AC 2011-564: THE EFFECT OF PROJECT-BASED LEARNING (PBL) ON IMPROVING STUDENT LEARNING OUTCOMES IN TRANSPORTATION ENGINEERING

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The Effect of Project-Based Learning (PBL) on Improving Student Learning Outcomes in Transportation Engineering

ABSTRACT

This paper discusses the results of an ongoing study on the effect of project-based learning (PBL) on students' learning outcomes in Transportation Engineering, a required junior level course in the Civil Engineering curriculum. The course was taught in 2008, 2009, and 2010 by the same instructor. The course was transformed from a lecture-based course to a project-based course, integrating a semester-long project as a stimulus for students' learning. To evaluate and compare students' learning between the lecture-based and project-based teaching approaches, the LITEE survey instrument (http://www.litee.org/site) was used. The survey instrument includes five constructs to measure five different aspects of students learning: higher-order cognitive skills, self-efficacy, ease of learning subject matter, teamwork, and communication skills. The survey on pre-assessment and post-assessment of student learning outcomes was conducted to determine the effectiveness of the project-based approach on enhancing students' learning outcomes. The results show that the use of the project-based approach significantly improved students' ease of learning the subject matter. Project based learning could be used as an effective teaching and learning strategy by educators to facilitate students' learning.

Keywords: Project-Based Learning, Self-Efficacy, Cognitive Skills, Teamwork

1. Introduction

Industry demand for professional engineers with multidisciplinary skills calls for teaching methodologies which can incorporate hands-on skills throughout the course materials. The idea of studying engineering to make a difference in the world often is an important factor motivating high school students, especially among women and minorities, to major in Science, Technology, Engineering and Mathematics (STEM).[1] Providing students with real-life projects and challenges related to their majors can therefore be instrumental in fostering and maintaining their interest in STEM. Being exposed to real projects and brainstorming society's current challenges provide students with a broader perspective related to the social-environment aspect of the application of the basic concepts they learn.[1]

Currently, most institutions use a pedagogical philosophy of creating a bookend curriculum that implements project-based courses at the beginning and end of the undergraduate engineering curriculum. First-year engineering courses introduce students to the basic design process and its role in an engineering career. Senior capstone courses aim to connect technical knowledge to solve a problem with an emphasis on professional skills.[2] However, in such cases it is not clear if the technical skills gained are well developed and retained when problem-based learning classes are only utilized in the freshman and senior years.[2]

2. Literature Review

Project-Based Learning (PBL) methodology has been integrated into course curricula by several scholars in order to improve student learning and motivation toward the subject matter[3-5]. It has been shown that PBL is a much more effective education methodology compared to traditional pedagogies to promote a collaborative learning environment that can in turn enhance students' social and problem-solving skills.[4] It also has been well documented that not only can PBL methodology foster teamwork in the classroom, but also, in some cases, use of PBL resulted in enhancement of students' confidence and employment rate.[3] Heo *et al*. (2010) further studied the effect of the quality of online interaction during project-based learning (PBL) on both the micro and macro levels.[6] They documented that team members in active teams not only shared information but also identified the areas of disagreement and clarified the goals and strategies. They also conducted some negotiations, which in turn affected their learning outcomes.[6] Lanning et al. used PBL in undergraduate aerospace and mechanical engineering courses to teach structural and materials failure mechanisms through a team-taught approach.[7] Wang's experience with the PBL method showed that university students working in teams on projects can adopt one of three major learning patterns: individual-led, group-led, or individual-group hybrid-led.[8] It was found that a group-led framework can create a supportive environment to enhance knowledge building.[8] Chen et al. effectively incorporated PBL in teaching renewable energy courses to engineering technology students; PBL helped students understand the basic concepts of various types of renewable energy while applying the concepts in design.[9] Echempati and Dippery found PBL a promising method to teach a mechanical engineering design course.[10] It has been well documented that most students who were exposed to the PBL methodology found it an exciting and rewarding approach, and they were able to produce original and innovative concepts (Tsai et al., 2010).[11] Melin et al. (2010) showed incorporation of the PBL method into course material can help students achieve a higher level of development in the cognitive domain.[12] Assuming many Civil Engineering graduating seniors will deploy to Afghanistan soon after they complete their undergraduate education, and considering the fact that to be successful, students need to know both the theory and the application of engineering concepts, Melin and his coworkers assigned students real construction projects that are ongoing in Afghanistan and found it to be an effective way of enhancing students' understanding of theoretical concepts.[12] It has been shown that combining theory with practical projects can enhance students' learning and their satisfaction of a course.[13] Participation of undergraduate students in hands-on projects has been found to be significantly effective in encouraging students to pursue advanced degrees and careers in science, technology, engineering, and mathematics fields (STEM) [14].

Research is an important component of project based learning. There have been many studies on the effects of undergraduate research experience on engineering students' learning and self-efficacy. [16] Undergraduate research has been shown to increase undergraduate student retention; this was found to be even more significant for underrepresented groups.[17] Undergraduate research has also been shown to be an effective tool to motivate students to pursue a graduate degree in engineering.[17-19] In addition, it has been shown by several researchers that hands-on research increases understanding, confidence, and awareness. [20-25] In addition, significant emphasis has been placed on enhancing students' decision-making skills and higher-level cognitive skills to improve their performance in the real-world work environment. [26] As such many educators have strived to provide students with the education necessary to become qualified managers. [26] Students benefit from working on real-world problems that require the synthesis of skills that they have acquired and refined during their studies. [27]

3. Course Conduct

Transportation Engineering is a required Civil Engineering undergraduate course. A semester-long project was carried out to teach various concepts of highway and pavement design. LTPP

Datapave Online (www.LTPP-Products.com) was used as the e-learning platform to provide the course materials, the wiki resource, and data for the project.[15] In addition, each team was asked to conduct research regarding factors affecting the ride quality of the roads. Each team reviewed five journal articles in addition to course materials to decide which design parameters need to be included in the model. Incorporating research into PBL methodology led to a more interactive class while students practiced working with related databases and online journals. Since the students were able to decide which parameters to include in their models, students on each team were more enthusiastic about building and comparing their model with those of other teams. It has been documented that enthusiasm is the key to encourage students toward STEM, and that greater attention should be given to providing undergraduate research opportunities for undergraduate students.[24-25]

To implement the PBL methodology in the aforementioned course, emphasis has been placed on developing project planning skills, building models, analyzing data, technical writing, classroom presentations, and, in three cases, presentations at an undergraduate research symposium. Analyzing students' responses from the pre-survey and post-survey proved the methodology was successful in improving the ease of learning the subject matter. In addition, all students who were involved in PBL methodology passed the course; the overall grade point average and median was higher than that for the control class that did not use PBL methodology. The course was taught by the same instructor in the fall of 2008, 2009, and 2010. The 2009 class was used as the control class and was compared with the 2010 class. The class in 2008 was not used in the analysis and comparison due to a relatively lower enrollment and the presence of eight senior level students in the class. The 2009 and 2010 class had similar enrollments and all students were junior level.

To evaluate the effect of incorporating PBL methodology on students' learning outcomes, questionnaires from the Laboratory for Innovative Technology and Engineering Education (LITEE, www.litee.org) developed through NSF grant #0442531, were administered before and after students were exposed to PBL methodology.

As part of the semester-long project, The Long-Term Pavement Performance (LTPP) database (www.LTPP-Products.com)[15] was presented to students to be used as the e-learning platform. LTPP is a twenty-year study of highway pavements. The Long-Term Pavement Performance program was initiated as part of the Strategic Highway Research Program (SHRP) in 1987 and is monitored by the Federal Highway Administration (FHWA). As part of the program, 2,500 asphalt and Portland cement concrete pavement test sections are monitored and tested through many experiments. The initial objective was to study why some pavements perform better than the others (LTPP Datapave Online, 2010) [15]. As part of the program, data related to parameters affecting pavement performance is collected. These data include International Roughness Index (IRI), pavement thickness, annual and monthly precipitation, equivalent single-axle loads (ESALs), materials test data, maintenance data, rehabilitation data, and traffic data. Pavement monitoring data are collected through pavement experimental sections and stored in the LTPP database. The LTPP data are housed in an Information Management System (IMS) that is the world's largest pavement performance database.

To incorporate PBL methodology, students were first taught how to use the LTPP database to extract required data. Data was used to establish a relationship between ride quality and various highway pavements' design parameters, including pavement type (concrete, asphalt), surface thickness, subgrade soil properties, traffic, temperature, and annual precipitation. The

International Roughness Index (IRI) was introduced as a measure of ride quality. Students used the LTPP database to extract data for building a regression model to study how ride quality (as reflected in IRI) is affected by various design parameters and the significance of each parameter. Each team extracted data for one specific state for both concrete and asphalt pavement (GPS 6 and 7 from LTPP were used, respectively). A total of ten states with different environmental conditions were analyzed by ten teams of three students (each enrolled in the Transportation Engineering course (CIEN350)).

The course blocks were arranged to cover ride quality and its measurement methods followed by each pavement design parameter. The course materials were covered through five blocks: introduction to transportation modes, highway elements, pavement performance evaluation, pavement design concepts and affecting parameters, pavement management and distresses.

Through working with the database and building a regression model, students learned various design factors affecting ride quality. Each team developed two regression models, one for concrete pavement and one for asphalt pavement, both located in the same state. Each team was asked to conduct research regarding factors affecting ride quality of the roads. Students decided which design parameters to include in their models based on reviewing five journal articles and course materials. They learned how to use SPSS software to build their regression model, how to evaluate the significance of each parameter, and the overall model significance. Acquiring a basic knowledge on the roles various parameters play in determining overall pavement performance, students built a platform to further learn how to measure and calculate each design parameter, including traffic, layer thickness, and climate. They further learned how different types of pavement (concrete and asphalt) vary in performance as well as design criteria.

4. Research Hypotheses

This section begins with the background that motivated an interdisciplinary program to solve real-world problems. The fundamental goal is to enhance students learning outcomes by placing them in the role of highway design engineers to develop performance prediction models and predict ride quality of the roads using real data and design parameters. To achieve this goal, Project-based learning using the LTPP data base was selected to be incorporated into the Transportation Engineering course (CIEN350). To test if students' learning outcomes were improved, the following hypotheses were developed:

H_1: Using PBL will significantly improve students' higher-order cognitive domain of learning.
H_2: Using PBL will significantly improve students' ease of learning the subject matter.
H_3: Using PBL will significantly improve students' self-efficacy.
H_4: Using PBL will significantly improve students' teamwork.
H_5: Using PBL will significantly improve students' communication skills.

5. Methodology

Two questionnaires were used to evaluate students' feedback on the PBL method. Each evaluation consisted of 23 bipolar descriptors (items). The students were asked to evaluate the effectiveness of the case study on a 5-point Likert scale (1 indicating an extremely negative rating and 5 an extremely positive rating). Since there were a total of 23 questionnaire items, items were mapped to the constructs based on information provided by LITEE at Auburn University (http://www.litee.org/site). The questionnaire included items to measure the five constructs of *higher order cognitive skills improvement, self-efficacy improvement, ease of learning subject matter, teamwork improvement, and communication skills improvement* (Table 1).

The students completed the questionnaires, included their comments and submitted them along with their projects. Statistical analysis was conducted using SPSS.[28] After mapping the 23 items to the five constructs, Cronbach Alpha was computed for each construct. Cronbach Alpha ranges from 0 to 1 and a value close to 1 indicates that the items coalesced together well enough to represent the construct. Cronbach Alpha's were computed for each construct to examine if the selected items related adequately to the construct.

Table 1: Constructs and items used to measure learning driven factors

Construct	**Items**
Higher-order cognitive domain of learning (HC)	Instructional materials improved my problem-solving skills and helped me to identify engineering tools that will assist me in decision-making, how to inter-relate important topics and ideas, how to identify various alternatives/solutions to a problem, and how to sort relevant from irrelevant facts.
Self-efficacy (SE)	This engineering course improved my confidence in applying engineering concepts to real situations, made my learning easier, emotionally engaged me in learning the course topics, increased my self-confidence, helped me achieve a sense of accomplishment in learning, and helped me assume a greater responsibility for personal learning.
Ease of learning subject-matter (EL)	I get frustrated going over engineering tests in class. I am under stress during engineering classes. Learning engineering requires a great deal of discipline.
Impact on teamwork (TW)	The instructional materials helped me improve my team-building and interpersonal skills, listen carefully to other's statements and ideas, arrive at decisions based on consensus building, share ideas with others, enhance my interactions with my classmates.
Communication skills (CS)	My writing skills improved; my presentation skills improved, and my informal communication skills improved.

There are several opinions on acceptable levels of Cronbach Alpha's. For example, Treacy recommends a value of 0.70.[29] Based on this recommendation and based on the previous study by LITEE (http://www.litee.org/site), a cutoff value of 0.7 was selected for Cronbach Alpha's.

5.1. Descriptive statistics

The mean and standard deviation for each variable along with other statistics have been provided in the tables below. Table 2 shows the information for the pre-test. To check the normality of the distribution, skewness and kurtosis have been calculated. Relatively small values for skewness and kurtosis values could be an indication of normality. Alternatively, Table 3 shows descriptive statistics for the post-test (i.e. after conducting the case study).

Table 2. Descriptive Statistics (Before Implementation of the PBL)

	N	Mean	Std. Deviation	Skewness		Kurtosis	
				Statistic	Std. Error	Statistic	Std. Error
HC	25	3.7600	.91708	-.844	.464	1.054	.902
SE	25	3.7333	.73441	-.098	.464	.233	.902
EL	25	3.1200	.63377	-1.292	.464	4.265	.902
TW	25	3.6320	.91411	-.539	.464	-.092	.902
CS	25	3.4200	1.00706	.038	.464	-.633	.902

As it is shown in Table 2, two variables, HC (Higher-Order Cognitive Domain) and EL (Ease of Learning), have relatively high skewness and kurtosis. This could be an indication of lack of normality in the data. To examine the normality, the Kolmogorov-Smirnov test of normality was conducted. The findings suggested that there is not any concern regarding the normality of data.

Table 3. Descriptive Statistics (After Implementation of PBL)

	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
HC	27	3.9259	1.05342	-1.325	.448	1.497	.872
SE	27	3.7716	.73256	-.154	.448	-.147	.872
EL	27	3.2963	.77533	-.788	.448	1.822	.872
TW	27	3.6593	.89066	-.587	.448	.341	.872
CS	27	3.3704	1.06150	-.648	.448	.114	.872

5.2. Reliability and validity of the instrument

Tables 4 and 5 show Cronbach's Coefficient Alpha for the constructs considered in the study. Cronbach's Alpha is used to measure the internal consistency of the instrument, and assesses the reliability of the instrument[30]. Reliability of an instrument shows the degree of consistency or repeatability of the measurement. Most of the constructs have a coefficient value of 0.7 or higher, which is an acceptable value for survey research.

Table 4. Reliability (before the project)

Construct	Number of Items	Cronbach's Alpha
Ease of learning subject matter (EL)	3	.146
Higher order cognitive domain of learning (HC)	5	.269
Self-efficacy (SE)	6	.916
Impact on team working (TW)	4	.940
Communication skills (CS)	3	.551

A review of the reliability measures for the constructs reveals some concern regarding ease of learning subject matter (EL). The construct has a relatively low reliability (Table 4) which is below the recommended threshold of 0.7.

Table 5. Reliability (after the project)

Construct	Number of Items	Cronbach's Alpha
Ease of learning subject matter (EL)	3	.527
Higher order cognitive domain of learning (HC)	5	.960
Self-efficacy (SE)	6	.859
Impact on team working (TW)	4	.905
Communication skills (CS)	3	.911

Since some of the reliability measures are below the recommended threshold of 0.7, the constructs and their items was examined further. Through checking the questions in terms of content, their factor loading, and their correlation with other items in the constructs, we eliminated questions that appear to be problematic. The reliability of the final survey instrument is provided in Table 6. The column "Before" refers to the reliability before implementing the project while the column "After" shows the reliability after completing the project.

Table 6. Reliability for the Final Survey Instrument

Construct	Number of Questions	Before	After
Ease of learning subject-matter (EL)	2	.750	.651
Higher Order Cognitive Domain of Learning (HC)	4	.952	.950
Self-Efficacy (SE)	6	.859	.916
Impact on team working (TW)	5	.905	.940
Communication skills (CS)	2	.857	.651

As it is shown in Table 6, there has been significant improvement in reliability measures for the problematic constructs. Hair *et al.* (2009) argue that an instrument has an acceptable reliability if most of the reliability measures are above 0.7, even if a few constructs have reliability between 0.6 and 0.7.[28] Therefore, we believe that our final instrument has acceptable reliability and can be used for future analysis and comparisons.

5.3. Correlations

We calculated the correlation between variables to determine the degree of association among them. Tables 7 and 8 show the correlation between variables before and after conducting the project based learning.

Table 7. Correlations (Before the project)

		HC	SE	EL	TW	CS
HC	Pearson Correlation	1	.844**	.482*	.800**	.723**
	Sig. (2-tailed)		.0001	.015	.0001	.0001
SE	Pearson Correlation	.844**	1	.333	.706**	.707**
	Sig. (2-tailed)	.0001		.104	.0001	.0001
EL	Pearson Correlation	.482*	.333	1	.410*	.326
	Sig. (2-tailed)	.015	.104		.042	.112
TW	Pearson Correlation	.800**	.706**	.410*	1	.745**
	Sig. (2-tailed)	.0001	.0001	.042		.0001
CS	Pearson Correlation	.723**	.707**	.326	.745**	1
	Sig. (2-tailed)	.0001	.0001	.112	.0001	
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).						

Several conclusions could be drawn from the correlation tables. First, we see positive correlation among constructs in both tables. This suggests that these constructs are all positively related to each other, i.e. improvement in one learning outcome leads to improvement in other learning outcomes.

Table 8. Correlations (After the project)

		HC	SE	EL	TW	CS
HC	Pearson Correlation	1	.731**	.640**	.747**	.593**
	Sig. (2-tailed)		.0001	.0001	.0001	.001
SE	Pearson Correlation	.731**	1	.333	.904**	.707**
	Sig. (2-tailed)	.0001		.090	.000	.0001
EL	Pearson Correlation	.640**	.333	1	.352	.411*
	Sig. (2-tailed)	.0001	.090		.071	.033
TW	Pearson Correlation	.747**	.904**	.352	1	.688**
	Sig. (2-tailed)	.0001	.0001	.071		.0001
CS	Pearson Correlation	.593**	.707**	.411*	.688**	1
	Sig. (2-tailed)	.001	.0001	.033	.0001	
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).						

Second, we see a significant improvement in the correlation between SE (self efficacy) and TW (impact on teamwork) after the completion of the project (r=.904) compared to correlation between SE and TW before the implementation of the project (r=.706). This indicates that as the results of this project in team-based format students self efficacy improved. This finding is consistent with *Cooperative Learning Theory* (CLT). According to CLT, cooperative learning happens when students are working together as a group on a project or assignment.[31-33] Working within a group helps students to acquire certain social skills, since they realize that they are responsible to carry out certain tasks to achieve the goal of the group. As the result of this, students develop a sense of mutual responsibility for each other's learning.[31-33]

6. Results: Assessment of Students' Learning

We used paired comparison procedures to examine the change in the average score before and after implementing the Project-Based Learning. The results are presented in Table 9.

Table 9. Paired Comparison

	Paired Differences					t	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
				Lower	Upper		
HC	.1458	.5610	.11452	-.09107	.38274	1.273	.216
SE	.0208	.4696	.09586	-.17748	.21914	.217	.830
EL	.1875	.5067	.10344	-.02648	.40148	1.813	.083
TW	-.0250	.5510	.11249	-.25770	.20770	-.222	.826
CS	-.0833	1.007	.20560	-.50865	.34198	-.405	.689

The findings suggest that at the level of significance of 0.10, there is significant improvement in the Ease of Learning (EL) construct. Therefore, H_2 is supported. We did not have enough evidence to support the other hypothesis. This is primarily due to the small sample size.

6.1. Non-parametric analysis

To investigate further the effects of Project-Based Learning on student learning outcomes, we conducted a non-parametric test. The non-parametric test is not sensitive to the assumption of normality. Since there was concern regarding the normality of a few constructs, we decided to conduct a non-parametric paired comparison as well. Table 10 shows the result of the Wilcoxon test.

Table 10. Wilcoxon Test Statistics

	HC	SE	EL	TW	CS
Z	-1.163	-.285	-1.698	-.471	-.155
Sig. (2-tailed)	.245	.775	.090	.637	.877

As indicated in Table 10, only the EL (Ease of Learning) result is significant. This confirms the result of the paired comparison (Table 9). Overall, we can conclude that using project-based learning has a significant effect on ease of learning the subject matter.

7. Discussion

This study was designed to determine the effect of PBL on students' learning. Through defining five constructs of students' perception (i.e. learning outcomes), students learning has been measured before and after implementing the PBL method. Using paired comparison t-test, the means for each construct before and after the project implementation were compared. While the averages for most of the constructs have been improved, only ease of learning the subject (EL) shows statistically significant improvement. One possible explanation for this is the small sample size. It is recommended that the study be replicated using larger sample sizes.

We also compared the average grade of the class after incorporation of PBL methodology with that of a control class that was taught using a traditional lecture-based approach. The average grade of the PBL-integrated class was found to be (3.6/5.0) significantly higher than that of the lecture-based class (3.4/5.0). While both classes had similar enrollment numbers and both were taught in a fall semester, there may be some bias due to the interval of one year. The control class was taught in 2009 and the PBL-integrated class was taught in 2010. It is recommend the study be repeated using two sections of the same course in one semester. Since enrollment of this course is limited to 30 students, using two sections of the same course was not doable in this study.

Regarding the correlation analysis, it is shown that there is significant correlation among constructs in both pre-test and post-test. The results showed a significant improvement in the correlation between SE (self efficacy) and TW (impact on teamwork) after the completion of the project compared to correlation between SE and TW before the implementation of the project

This finding is consistent with *Cooperative Learning Theory* (CLT), which asserts that working in teams has a significant effect on learning outcomes.

8. Conclusion

This study was designed to assess improvement in students' learning outcomes through using project-based learning (PBL) methodology. The findings suggest that PBL significantly improves students' ease of learning. Educators can use a project-based learning approach to facilitate students' learning. Furthermore, working together on the project improves students' teamwork skills. This suggests that PBL is an effective method which enables students to relate course materials to practice while improving their level of understanding about the subject matter.

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