Improving Students' Learning of Sustainability Using Project-Based Learning (PBL)

Abstract/Innovation Summary

This paper provides a new approach to teaching and learning through using Project-Based Learning (PBL) methodology. It discusses the process of incorporating PBL into a transportation course as well as the impact of this intervention on students' learning outcomes. To evaluate and compare students' learning between the lecture-based and project-based teaching approaches, the Laboratory for Innovative Technology and Engineering Education (LITEE) survey instrument (http://www.litee.org/site) was used. The survey instrument includes five constructs to measure five different aspects of students' learning in the undergraduate transportation engineering: 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 in enhancing students' learning outcomes. The results show that the use of the project-based approach significantly improves 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, Sustainability; Self-Efficacy, Cognitive Skills, Teamwork, Transportation

1. Introduction

According to the American Society of Civil Engineers Report Card, the overall grade for the nation's infrastructure is D and the cost to bring it up to good condition is $2.2 trillion[1]. Of this amount, $930 billion is related to transportation (roads and bridges), this level of investment calls for a huge number of well-trained professionals who specialize in the transportation and construction fields[1]. This industrial demand for transportation professionals who are well aware of the impact of their solutions in a sustainable global context calls for updating instructional materials to incorporate concepts on sustainability and practices throughout the engineering curriculum. Industry demand for engineers and managers with multidisciplinary skills calls for teaching methodologies which can incorporate hands-on skills throughout the course materials. The idea to pursue a career in engineering to make a difference in the world is often an important factor motivating high school students, especially among women and minorities, to major in Science, Technology, Engineering and Mathematics (STEM).[2] 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 provides students with a broader perspective related to the social and environmental aspect of the application of the basic concepts they learn in the classroom.[2]

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.[3] However, in such cases it is not clear if the students' technical skills are well developed and retained when problem-based learning classes are only offered in the freshman and senior years.[3]

In this study, a project-based learning (PBL) methodology was used to examine students' learning outcomes of sustainability concepts in the undergraduate transportation engineering course. The course was taught by the same instructor in fall of 2009 and 2010. The 2009 class (28 students) was used as the control class and was compared with the 2010 class (27 students). We found that using PBL significantly improves students' ease of learning of the sustainability concepts in the context of transportation.

The rest of the paper is organized as follows: Firs we discuss the theoretical perspectives that are relevant to learning. We review the literature and develop our hypotheses. The discussion is followed by describing the course conduct and the implementation of PBL. Finally, we present the results and discuss the findings of the study.

2. Relevant Literature

The importance of utilizing conceptual frameworks and learning theories in technology education and its impact on program development has been addressed in the literature.[4] Here, we provide several theoretical perspectives on learning. Each of those learning theories has been briefly explained below.

2.1. Theoretical Perspectives

2.1.1 Constructivist theory

There has been a very strong debate on the development of new educational methodologies.[5] Due to the rapid rate of change in the environment, traditional methods of education cannot meet the needs of the workplace environment.[6,7] It has been suggested that constructivist theory can provide some useful insight and direction to address such needs. [8-10].

Constructivist is a theory of learning which claims that students construct knowledge rather than merely receive and store knowledge transmitted by the teacher. It can create an environment for learners to develop their thinking, communication and social skills, and subsequently use those skills in the real world.[11] Two forms of constructivists are defined: psychological constructivism is a theory about the way an individual learns. Social constructivism is the assertion that the actual content of scientific theories is determined by social factors.

It has been shown that application of constructivist theory can have positive impact on students' learning.[12] The use of a constructivist based approach can also provide a firm mental model for the weak students and help them understand conceptual matters better.[13,14]. Wang and Liu argued that China's accounting education needs to be built based on the constructivist theory to be able to train qualified accountants to address problems associated with China's rapid economic and social development.[15] Cognitive skills such as critical thinking, decision making, and creativity can be well addressed through the constructivist theory of learning.[5]

2.1.2 Modes of learning theory

The modes of learning theory can be utilized to address the effectiveness of project-based learning on improving students' learning. The modes of learning theory emphasizes three modes of learning: accretion, structuring, and tuning.[16] Accretion refers to the addition of new knowledge to the exiting knowledge about the subject. This follows by structuring which is the formation and development of new conceptual models or frameworks. Tuning involves the adjustment of the knowledge to a task which usually happens through practice. The classical example of this theory is learning Morse code .[17]

With reference to the transportation engineering course, students learn a variety of new topics and concepts (accretions stage). Due to the modular structure of the course they need to understand the interrelationship among different concepts so that they can develop conceptual models of construction engineering (e.g. relating a topic learned in chapter one to another topic in chapter three). Throughout the semester, students become familiar with tools, techniques and concepts of transportation engineering and would be able to develop conceptual models of transportation engineering (structuring). Tuning would not happen until students get the opportunity to practice transportation engineering (the project). This could be achieved through working on a project. Looking through the constructivism theory, case a project-based learning approach enables students to build a better (or a more accurate) mental model of the reality of transportation engineering. Therefore, the application of PBL in transportation engineering enables students to achieve higher level of learning and enhances their learning.

2.3. Literature review

Project-Based Learning (PBL) methodology has been integrated into course curricula by several scholars in order to improve students' learning and motivation toward the subject matter[18-19]. It has been shown that PBL is a more effective education methodology compared to traditional pedagogies. It promotes a collaborative learning environment that can in turn enhance students' social and problem-solving skills.[19] 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 results in enhancement of students' confidence and increase in employment rate.[18] Heo et al. further studied the effect of the quality of online interaction during project-based learning (PBL) on both the micro and macro levels.[20,21] 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.[21] Lanning et al. used PBL in undergraduate aerospace and mechanical engineering courses to teach structural and materials failure mechanisms through a team-taught approach.[22] 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. [23]

It was found that a group-led framework can create a supportive environment to enhance knowledge building.[23] Chen et al. effectively incorporated PBL in teaching renewable energy courses to engineering technology students where PBL helped students understand the basic concepts of various types of renewable energy while applying the concepts in design.[24] Echempati and Dippery found PBL a promising method to teach a mechanical engineering design course.[25] 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.[26] Melin et al. showed incorporation of the PBL method into course material can help students achieve a higher level of development in the cognitive domain.[27]

In order to assess student knowledge about the theory and application, Melin and his colleagues assigned students real and ongoing construction projects in Afghanistan and found it to be an effective way of enhancing students' understanding of theoretical concepts.[27] It has been shown that combining theory with practical projects can enhance students' learning and their satisfaction of a course.[28,29] 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) [30].

Research is an important component of PBL. There have been many studies on the effects of undergraduate research experience on engineering students' learning and self-efficacy.[31] Undergraduate research has been shown to increase undergraduate student retention; this was found to be even more significant for underrepresented groups.[32] Undergraduate research has also been shown to be an effective tool to motivate students to pursue a graduate degree in engineering.[32-34] In addition, it has been shown by several researchers that hands-on research increases students' understanding, confidence, and awareness of the subject matter. [35-38] It has been documented that instilling enthusiasm is the key to encourage students toward STEM, and that greater attention should be given to providing undergraduate research opportunities for undergraduate students. [39, 40] In order to improve student performance in the real-world work environment practices such as enhancing students' decision-making skills and higher-level cognitive skills have been emphasized. Therefore, many educators have strived to provide students with the education necessary to become qualified managers. [41] Students benefit from working on real-world problems that require the synthesis of skills that they have acquired and refined during their study. [42]

3. Innovation

The innovation of this teaching methodology is to use Project-Based Learning (PBL) methodology to improve students' learning outcomes of sustainability topics in the undergraduate transportation. Our approach/methodology is expected to improve students' learning outcomes as follows: Higher-order cognitive domain of learning (HC), Self-efficacy (SE), Ease of learning subject matter (EL), Impact on teamwork (TW), and Communication skills (CS).

The purpose of this PBL activity is to place students in the role of highway design engineers using real data to develop regression models to study various design parameters. Project-based learning using the LTPP data base was selected to be incorporated into a 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.

4. Implementation

The targeted undergraduate course for this study was Transportation Engineering which is a required Civil Engineering undergraduate course. It should be noted that, due to the context sensitivity of sustainability aspects (equity, economy and environment), having an appropriate context for implementation of the concepts is very important to help students relate the concepts to the context. Transportation context found to be appropriate because of the significant implications of sustainability in the transportation sector and due to the tangible nature of transportation system.

4.1 The project

A semester-long project was carried out to teach various concepts of highway and pavement design. LTPP Datapave Online[30] was used as the e-learning platform to provide the course materials and data for the project (www.LTPP-Products.com).[30] Each team was asked to conduct research on design and performance parameters affecting aspects of sustainability in transportation including environment (ex. carbon footprint of construction materials and vehicle), equity (ex. ride quality, accident, traffic delay, noise) and economy (including cost to highway agencies and consumers' related costs). Each team reviewed five journal articles in addition to course materials to decide which design parameters need to be included and which performance factor should be investigated. The necessary discussions of peer review in class was used to help students begin to identify themselves as researchers and began to develop their plan for research related to sustainable transportation. Incorporating research into PBL methodology led to a more interactive class while students practiced working with related databases and online journals.

To implement the PBL methodology in the course, emphasis was placed on developing project planning skills, building models, analyzing data, technical writing, classroom presentations, and in three cases, presentations at an undergraduate research symposium. All students who took the course passed it; 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.

4.2 Design and structure of the project

To evaluate the effect of incorporating PBL methodology on students' learning outcomes, a questionnaire from the Laboratory for Innovative Technology and Engineering Education (LITEE, www.litee.org) developed through NSF grant #0442531, administered before and after students were exposed to PBL methodology. The Long-Term Pavement Performance (LTPP) database (www.LTPP-Products.com)[30] 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) [30]. 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), material 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 (as an indication of social and economic aspects of pavement's sustainability) and various 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 to determine the significance of each parameter. The IRI was then related to the cost associated with the pavement damages (ex. pavement preservation and rehabilitation) as well as potential cost to consumer (ex. increased rare of accident) to make the linkage between social and economic aspect of sustainability. 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 in the U.S. with different environmental conditions were analyzed by ten teams (three students in each team) in the Transportation Engineering course (CIEN350). Each team developed two regression models, one for concrete pavement and one for asphalt pavement. The environmental aspect of sustainability was then taught through comparing the two pavement types and discussing the carbon footprint and energy consumption of both models.

4.3. Integrating the project into the course

The course modules were designed to cover ride quality and its measurement methods followed by each pavement design parameter. The course materials were covered through five modules: introduction to transportation modes, highway elements, pavement performance evaluation, pavement design concepts and 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 for the same state.

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 multivariate regression model, how to evaluate the significance of each parameter as well as the significance of the overall model. Through acquiring a basic knowledge on the roles of various parameters in determining overall pavement performance students built a platform to learn how to measure and calculate each design parameter such as traffic, layer thickness, and climate. They further learned how different types of pavements (concrete and asphalt) vary in performance, design criteria as well as their sustainability measures. Each team presented their project and made the case for their parameters selections accounting for project's social, environmental and economic aspects. Presentations were followed by discussion and brainstorming on various performance measures for highway pavements as well as their implications for sustainable transportation.

5. Effectiveness and Benefits of PBL

Two questionnaires were used to evaluate students' feedback on the PBL method. Each evaluation consisted of 23 items. Students were asked to evaluate the effectiveness of the study on a 5-point Likert scale (1 indicating an extremely negative rating and 5 an extremely positive rating). The questionnaire included items to measure five constructs: *Higher order cognitive skills improvement, self-efficacy improvement, ease of learning subject matter, teamwork improvement, and communication skills improvement* (Table 1). Students completed the questionnaires, included their comments and submitted them along with their projects. Statistical analysis was conducted using SPSS.[43,44]

Table 1: Constructs and Items Used to Measure Learning Outcomes

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 (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.

5.1. Descriptive statistics

The mean and standard deviation (S.D.) for each variable along with other statistics have been calculated. Table 2 shows descriptive statistics for the pre-test. To check for normality of the data, 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 project).

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

Construct	N	Mean	S. D.	Skewness	Kurtosis
Ease of learning subject matter (EL)	25	3.76	0.92	-0.84	1.05
Higher order cognitive domain of learning (HC)	25	3.73	0.73	-0.10	0.23
Self-efficacy (SE)	25	3.12	0.63	-1.30	4.27
Impact on team working (TW)	25	3.63	0.91	-0.54	-0.09
Communication skills (CS)	25	3.42	1.00	0.04	-0.63

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, a Kolgomorov-Smirnov test of normality was conducted. The findings suggested that the requirements of normality have been met.

Table 3. Descriptive Statistics (After Implementation of the PBL)

Construct	N	Mean	S. D.	Skewness	Kurtosis
Ease of learning subject matter (EL)	27	3.93	1.05	-1.33	1.50
Higher order cognitive domain of learning (HC)	27	3.77	0.73	-0.15	-0.15
Self-efficacy (SE)	27	3.30	0.78	-0.79	1.82
Impact on team working (TW)	27	3.66	0.89	-0.59	0.34
Communication skills (CS)	27	3.37	1.06	-0.65	0.11

5.2. Reliability and validity of the instrument

Tables 4 and 5 show Cronbach's coefficient alpha for the constructs in the study. Cronbach's alpha measures the internal consistency of the instrument, and assesses the reliability of the instrument[31]. Reliability of an instrument shows the degree of consistency or repeatability of the measurement. There are several opinions on acceptable levels of Cronbach Alpha's. For example, Treacy recommends a value of 0.70 for reliability[45]. Based on this recommendation and based on the previous studies by LITEE (http://www.litee.org/site), a cutoff value of 0.7 was selected for Cronbach's Alpha. Most of the constructs have a coefficient value of 0.7 or higher, which is an acceptable value for survey research. The reliability for the constructs (before and after implementing the PBL) is provided in Table 4.

Table 4. Reliability

Construct	Number of Items	Cronbach's Alpha	
		Before the PBL	After the PBL
Ease of learning subject matter (EL)	3	.146	.527
Higher order cognitive domain of learning (HC)	5	.269	.960
Self-efficacy (SE)	6	.916	.859
Impact on team working (TW)	4	.940	.905
Communication skills (CS)	3	.551	.911

Since some of the reliability measures are below the recommended threshold of 0.7, the constructs and their items were examined in more details. Through checking the questions in terms of content, their factor loading, and their correlations with other items in the constructs, we eliminated questions that appeared to be problematic (questions 1 and 2 in the survey). The reliability of the final survey instrument is provided in Table 5.

Table 5. Reliability for the Final Survey Instrument

Construct	Number of Items	Cronbach's Alpha	
		Before the PBL	After the PBL
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 5, there has been significant improvement in reliability measures for the problematic constructs. Hair *et al.* 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.[43] Therefore, we believe that our final instrument has acceptable reliability.

5.3. Correlations

We calculated the correlation between variables to determine the degree of association among them. Tables 6 and 7 show the correlation between variables before and after conducting the project based learning.

Table 6. Correlations (Before the PBL)

		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 *Correlation is significant at the 0.05 level						

Several conclusions could be drawn from the correlation tables. First, there is positive correlation among constructs in both tables. This suggests that the constructs are positively related to each other, i.e. improvement in one learning outcome leads to improvement in other learning outcomes. 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 has been improved.

Table 7. Correlations (After the PBL)

		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			*Correlation is significant at the 0.05 level			

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.[46-48] 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.[46-48]

6. Assessment of Students' Learning Outcomes

We used paired comparison procedures to examine the change in the average score before and after implementing the PBL. The results are presented in Table 8.

Table 8. Paired Comparison

Construct	Paired Differences				t	Sig.
	Mean	S. D.	95% Confidence Interval of the Difference			
			Lower	Upper		
HC	0.15	0.56	-0.09	0.38	1.27	0.22
SE	0.02	0.47	-0.18	0.22	0.22	0.83
EL	0.19	0.51	-0.03	0.40	1.81	0.08
TW	-0.03	0.55	-0.28	0.21	-0.22	0.83
CS	-0.08	1.00	-0.51	0.34	-0.41	0.69

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 hypotheses. One possible explanation would be the small sample size.

6.1. Non-parametric analysis

To investigate further the effects of PBL on student learning outcomes, we conducted a non-parametric test. The non-parametric test is not sensitive to the assumption of normality. Since a few constructs had relatively high skewness and kurtosis values, we decided to conduct a non-parametric paired comparison as well. Table 9 shows the result of the Wilcoxon test.

Table 9. Wilcoxon Test Statistics

Z	HC	SE	EL	TW	CS
	-1.16	-0.29	-1.70	-0.47	-0.16
Sig.	0.25	0.78	0.09	0.64	0.88

As it is shown in Table 9, only the EL (Ease of Learning) is significant. This confirms the result of the paired comparison (Table 8). Overall, we can conclude that using project-based learning has a significant effect on improving ease of learning of transportation concepts.

7. Discussion: Transferability and Implications for Educators

This study was designed to determine the effect of PBL on students' learning. Through defining five constructs, students' learning has been measured before and after implementing the PBL method. Using paired comparison t-test, the mean for each construct before and after the project implementation was compared. While the mean scores for most of the constructs have been improved, only ease of learning the subject (EL) shows significant improvement. One possible explanation for this is the small sample size. It is recommended that the study be replicated using a larger sample size in order to obtain more robust results.

Students' comments and written feedback was also positive. One student said "the project helped me to see the big picture". Students learned how to relate the course materials to practice; comments such as "… it was a very good hands-on experience", "…using PBL I learned how the design of maintenance and design of road actually happens", "working in teams we managed to develop prediction models for roughness..", "the project helped me learn the connection between various design parameters and performance..", and "using the LTPP database and SPSS statistical software, I learned how to make meaningful models to predict pavement roughness..." all support the positive effect of the PBL on students' learning.

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). The control class was taught in 2009 and the PBL-integrated class was taught in 2010. For future studies, 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 before and after using PBL. 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 the 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.

We believe that the findings of this study could be easily generalizable to courses such as logistics, supply chain and operations/production management. In the transportation engineering, students learn different topics (e.g. transportation design, traffic management, demand analysis, driver behavior, and pavement design). Transportation engineering is an interdisciplinary course where students should be able to integrate different concepts/theories in order to address transportation issues. This is similar to production and operations management, supply chain management, and strategic management where students should be able to integrate several concepts such as quality management, supplier relationship management, and product design in order to decide how to design and develop a new product or how to maintain an organization's competitive advantage.

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 improve students' learning. Furthermore, working together on the project improves students' teamwork skills. This suggests that PBL is an effective teaching and learning method which helps students relate course materials to practice while improves their level of understanding about the subject matter.

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