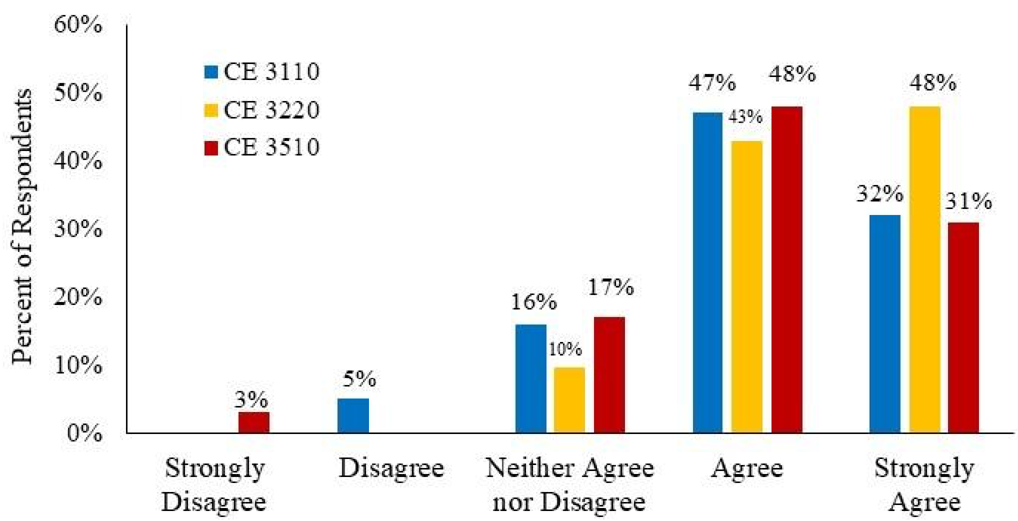

Figure 2. Students' feedback on enhancement of the skill development

Providing feedback is critical to students' learning and is an essential component of the PBL strategy [16]. It helps all students in general and the neurodivergent ones in particular, improve their understanding of the subject matter. In all three courses, the instructors provided multiple opportunities and methods (office hours, discussion before and after class, emails) for students to reach out and seek help or receive feedback on their work. Table 1 shows the students' response rate on the effectiveness of the feedback they received as well as the adequacy of the timeline and instructions in completing their projects.

It is evident from Table 1 that the majority of the respondents (87% in CE 3110, 94% in CE 3220, and 86% in CE 3510) agreed or strongly agreed that they received timely feedback from their instructor and teaching assistants (TA). 89%, 87%, and 96% of the respondents in CE 3110, CE 3220, and CE 3510, respectively also agreed or strongly agreed that the feedback they received from their instructor/TAs was helpful in completing their assignments. Table 1 further shows that the majority of the respondents (85% in CE 3110, 72% in CE 3220, and 76% in CE 3510) agreed or strongly agreed that the instructions/directions provided for their projects were adequate. The majority of the respondents (84% in CE 3110, 90% in CE 3220, and 90% in CE 3510) also found that the timeline for completing their assignment was reasonable.

Table 1: Students' evaluation of the project timeline, instructions, and effective feedback

Students Feedback	Courses	Strongly Disagree (%)	Disagree (%)	Neither Agree nor Disagree (%)	Agree (%)	Strongly Agree (%)
The feedback I received from my instructor/TAs on this assignment was timely.	CE 3110	0	4	9	43	44
	CE 3220*	0	7	0	27	67
	CE 3510**	5	10	0	48	38
The feedback I received from my instructor/TAs was helpful in completing the assignment.	CE 3110	0	1	9	49	40
	CE 3220*	7	0	7	40	47
	CE 3510**	0	5	0	67	29
I was provided with sufficient information/directions to complete this assignment	CE 3110	0	4	11	41	44
	CE 3220	0	0	28	24	48
	CE 3510	0	3	21	55	21
The timeline for completing this assignment was reasonable.	CE 3110	1	1	13	43	41
	CE 3220	0	5	5	33	57
	CE 3510	0	7	3	59	31

*For this survey question: n = 15/64, since all the students did not require feedback or assistance.
**For this survey question: n = 21/80, since all of the survey respondents did not ask for feedback or assistance.

In two other survey questions, students were asked to reflect on the use of their strengths and talents as well as creativity in completing the projects. More than 70% of the survey participants in each course (74% in CE 3110, 76% in CE 3220, and 83% in CE 3510) strongly agreed or agreed that the projects allowed them to use their strengths and talents (Figure 3). This data indicates that incorporating inclusive teaching standards and strengths-based teaching approaches in offering the projects for all three classes were satisfactory.

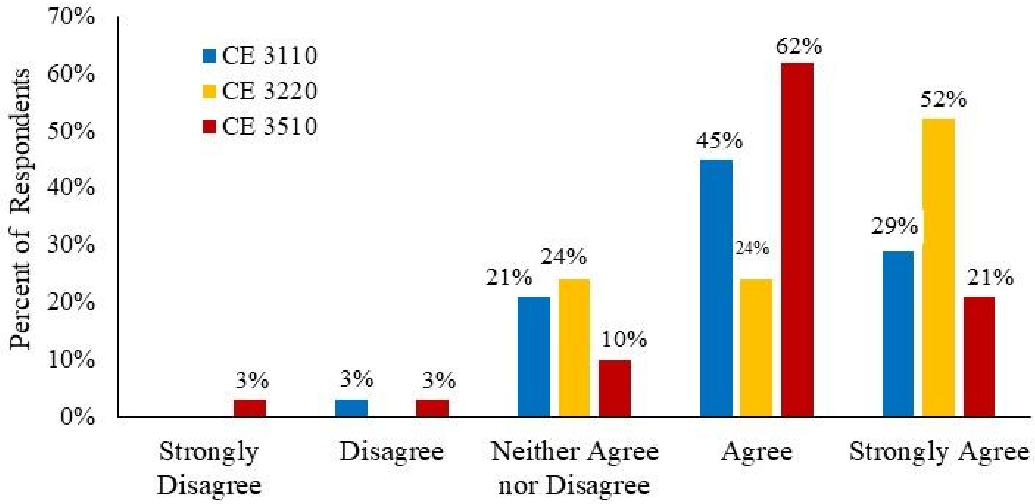

Figure 3. Students' feedback on use of their strengths/talents in the projects

Figure 4 shows that more than 80% of the respondents in CE 3110 and CE 3220 expressed their agreement with the statement that the project allowed them to use their creativity. In both of these courses, students were provided with alternative choices for their projects, which were less predefined and less structured. However, in CE 3510, only 31% of the respondents agreed that the project allowed them to use their creativity. In the future deliveries of the course, the project could be made less structured in order for the students to use their creativity in solving the project problem.

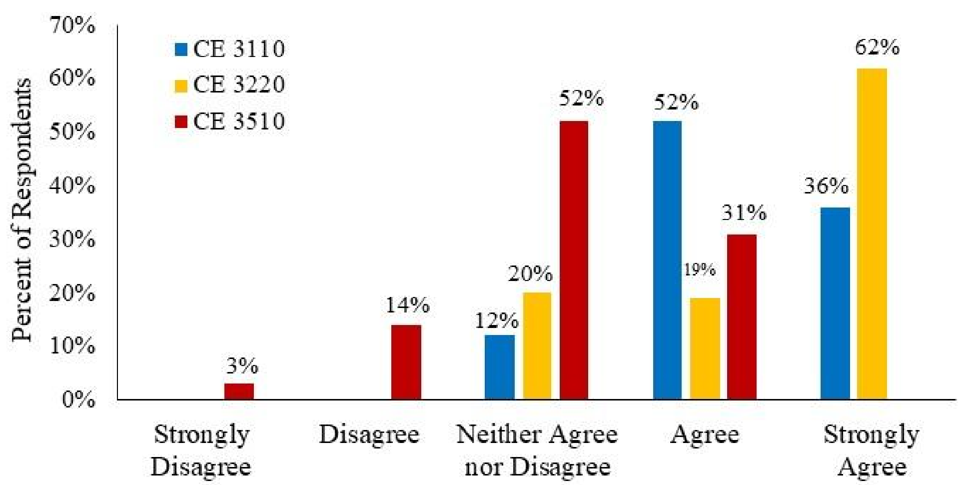

Figure 4. Students' feedback on use of their creativity in the projects

To assess if the students had access to the instructors and the teaching assistants, they were asked to share if they felt comfortable reaching out to the instructors when they needed help with their projects. Figure 5 displays that the majority of the respondents (80% in CE 3110, 93% in CE 3220, and 89% in CE 3510) agreed or strongly agreed that the instructors as well as the teaching assistants were approachable and that they felt comfortable asking questions about the projects. It is noteworthy that all instructors for these three courses underwent a comprehensive training program on UDL as part of a larger departmental effort to provide more inclusive courses.

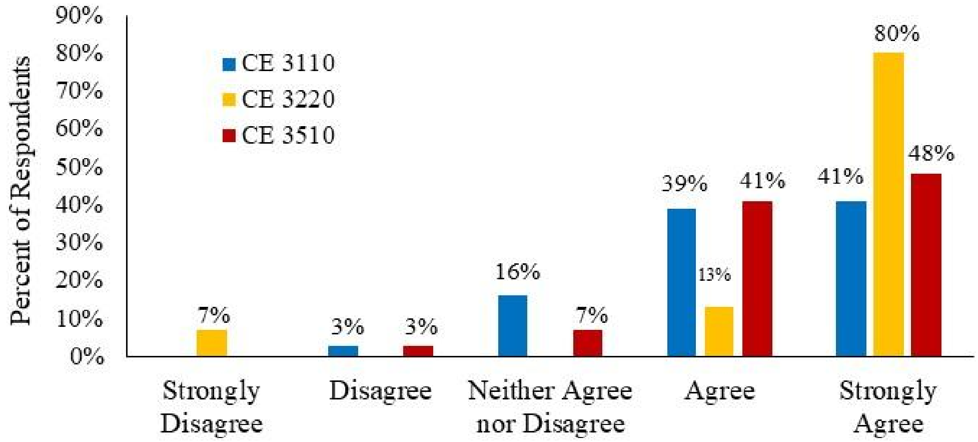

Figure 5. Accessibility and approachability of the instructors and teaching assistants

In addition to the surveys administered in all three courses, a post-assessment test was conducted in CE 3110. The goal was to understand if completing the SBPs improved the students' learning outcomes and enabled them to apply mechanics concepts to other real-world examples. As part of this test, two sections of the course were divided into two groups: an experimental group and a control group. Both the experimental and control groups were subjected to an identical teaching method, instructor, and course materials. Students in the experimental group completed the SBPs, whereas the control group students did not do the SBPs. The experimental group had the advantage of clarifying their misconception, if any, with the instructor upon completion of the Strengths-Based project. This project allowed for more interaction with the instructor via feedback on proposed drafts and one-on-one support during office hours or through email. To study the effectiveness of the SBPs, students from both the groups were asked to solve two problems drawn from a playground (Figures 6(a) and 6(b)) and their scores were compared.

(a) (b)

Figure 6. A real-life example in the post-assessment test in CE 3110

In the first problem, students were asked to identify the types of stresses and strains and then calculate their values when the rod in Figure 6(a) is under both an axial load and a twisting moment. In the second problem, they were tasked to design the chain for the swing and the pin connecting the chain to the frame in Figure. 6(b). The results from the post-assessment test are outlined in Table 2 and Table 3.

Table 2 shows that the experimental group outperformed the control group in identifying the types of stresses and strains and calculating those values for problem 1. Approximately 75% of the students in the experimental group were able to identify the types of stresses and strains correctly. In the control group, only an average of 58% of the students were able to perform the same task correctly. An average of 50% of the experimental group students calculated the stress and strain values correctly but only 30% of the students in the control group handled this problem correctly. Majority of students in both groups were able to solve the problems partially.

Table 2. Students' performance for problem 1

	Experimental group			**Control Group**		
	Not able (%)	**Partially (%)**	**Correctly (%)**	**Not able (%)**	**Partially (%)**	**Correctly (%)**
Recognizing types of stresses	1	21	78	4	31	68
Calculating stresses	3	49	49	13	54	33
Recognizing types of strains	5	29	65	4	48	48
Calculating strain	5	40	55	8	63	29

For problem 2, both experimental and control groups performed similarly in applying the factor of safety and distributing the weight of the kid between two swing chains (Table 3). Most of the students in both groups (84%) applied the factor of safety correctly but only an average of 48% in each group distributed the load equally between the swing chains.

Table 3. Students' performance in problem 2

	Experimental Group		Control Group	
	Wrong (%)	Correct (%)	Wrong (%)	Correct (%)
Applying factor of safety	15	85	17	83
Distributing the load between chains	51	49	54	46

Table. 4 shows the performance of students for problem 2 when they were asked to select the diameter of the chain and the diameter of the pin for a given material strength. Over 75% of students from both control and experimental groups were able to solve problems partially or correctly. Nevertheless, the proportion of students who solved the problem correctly was significantly higher in the experimental group. 40% of the students in the experimental group designed the chain correctly. However, only 25% of the students in the control group had a flawless design. It is likely due to the additional interaction with the instructor and the opportunity to compete for the projects.

Table 4. Students' performance in problem 2-design of chain and pin

	Experimental group			Control Group		
	Not able (%)	partially (%)	Correctly (%)	Not able (%)	partially (%)	Correctly (%)
Design of chain	9	51	40	12	62	25
Design of pin	19	58	23	25	59	16

Students' Comments

In addition to taking the surveys, students were encouraged to provide suggestions or comments regarding the projects. This section highlights some of the relevant comments.

Students in **CE 3110** shared their comments in the Student Evaluation of Teaching (SET) survey about their experience of completing the strengths-based projects.

"It caused me to better learn and understand the material. it allowed me to make sure I knew what was actually going on in the class."

"I enjoyed the SBP and the freedom to explore a topic that was interesting. Something that I think could help in the future would be giving a little more time between when the draft is due and when the final project is due."

"I enjoyed the creative track of the SBP the most because we were allowed to use our creativity and practice our skills on something that interested us personally. "

"The strength-based project was my favorite part of the whole course. I loved that we had options to build, analyze, or get creative with our ideas. Also making a connection from the course material to the real world makes it seem like there's a reason for all of the math and analysis."

In **CE 3220**, students expressed the benefits and level of satisfaction they experienced by completing the final project:

"The SB project was very helpful to understand the material better and it felt more of a hands-on part of the class. It also was very efficient since we do not have to take the final exam Saturday. I also got to understand my peer's perspective on different aspects of the project and

we all got to combine our ideas and finish the project. I have no complaints about the project. We had enough time to complete it, we got to go see the Tree and take measurements ourselves. The project was complex but not hard which is great for the level we are in now."

Some of the constructive comments in CE 3220 were as follows:

"I believe that giving more time to see the solar tree and ask questions would help a lot in the future."

"I feel that we should create groups based only on people who 100% want to do the project instead of the exam. That way people don't decide they don't want to do the project towards the end of the semester."

The following comments/constructive feedback were shared by the students in **CE 3510** regarding the group term project.

"The projects and discussions we had helped meet some of my peers and hear their opinions on things. Gave me different perspectives on things we discussed."

"I like the term project as is. I don't think it should be changed."

"I think the project was a great idea. I would have preferred choosing my own teammates but I still had a good team and I think we did a good job. The last two parts came up suddenly, however I understand since we just learned the consolidation part."

"The term project was very reasonable part 2 seemed a little bit tricky but after some review it was able to be completed."

"I think somehow there needs to be better accountability for all team members completing a fair share of the project regardless of knowledge of the course material or necessary applications to complete it. I'm not sure how to incorporate this. Certainly, the peer review helps, but at that point the work has already been done."

Conclusions

A Project-Based Learning (PBL) strategy was developed and implemented in three upper-level Civil Engineering courses (viz. Mechanics of Materials, Principles of Construction I, and Soil Mechanics) at the University of Connecticut with a common goal to engage students in authentic projects. These courses were offered as a part of the inclusive approach taken by the Civil and Environmental Engineering department.

The purpose of this paper is to investigate whether those projects enhanced the students' learning experience as well as their overall learning outcomes. The PBL approach was found to be effective in enhancing students' learning experiences. The majority of the respondents from all three courses agreed or strongly agreed that the projects helped them become more confident in applying the course materials to real-life situations. Students were highly satisfied with the implementation of PBL. Most of the respondents (over 75%) in all three courses agreed or strongly agreed that the timeline, initial instructions, and the support during the project have been adequate. Additionally, more than 75% of the survey participants in each course confirmed that the project allowed them to use their strengths and talents. The majority of the students in the courses with flexible structure for the projects (CE 3110 and CE 3220), felt they had used their creativity compared to the respondents from the course where the project had more determined outcomes (CE 3510).

The results of the post-assessment test in CE 3110 revealed that completing the strengths-based projects, coupled with additional instructor interaction, could improve students' performance by enhancing their skill of applying mechanics concepts to other real-life examples. In that test, most of the students in both groups were able to complete the assessment partially. However, more students from the experimental group (who completed the SBP project) were able to solve the problems correctly compared to the control group.

Overall, the results of the surveys indicate a significant impact on students' learning experience when PBL is implemented with an inclusive mindset.

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