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Development of a Problem-Based Learning (PBL) and Cooperative Learning (CL) Transportation Engineering Course for Undergraduate Students

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**DEVELOPMENT OF A PROBLEM-BASED LEARNING (PBL) AND
COOPERATIVE LEARNING (CL) TRANSPORTATION
ENGINEERING COURSE FOR UNDERGRADUATE STUDENTS**

Prepared for

**OHIO TRANSPORTATION CONSORTIUM (OTC)
The University of Akron**

By

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Abstract

This study reports the findings of a project that was done during the implementation of a problem-based learning (PBL) and cooperative learning (CL) elements into an undergraduate transportation engineering course. The study procedure used the student course evaluations, including a survey questionnaire, and university-wide standardized student evaluations. Additionally, student homework, tests, and exam grades were used as part of the evaluation process. Two methods of teaching formats were evaluated: the traditional teaching method of lecturing and using end-of-chapter book questions for homework assignments and the new currently used teaching method of student field data collection, preparation of a lab report for each data collection exercise and use of their data to answer homework questions. The semesters in which data were used in the analyses include, fall 2005, fall 2006, and spring 2007 taught using the traditional format and fall 2007 and spring 2008 taught using the new teaching format. The findings of this study have revealed that students do prefer the current teaching format that incorporates some forms of problem-based learning (PBL) and cooperative learning (CL) elements over the traditional format of teaching. Students favor this method mainly because they believe that collecting their own data, getting involved in using these data in solving example problems in class and using them as a source of homework assignments improves their learning process.

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1. BACKGROUND

1.1 Introduction

Lecturing is a traditional teaching method that has been used for many years mainly due to its familiarity and ease. However, it has lately been criticized that it does little to foster the development process skills to complement content knowledge (Duch et al., 2001).

Some researchers have noted that there are teaching practices that do promote skill development without forsaking content (Duch et al., 2001). Such teaching techniques provide true learning through discovery guided by mentoring rather than transmission of knowledge (lecturing). The best educational setup should produce a student equipped with a spirit of inquiry and with eagerness for problem solving and possessing other pertinent skill such as communication, clear thinking, and diverse experience.

Problem-based learning (PBL) is a student-centered, inquiry-based instruction that provides a forum in which essential skills are better developed as compared to traditional learning by lecturing only (Duch et al., 2001). The benefit of a PBL is that learning is initiated by a posed problem, query, or puzzle that the student needs to work out (Boud and Feletti, 1991). Furthermore, in PBL approach, complex, real-world problems are used to stimulate students to identify and explore concepts and principles they need to know to work through those problems. Duch et al (2001) say that in a PBL learning, students work together in small teams that help to bring together combined skills. The desirable learning outcomes of the PBL teaching that benefit students include the following (Duch et al, 2001):

- ❖ Think critically and be able to analyze complex, real-world problems

- ❖ Find, evaluate, and use appropriate learning resources
- ❖ Work cooperatively in teams and small groups
- ❖ Demonstrate versatile and effective communication skills, both verbal and written
- ❖ Use content knowledge and intellectual skills acquired at the university to become continual learners.

Also, there is extensive literature on undergraduate engineering education that claims a number of benefits of cooperative learning techniques as instruments for improving student learning (McKeachie, 1999; Burmeister and Fernandez, 2004). Cooperative learning (CL) involves individual students working together and helping each other to achieve a common set of objectives. One example of CL is homework performed as a group assignment. Some research efforts have shown that when students work together they become more motivated and learn better than when they work individually (Light, 2001; Masten et al., 2002).

1.2 Specific Educational Objectives

The major objective of PBL and CL learning setups is to help students become active learners, a method highly regarded as a better method for student's understanding. Basically, students in this course are expected to acquire the best of their education by doing the following as part of the course requirement:

- ❖ Have hands-on experience of what engineers do in the field. How to solve a real problem and how to collect real data, analyze it and come to the solution.
- ❖ Experience working in a team while tackling a certain engineering assignment.

- ❖ Experience in using some useful computer software packages that are in use in the field.
- ❖ Experience in using numerous data sources, e.g., relevant field data collection, internet, library, manuals, departments of transportation data sources and personnel (including local, state, and federal), etc.
- ❖ Practice presenting results in front of colleagues as transportation engineers do to the elected officials, public, and clients.

1.3 Methods Used in Teaching this Course

1.3.1 Traditionally Teaching Format Used in this Course

The transportation engineering course, CEE 403 at the University of Dayton, is a required compulsory course for all students majoring in civil engineering. It is a three credit hour course taught at the junior level with an enrollment that has ranged between 15 - 35 students per semester in the last five semesters. The class meets three times a week, Monday, Wednesday, and Friday, and each session lasts for 50 minutes. Originally, the course was taught by lecture format covering theory and formulas. The instructor used several examples from the text book or made up some questions and assigned homework using problems in the text book (end-of-chapter questions), made up some questions, or provided questions taken from other sources.

1.3.2 New Teaching Format Currently Used in this Course

Under this teaching format, students learn in part by participating in exercises (i.e., collecting and measuring their own data). Monday session: the instructor covers a theory

about the topic and solves problems based on students' previous collected data.

Wednesday session: Further topic coverage and description of the next traffic study to be conducted. Friday session: students conduct a specified traffic study by collecting data in the field. Each group of students is required to submit a written report in which they are expected to interpret and analyze their data. Homework assignment questions are provided per group and students use their own data to answer the related homework questions.

1.3.3 Student Groups Formation and Data Collection

Groups of 2-4 members, known as engineers-in-training, are formed depending on the number of students enrolled in the course. The instructor preferred to form groups rather than students select their own groups. This is simply because when you go to the industry and get employed you do not know who you will find in your new office and you do not have the opportunity to select colleagues with whom you will work. However, this did not work well because most of the work is done out of the classroom and during weekends, so students complained of difficulty to meet as groups during off class times. As a result, the instructor allowed the students to form their own groups depending on their ability to meet outside of class which solved the problem. While most of the data was collected from roadway sections such as intersections, freeway ramps, parking lots, etc., some of them were obtained from transportation agencies such as Ohio Department of Transportation, city engineer's offices, county engineer's offices, local police agencies, and the Miami Valley Regional Planning Commission (MVRPC) office.

Students were also involved in vigorous evaluation of each peer's participation in data collection, analysis of data, report, and homework assignment stages. Each student's participation score as assessed by peers in the group was used as part of the individual coursework grade. The testing procedure remained the same (i.e. two tests and a comprehensive final exam, all of which are performed individually). In addition, the course comprised a design project and a term paper, which are performed as group assignments.

2. METHODS USED IN ASSESSING AND EVALUATING THE PROJECT'S RESULTS

The course syllabus has mainly remained the same as the course has been taught in the past at the University of Dayton. However, the course enhancement has largely been on how the course materials are being delivered whereby the major component added is involving students in collecting and obtaining real-world data and engaging them in problem solving as part of the learning-process.

Two course evaluations were administered by the instructor during the winter 2008 semester, one mid-way and the other at the end of the semester. The mid-term evaluation used the university-wide standard method known as Mid-term Instructional Diagnosis (MID), which basically asks students three questions. The questions are: (1) What is helping you learn in this class? (2) What is hindering your learning in this class? (3) What suggestions do you have for improving your learning in this class? At the end of semester evaluation, students were requested to provide their evaluation through a

questionnaire that asked students to give their inputs on how to further enhance and improve their learning process and also compare their learning process between this new teaching format and the previously used traditional format. The homework, two tests and final exam result scores were compared with previous scores performed in previous semesters. In addition, the university-wide mandatory end-of-semester evaluations, which are required to be conducted during the last few weeks before the end of the semester, were used to compare the evaluations performed in different semesters.

Also, students' peer review results were used to check whether students' participation and collaboration were working to the anticipated level. For instance, the aim of CL is to improve students' understanding, collaboration, and hence material retention.

3. RESULTS

The semesters for which the traditional format was used as a method of instruction include the following: fall 2005, fall 2006, and spring 2007. The current teaching format was first introduced in the fall 2007 semester and also used in the spring 2008. It is noteworthy to mention that prior to 2007, the course was being offered only in the fall semesters. The results based on the evaluation methodology described in Section 2 are presented below.

3.1 Student Grades

The students' grades in terms of homework assignments, tests, final exams, and final class grade score are shown in Figure 1. It is noteworthy to mention that the final grade

includes the term paper and design project grades which are not shown in Figure 1. A very interesting observation is that for a semester when the students have higher homework and test grades, i.e., a good coursework grade, they ended up scoring the lowest grade in the end of term final exam and vice versa. This may be explained that when students feel that they have a good coursework grade going into the final exam, which is comprehensive and more demanding, they end up relaxing their effort and the opposite is true that when they do not have a good coursework grade they study harder for the final exam.

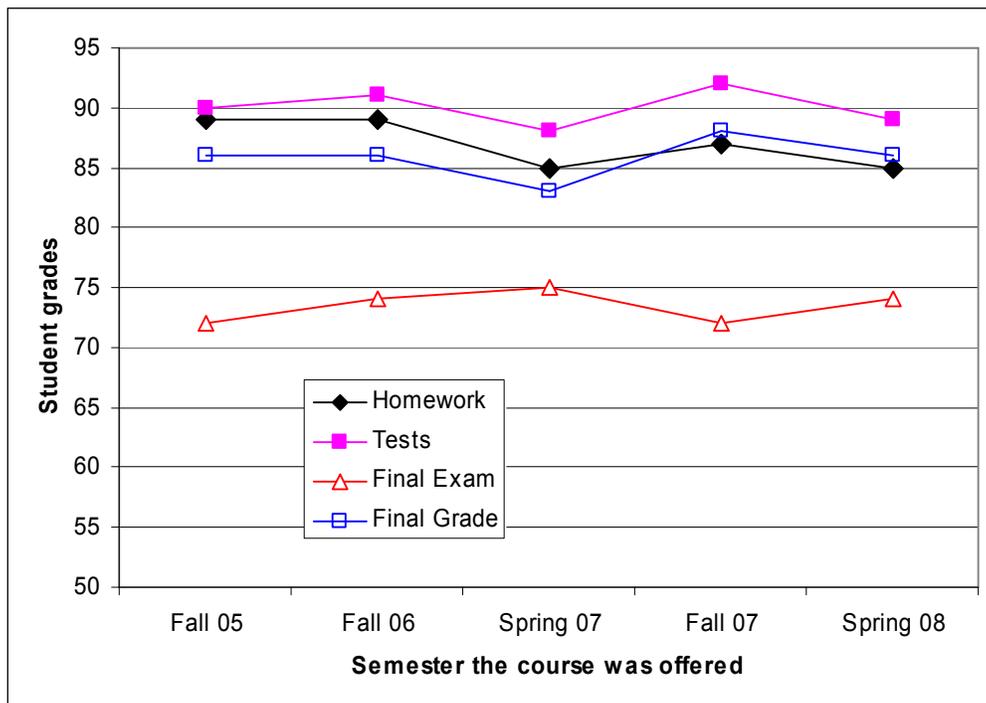


Figure 1 Summary of student grades for fall 2005 – winter 2008 semesters

When combined and summarized as groups of semesters taught by traditional format (fall 2005 – winter 2007) and current format (fall 2007 – winter 2008) no clear difference is

observed for the different assignments for which students were tested. These results are summarized in Figure 2.

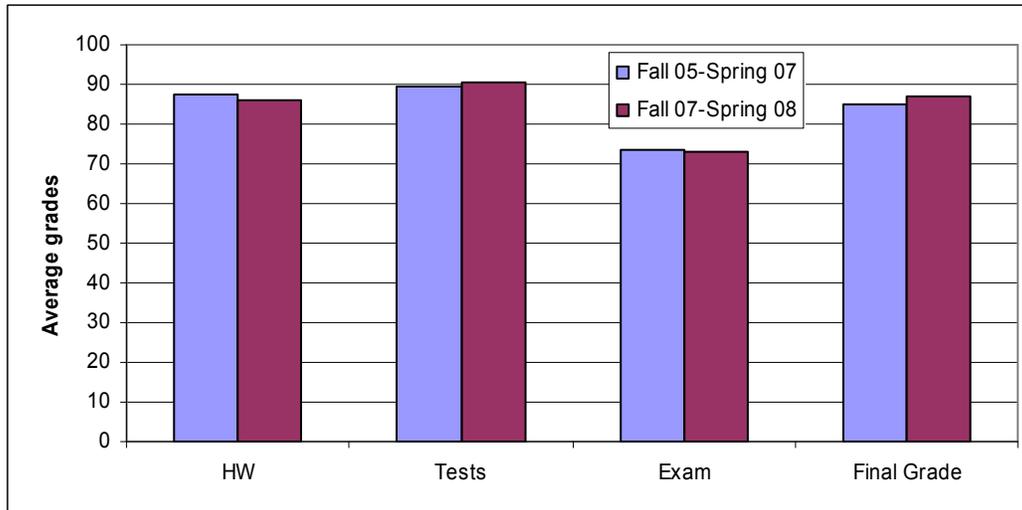


Figure 2 Student grades summarized by the method of teaching format used

3.2 University Mandated End of Semester Student Course Evaluation

The summary of student course evaluations is summarized in Figure 3. These are standardized end of semester evaluations that are mandatory for all courses offered at the University of Dayton. These evaluations are always administered during the last few weeks before the end of the semester. The fall 2005 evaluations were taken as a reference (index = 100) and the other semesters were compared with this reference semester. This method is convenient in such a way that it compares different semester class evaluations relative to each other without revealing the actual instructor's student evaluations. When the evaluations are summarized between the traditional teaching format and the current teaching format as groups of teaching methods, however, they reveal some significant differences. In that case the student evaluations for classes taught using the current

teaching format were significantly higher than those taught using the traditional teaching format. These results are depicted in Figure 4.



Figure 3 Summary of student class evaluations fall 2005 – spring 2008

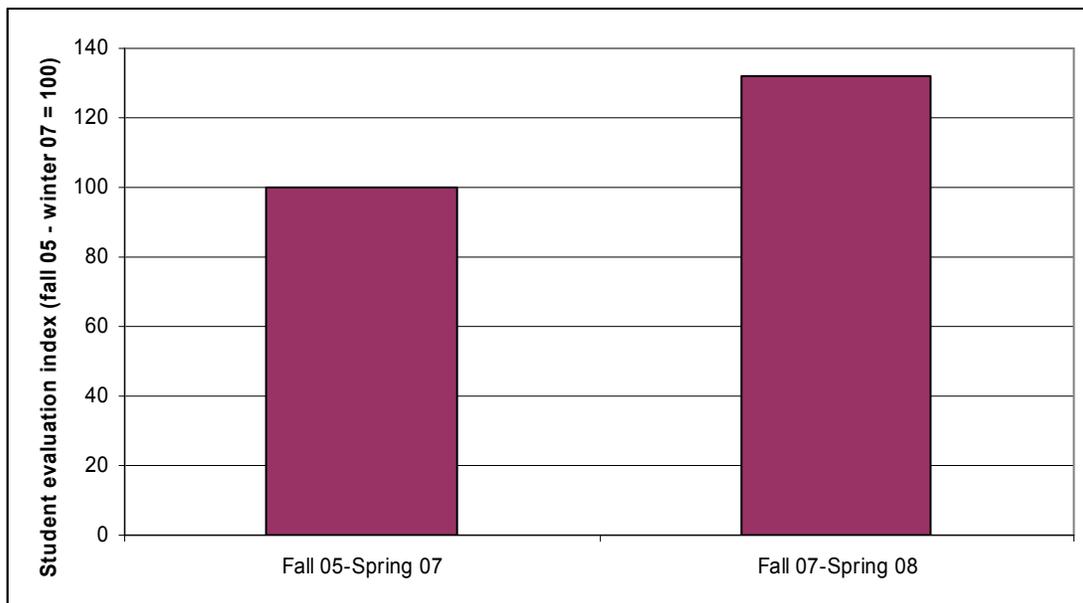


Figure 4 Student evaluations summarized by teaching method used

3.3 Mid-Term and End of Term Instructor Administered Student Evaluations

The mid-term Instruction Diagnosis results are summarized below. Each question is restated and followed by its corresponding student responses with the percentages of students agreeing to that response in parentheses.

Question 1: What is helping you learn in this class?

- In class examples based on real-world data collected by students (100%)
- Class participation (93%)
- Data collection and project – based on real-life data (100%)
- Professor’s flexibility (100%)
- Repetition of important information (75%)
- Excitement and enthusiasm of professor for the subject (100%)
- Professor gets to know students (100%)
- No power point lectures (100%)

Question 2: What is hindering your learning in this class?

- Excessive length of notes (100%)
- Doing homework as a group (85%)

Question 3: What suggestions do you have for improving your learning in this class?

- Make it optional for homework to be done as a group, i.e. students decide either to submit their assignment as a group or individually (100%).
- Data collection and project - keep them group assignments (100%)
- Better clarification of lab data collection before field work (40%)

The end of term survey questionnaire consisted of seven questions. The first six were multiple choice questions with the sixth question consisting of an open-ended portion if the choice was number 3 out of the three choices given. Question number seven was an open-ended question that asked students to give their suggestion in order to improve the learning process. The questions asked and their responses are summarized below. Table 1 depicts the results of the first question that asked students their experience in collecting real world data in their classes before taking this course. Most of the students (79.3%) responded that they either never or almost never have done that in other classes.

Table 1 Before taking this class, had you ever collected real-life data in the field for a class assignment?

Selection		Frequency	Percent
1	Never	9	31.0
2	Almost never	14	48.3
3	In between (neutral)	5	17.2
4	Somewhat frequently	1	3.4
Total		29	100.0

The second question asked if conducting real field data collection increased or decreased their interest in transportation engineering. These results are summarized in Table 2. More than half of the students (62.1%) said that it actually increased their interest in transportation engineering. About 35% thought that there was no effect in their interest. It has to be noted here that most of the surveys that are usually informally conducted in the department show that most of the civil engineering undergraduate students reveal that structural engineering and construction engineering are their main career paths of interest.

Table 2 Did collecting real-world data in the field increased or decreased your interest in transportation engineering?

Selection		Frequency	Percent
1	Greatly decreased	0	0.0
2	Decreased	1	3.4
3	No effect	10	34.5
4	Increased	17	58.7
5	Greatly Increased	1	3.4
Total		29	100.0

Question three asked students to rate the overall value of collecting their own data in the field or from transportation engineering officials. The majority, about 76% agreed that the overall value was at least somewhat high. With only 3.4% selecting low as their overall value, it shows that students valued highly the experience of conducting their own data collection.

Table 3 Rate the overall value of getting out there collecting your own data in the field or from the transportation engineering officials?

Selection		Frequency	Percent
1	Low	1	3.4
2	Somewhat low	2	6.9
3	Neutral	4	13.8
4	Somewhat high	16	55.2
5	High	6	20.7
Total		29	100.0

The results of question four that asked students to compare their learning effectiveness between the traditional format and the current format course deliveries are summarized in Table 4. More than half of the students (55.2%) indicated that they at least somewhat learn better when the course is delivered through the current teaching format as compared

with the traditional format. Only 6.8% suggested that at most the traditional format is better.

Table 4 When comparing doing problems at the end of the chapter based on hypothetical problem with the one used in this class based on your data collected in the field, which one do you think you learn better?

Selection		Frequency	Percent
1	Based on chapter questions	1	3.4
2	Somewhat based on chapter questions	1	3.4
3	No difference	11	37.9
4	Somewhat based on own data	12	41.4
5	Based on own data	4	13.8
	Total	29	100.0

Table 5 summarizes the results of question five that asked the students if doing homework and project assignments as a group helped them to improve their grades as opposed to doing them individually. This question was posed to determine whether or not students liked working together in performing assignments with grade improvement as a factor. The results show that almost half of the students (48.2%) agreed. While about 24% disagreed and the other 24% were neutral, however, the reason was revealed in the mid-term evaluations (MID) and in questions 6 and question 7 (open-ended questions). The findings show that the main reason students did not prefer to do homework as a group was the problem of being able to meet and do the homework assignments together outside of the classroom almost on a weekly basis due to having conflicting schedules and places of residences (different dorms, commuter students, etc.). Therefore, the problem was rather a convenience issue and not a learning problem. Additionally,

students insisted their preferences of keeping the term paper and design project as group assignments in their MID evaluation responses.

Table 5 Team work/group projects and homework assignments mostly improved my understanding and possibly increased my grade compared with doing them individually

Selection		Frequency	Percent
1	Highly disagree	1	3.4
2	Disagree	7	24.1
3	Neutral	7	24.1
4	Agree	11	37.9
5	Highly agree	3	10.3
Total		29	100.0

Table 6 summarizes the results of question six that asked the students to give their overall suggestions in terms of which teaching format they would prefer to be continued in this course. Overwhelmingly, all students (100%) preferred the current teaching format to be continued with almost half of them (51.7%) providing some suggestions that may even make their learning better without changing the current teaching format. Almost all of the students who selected choice number 3 in question six provided their suggestions and these suggestions are summarized in Table 7. All suggestions were read carefully and were summarized into major categories/themes as shown in Table 7. Results of Table 7 show why there were a relatively high percentage of students who indicated that working in a group did not necessarily improve their grade. Most students preferred working in groups but performing homework assignments individually whenever possible due to reasons already discussed above.

Table 6 Overall suggestions to improve this course

Selection		Frequency	Percent
1	Keep the current format	14	48.3
2	Drop it completely (go back to traditional teaching)	0	0.0
3	Keep it but make some changes (give suggestions)*	15	51.7
Total		29	100.0

* Suggestions provided in selection 3 are summarized in Table 7

Table 7 Keep it but change it by doing this

Suggestion		Frequency	Percent
1	Do homework individually	8	44.4
2	Two tests are not enough - make 3 tests	2	11.1
3	Add more advanced/complicated data collection studies	1	5.6
4	Better clarification of lab procedures before data collection	3	16.7
5	Homework done as group work be optional	2	11.1
6	More smaller homework assignments rather than fewer large ones	1	5.6
7	More lab time for data collection	1	5.6
Total		18	100.0

The results of the last question are summarized in Table 8. These results reflect the same suggestions provided in Table 7. The majority of the students suggested an addition of one more test as they claimed that two tests were not enough for the whole semester as each test covered much more materials to study for the test. Also, about 9% of the suggestions were about better clarification of lab procedures before data collection.

Table 8 General suggestions to improve this course

	Suggestion	Frequency	Percent
1	Have more than two test - preferably 3	12	54.6
2	More clarification on lab work before field data collection	2	9.1
3	More homework assignments	1	4.5
4	More examples	2	9.1
5	I felt doing assignment with a group decreased my understanding because I was only doing a portion of the work	1	4.5
6	Do data collection on warm and sunny days	2	9.1
7	Sending out examples via email is not helpful. Bring the printed version with you to class	2	9.1
	Total	22	100.0

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The findings of this study have revealed that students do have a preference for the current teaching format that incorporates some forms of problem-based learning (PBL) and cooperative learning (CL) elements over the traditional format of teaching. Students favor this method mainly because they believe that they learn better and benefit from collecting their own data and getting involved in using these data in solving example problems in class and using them as source of homework assignments. A few data sets available that were used in this study may be a reason that student grades did not differ substantially between those learned through the different teaching formats discussed in this study. Additionally, students prefer to have more tests that cover short-term course materials

rather than having fewer tests that cover much more course materials. All students (100%) surveyed suggested that the current method of teaching, which incorporates the PBL and CL teaching, be kept and enhanced for better student learning.

4.2 Recommendations

Based on the results of this study, it is recommended that this teaching format which currently incorporates some elements of PBL and CL teaching delivery be enhanced with a goal of making it a fully-fledged PBL teaching format. This will be achieved by improving the lecture part of the class into more of an active learning whereby students will be more involved in the learning process than they are currently involved. Involving the students in solving examples that utilize data they collected themselves is a positive step towards a fully fledged PBL delivery teaching. Also, it is recommended that the instructor continue surveying students every semester and improving and adding more questions to the survey questionnaire, which will capture more information from students' responses towards their learning and understanding of the course materials taught.

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