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Problem-Based Learning: Perceptions and Impact on Student Learning in a Sustainable Infrastructure Course

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Work in Progress: Problem-Based Learning: Perceptions and Impact on Student Learning in a Sustainable Infrastructure Course

Abstract

The purpose of this study is to investigate the impact of problem-based learning on students' critical thinking and communication skills within the context of a Sustainable Infrastructure course. The course is a liberal studies class offered by an instructor from the College of Engineering. Students enrolled in the course are from a range of engineering and non-engineering majors across the university. The mix of majors is suitable for the interdisciplinary teamwork often found in real-world problem solving, thus giving students experience in critical thinking and communication with technical and non-technical peers. Students worked in teams of three and four to solve ill-defined problems presented by the instructor. Topics covered Construction Waste, Energy Efficiency in Buildings, Recycling Education, Public Transportation, and Campus Transit. Deliverables, including a technical report, an oral presentation, and an analytical reflection, were used as data for this project. Students were surveyed to assess their perceptions of problem-based learning. There were seventy-two participants over three semesters. One preliminary result from both the survey and qualitative data is that students felt confident about working with others from different disciplines. Students mostly commented positively about their communication as a multidisciplinary team in their reflections. Also, the question "I can work well with others from different disciplines" received the highest number of "strongly agree" responses. Concerning students' assessment data, the results show that students' actual performance and their perceptions about problem-based learning were somewhat aligned. However, their overall perceptions were more positive than actual performance. In terms of knowledge gained, students reported that they were more aware of infrastructure problems and were more confident in their approach to contributing to solutions to ill-defined problems.

Introduction and Background

Problem-based learning (PBL) is well-established as an active learning, student-centered strategy and is categorized as "learning by doing" [1]. The approach uses ill-structured problems to reflect realistic scenarios that students encounter when they become professionals, rather than textbook-type problems with known solutions. Gallagher et al. [2] defined the role of the teacher as a facilitator and students as self-directed learners in this approach. The concept hinges on learning occurring within small groups; and the given problems as the tool to enhance skills in problem solving. The given problem is intended to stimulate self-directed learning [2]. Overall, the aims of problem-based learning include collaborative and interdisciplinary problem solving, critical thinking, active learning, and motivation for learning [1], [3].

Though often interchanged in engineering and engineering technology, problem-based and project-based learning are different. According to Lee [4], the focus of problem-based learning is the problem solving and learning process, while the project outcome is the focus of project-based learning. Since project-based learning is commonly seen in senior students' capstone design courses, problem-based learning can be used as a prelude to project-based learning in prior courses. In this way, students can develop the skills necessary to apply to project-based learning activities.

Gijbels et al. [5] state that assessments for problem-based learning can include collaborative teamwork assessment, exams, reports, and self and peer assessment. Several factors play a role in the impacts of PBL that are reported. Some examples include the study design, scope of implementation, student year of study, and method of assessment. The goal of this study is to assess the impact of problem-based learning on students' critical thinking skills and their perception of this learning strategy on their critical thinking skills in a Sustainable Infrastructure course.

Methods

Qualitative and quantitative data collection methods were used to carry out this study. Data was collected for students' perceptions and problem-based learning impacts. There were 77 students from a range of majors across the university over the three semesters of this study. 52% of students were from the College of Engineering with majors including Mechanical, Civil, Systems, Electrical, and Computer Engineering, Engineering Technology, and Construction Management. Some non-College of Engineering students' majors included Elementary Education, Communication Studies, English, Psychology, Sociology, Biology, Finance, Pre-Business, Architecture, Health Systems, and Kinesiology.

Table 1 shows the aggregate numbers of Engineering and non-Engineering students. In Fall 2018, the course description was not posted when the course schedule was released, possibly due to an administrative error. The absence of course details may account for why less than half the students were from the College of Engineering, unlike Spring 2019 and Fall 2019. Not all students were aware of the problem-based learning technique used in the course until they attended the class, as this was not included in the course description during the class sign up period, but in the syllabus. This teaching method was used as the primary pedagogy only in the second half of the semester.

Table 1: Number of students with College of Engineering majors versus non-College of Engineering majors per semester of study

Semester	College of Engineering	Non-College of Engineering
Fall 2018	6	10
Spring 2019	13	13
Fall 2019	21	14

Problem-Based Learning impacts: Students worked in teams of 3-4 to solve ill-defined problems given by the instructor. The problems were ill-defined such that they allowed flexibility for students to develop objectives and approaches to the given situation. Students were constantly reminded that there was not a single solution to their problem. Some topics included Construction Waste, Recycling Education, Campus Transit, Greenway Expansion, Building

Energy Efficiency, Runoff from Campus, Trash in Streams, and Commuting Air Quality Impacts. Short problem statements were developed by professionals who work in the City of Charlotte, on-campus professionals, and by the instructor. One example of a problem statement submitted by a city Civil Engineer on the topic Trash in Streams, was "All our streams seem to have lots of tires, and all the debris jams collect lots of bottles. How can the city do a better job keeping tires and plastic bottles out of streams? How could what currently exists be removed?"

The teams were interdisciplinary to mirror the reality of problem-solving in professional settings. For instance, there were students in both engineering and non-engineering majors in each group based on the majors represented in the class. Students were allowed to choose their own groups but had to adhere to the requirement of having a mix of engineering and non-engineering majors in their groups. Deliverables, including a technical report, an oral presentation, and an analytical reflection, were used as data for this project.

Student perceptions: Students were given a survey to assess their perceptions of PBL. The survey contained Likert-scale questions that assessed students' perceptions of their ability to clearly define a problem for systematic inquiry, gather valid evidence for analysis, and come to logical conclusions. Students were also asked about their ability to organize and articulate ideas. The students were expected to write a reflection on the assignment, which was included as qualitative data. The 5-point response scale was from strongly disagree (1) to strongly agree (5).

Results and Discussion

In this section, the results focus on student perceptions. The problem-based learning impacts on critical thinking and communication have been collected and will be analyzed in a continued study. Preliminary analysis of the learning impacts shows that students' actual performance in critical thinking and communication versus their perceptions about problem-based learning were somewhat aligned. However, their overall perceptions about their performance were more positive than actual performance.

Fifty-nine students completed the survey about their perception of problem-based learning. Some descriptive statistics, including the mean, median, standard deviation, and variance of the resulting data, are shown in Table 2. One prominent result from both the survey and qualitative data is that students felt confident about working with others from different disciplines. Students mostly commented positively about their communication as a multidisciplinary team in their reflections. In the first half of the semester, students worked in different groups to complete in-class assignments in preparation for working with a diverse team for the PBL assignment. That may have contributed to those positive responses. Also, the question "I can work well with others from different disciplines" received the highest number of "strongly agree" responses.

Table 2: Descriptive statistics of students' perception of their performance on their problem-based learning assignment

Statement	**Mean**	**Median**	**Standard Deviation**
I can clearly define a problem	4.31	4.00	0.75
I can develop approaches to solving problems	4.37	4.00	0.64
I can gather relevant information for analysis	4.24	4.00	0.73
I can analyze information	4.31	4.00	0.75
I can develop logical conclusions	4.29	4.00	0.64
I can organize and articulate ideas	4.34	4.00	0.69
I can solve problems in sustainability	4.19	4.00	0.75
I can work with others from different disciplines	4.51	5.00	0.63

Conclusion

The inclusion of a problem-based module in the course allowed students to undergo the process of solving ill-defined problems. Because of this work, the course structure is currently being improved to align better the learning objectives, instructional strategies, and assessments for sustainable infrastructure topics. Subsequent problem-based learning activities are being revised and improved.

Acknowledgments

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