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# Problem-based approach to teaching transportation engineering

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ABSTRACT: Transportation engineering is taught in the junior year as a required course for all civil engineering students. The course provides an introduction to various aspects of transportation engineering. The course, which is traditionally a lecture course, was redesigned to ensure the active participation of every student so they understand the physical elements of transportation design. Throughout the course, the faculty conducted a simulating and engaging exercise during class of requiring students in teams of two to solve practical problems immediately after covering the relevant theory. Such an activity considerably increased the level of interest and provided a greater satisfaction of tackling the problem, rather than just following set example problems. The global learners remained engaged as they could visualise the relevance of the theory being taught in class, and the more sequential learners after the initial struggle followed the problems through the explanation in class and the solution provided at the end of class. The course outline, with a week-by-week breakdown of activities, and the typical hand outs, is presented in this article. The student evaluations and course outcomes are also presented and discussed in the article.

Keywords: Innovative, transportation engineering, problem-based learning

## INTRODUCTION

### Problem-Based-Learning

As the title implies, problem-based learning is an educational approach where an ill-structured problem initiates learning. Problem-Based Learning (PBL) is necessarily interdisciplinary: By addressing real-world problems, students are required to cross the traditional disciplinary boundaries in their quest to solve the problem. One of the primary features of PBL is that it is student-centred. *Student-centred* refers to learning opportunities that are relevant to the students, the goals of which are at least partly determined by the students themselves [1].

This does not mean that the teacher abdicates her or his authority for making judgments regarding what might be important for students to learn; rather, this feature places partial and explicit responsibility on the students' shoulders for their own learning. Creating assignments and activities that require student input presumably also increases the likelihood of students being motivated to learn.

A common criticism of student-centred learning is that students, as novices, cannot be expected to know what might be important for them to learn, especially in a subject to which they appear to have no prior exposure. The literature on novice-expert learning does not entirely dispute this assertion; rather, it does emphasise that students come to university, not as the proverbial blank slates, but as individuals whose prior learning can greatly impact their current learning [2]. Often they have greater content and skill knowledge than teachers (and they) would expect. In any case, whether their prior learning is correct is not the issue. Whatever the state of their prior learning, it can both aid and hinder their attempts to acquire new information. It is, therefore, imperative that instructors have some sense of what intellectual currency the students bring with them.

The context for learning in PBL is highly context-specific. It serves to teach content by presenting students with a real-world challenge similar to one they might encounter were they a practitioner of the discipline. Teaching content through skills is one of the primary distinguishing features of PBL. More commonly, instructors introduce students to teacher determined content via lecture and texts. After a specific amount of content is presented, students are tested on their understanding in a variety of ways. PBL, in contrast, is more inductive: students learn the content as they try to address a problem.

The *problems* in PBL are typically in the form of *cases*, narratives of complex, real-world challenges common to the discipline being studied. There is no right or wrong answer; rather, there are reasonable solutions based on application of knowledge and skills deemed necessary to address the issue. The *solution*, therefore, is partly dependent on the acquisition and comprehension of facts, but also based on the ability to think critically.

By having students demonstrate for themselves their capabilities, PBL can increase students' motivation to tackle problems. Three major complaints from employers about college graduates are graduates' poor written and verbal skills, their inability to solve problems, and their difficulties working collaboratively with other professionals. PBL can address all three areas. However, the pedagogical technique used in this study is a combination of both PBL and traditional lectures. The students are given the basic theory in class; however, they come to understand the theory by solving real-world problems that are relevant to the theory.

Course Outline

Transportation engineering is taught in the junior year as a required course for all civil engineering students. The course provides an introduction to various aspects of transportation engineering. The course, which is traditionally a lecture course, was redesigned to ensure that every student actively participates and understands the physical elements of transportation design. The students, then, have the option of taking a course in advanced transportation Design and Planning or pavement Design and Evaluation.

The course (Table 1) includes six topics: 1) driver, pedestrian, vehicle and road characteristics; 2) horizontal and vertical curves, and super elevation; 3) traffic stream flow; 4) freeway- level-of-service analysis; 5) queuing theory; and 6) warrants. The class meets for 75 minutes twice a week.

Table 1: Course outline.

| Week | Topic |
|---|---|
| Week 1 | Introduction and Background |
| Week 2 | Driver, Pedestrian, Vehicle and Road Characteristics |
| Week 3 | |
| Week 4 | Horizontal and Vertical curves, and Super Elevation/Examination 1 |
| Week 5 | |
| Week 6 | Traffic Stream Flow/Examination 2 |
| Week 7 | |
| Week 8 | |
| Week 9 | Freeway |
| Week 10 | |
| Week 11 | Queuing theory |
| Week 12 | Warrants/Examination 3 |
| Week 13 | |

Pedagogical Technique

During the past four years the author has tried innovative teaching techniques in a wide range of classes such as pavement materials [1], surveying and engineering graphics [2] and civil engineering materials [3]. Throughout this course, the author required students to solve practical problems during class in teams of two immediately after covering the relevant theory. The practical problems were assigned before any example problems were solved in the class. Therefore, each class was divided into two parts, theory (30-35 %) and practical in-class problem solving (65-70%). For example, immediately after a concept of vertical curve and its derivations from basic equations were covered, students solved a problem individually or in teams of two on determining the length of a curve necessary for providing enough clearance under a bridge (Figure 1).

In this case, they were asked to take the theory just covered and translate it to solving practical problems. During the class, the author answered any questions from the groups, while solving the problems. At the end, the problem was solved in class based on information gathered from the groups. At this time, the groups had the opportunity to compare their solution with the one solved in class. Eventually, the correct solution was distributed (Figure 2). The class notes were supplemented with hand-outs from the AASHTO Policy of Geometric Design and Highway Capacity Manual.

*A -4 % grade and a 0 % grade meet at station 24 + 00.00 at elevation 2421.54 ft. They are joined by an 800-ft vertical curve. The curve passes under an overpass at station 25 + 00.00. If the lowest elevation of overpass is 2439.93 ft. Calculate available clearance.*

Figure 1: A problem distributed to the class.

Impact of Technique

The above mentioned pedagogical technique requires students to think through the problem. They have to assimilate the information provided and translate it to suit the problem at hand. This activity initially frustrated the students because they were traditionally used to following example problems. However, this exercise forced them to take the theoretical concepts and apply them directly to transportation engineering analysis and design problems.

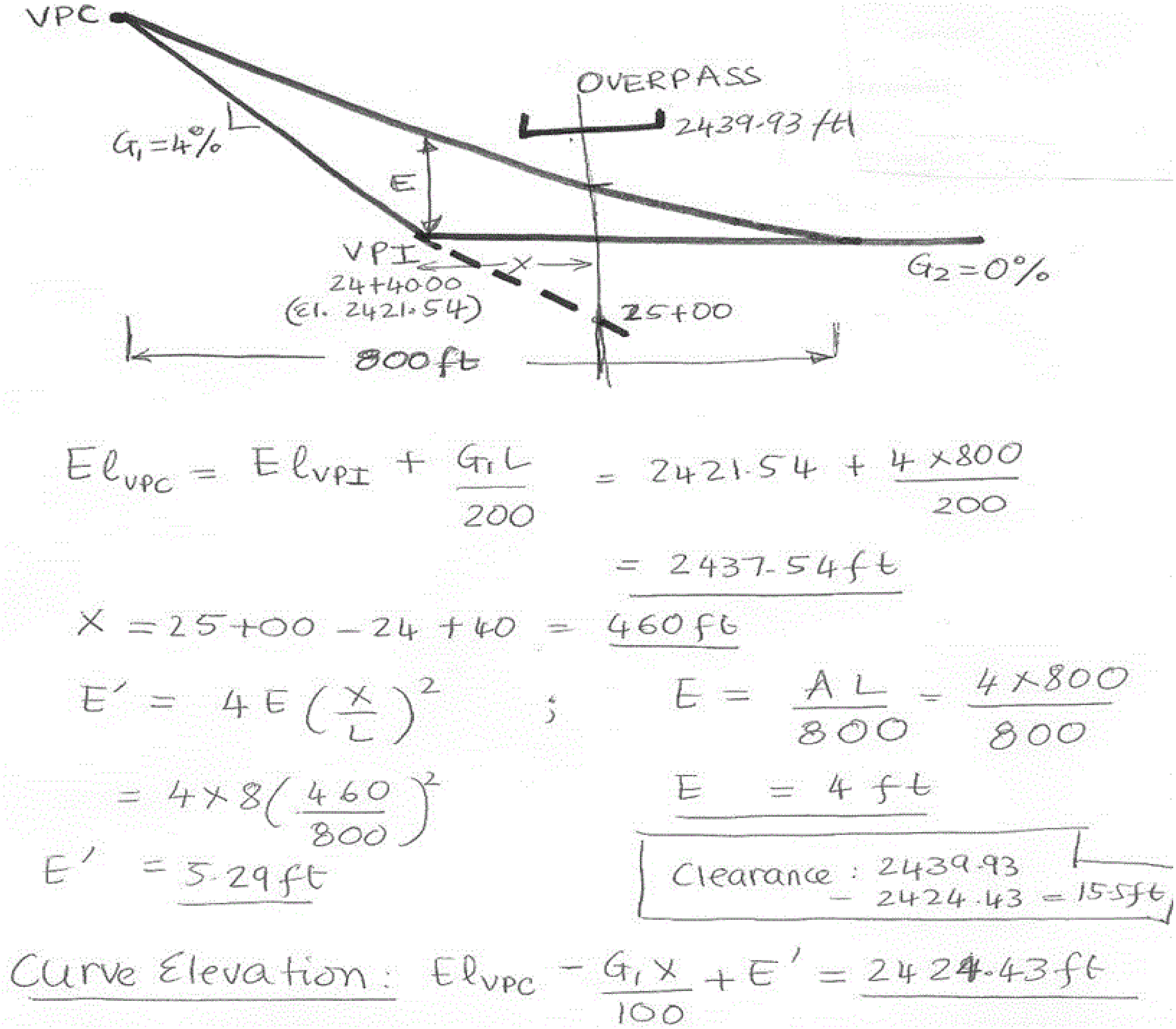


Figure 2: Hand-out with the solution [4].

Such an activity considerably increased the level of interest and provided a greater satisfaction of tackling the problem, rather than just following set example problems. On the other hand, learners remained engaged as they could visualise the relevance of the theory taught in class, and the more sequential learners, after the initial struggle, followed the problems through the explanation in class and the solution provided at the end of class. The author believes that the technique can be implemented in a 50 minute class, however, the number of in-class problems may have to be reduced.

Homework, Examinations and Quizzes

All homework and examinations were take-home and team-based. The homework exercises were to be submitted within a week and the examinations to be submitted within 48 to 72 hours, during which time the team-members could discuss their effort as they presented their solutions to complex analysis and design problems. The take-home examinations allowed the instructor to push the students to conduct complex analysis of existing transportation applications.

The examinations required them to refer to all available resources, beyond the textbook and the class notes, to solve the problems. On the other hand, the quizzes every week were conceptual questions to be attempted by each student individually and it was closed book. The purpose of the quizzes was to see if the students understood the concepts taught in the class. The quizzes were short, taking students an average of 10 minutes to answer the questions. The students who read the material regularly performed well in the quizzes.

Grading

The homework was weighted at 15%. Each of the three examinations (including the final examination) was also weighted at 15%, each. The project report was weighted at 10%. The twelve quizzes were weighted at a total of 30%.

Student Evaluation

The instructor's evaluation (Table 2) was positive. The responses to questions 2 and 5 clearly showed that a significant percentage of students (96%) were actively engaged in teaching and learning, and found the class stimulating. They also felt that the laboratory complimented well with the courses. The comments (Table 3) clearly showed that the students perceived the class positively. The students found the class to be challenging and liked the teaching style.

Table 2: Student evaluations (68 students over four courses).

| | | Student Scores (68 students) | | | | |
|---|---|---|---|---|---|---|
| | Question | 1 (poor) | 2 | 3 | 4 | 5 (excellent) |
| 1 | Was the professor enthusiastic about the subject? | | | 1 | 6 | 61 |
| 2 | Did the professor stimulate thinking? | | | 2 | 17 | 49 |
| 3 | Did the professor require a high level of student performance? | | | | 10 | 58 |
| 4 | Did the professor encourage questions and comments during the class? | | | 1 | 13 | 54 |
| 5 | Did the professor actively involve students in teaching and learning? | | | 3 | 19 | 46 |
| 6 | Were hand-outs and assignments helpful for understanding the subject? | | | 2 | 22 | 44 |

Table 3: Student comments.

| No | Comments |
|---|---|
| 1 | Expected students to work hard, but in return we learned a great deal. |
| 2 | Methods of grade examinations should be more standardised. Questions should be more clearly written. |
| 3 | I enjoy the challenge he presents to the students. I like his teaching style. |
| 4 | I enjoy the challenge. |
| 5 | Great method of teaching. |
| 6 | Good teacher. Expects a lot from students, but wants everyone to learn. |
| 7 | This class opened my eyes to a concentration of civil engineering that I really like. Because of this class, I have had an interview with the Department of Transport (DOT) and may end up in a transportation career. |
| 8 | I really enjoy and learn in this class. I think I would like to do an internship on transportation maybe even go into transportation. Thank you for all your help. |

Long Term Evaluation

Several students pursued transportation engineering after graduation and there have been favourable responses from employers. This has been complemented by the employers seeking this University students for employment in transportation engineering in subsequent years. The author also taught the same group of students in the advanced class of Transportation Design and Planning the following year. The author observed that they had a significant retention of the material and understood the concepts reasonably well. However, the instructor has not conducted a formal evaluation of student learning before and after the proposed technique study was implemented. Therefore, a formal evaluation of the proposed technique is not available.

Course Outcomes

The transportation course, which is traditionally a lecture course, was redesigned in spring 2005 to ensure the active participation of every student and that they understand the physical elements of transportation design. Throughout the course, the faculty conducted a stimulating and engaging exercise of requiring students to solve practical problems during class in teams of two immediately after covering the relevant theory. The practical problems were assigned before any example problems were solved in the class. During the class, faculty members were available to answer any of the students' questions. At the end, after following through the solution in class, the correct solution was distributed. This allowed the students to see how they thought through the problem and also provided them with a correct solution for future reference.

The author has identified the following five outcomes most relevant for the Transportation Engineering course from the above rubric to determine how the students performed over several semesters:

1. Students will demonstrate the ability to apply mathematics, science and engineering principles to solve engineering problems.
2. Students will use techniques, skills and modern engineering tools to facilitate the problem solving.
3. In classroom, design and laboratory activities, students will identify known variables, formulate key relationships between them and solve engineering problems.
4. Students will identify, formulate and solve problems in technical areas in which they have not received formal training.
5. Graduates will write effectively.

Figure 3 shows the assessment of transportation engineering course. After the new pedagogical technique was implemented, a steady rise in the percentage of students achieving the last four outcomes listed above was observed. Due to the structure of the course, which requires extensive problem solving, all the students achieved this outcome.

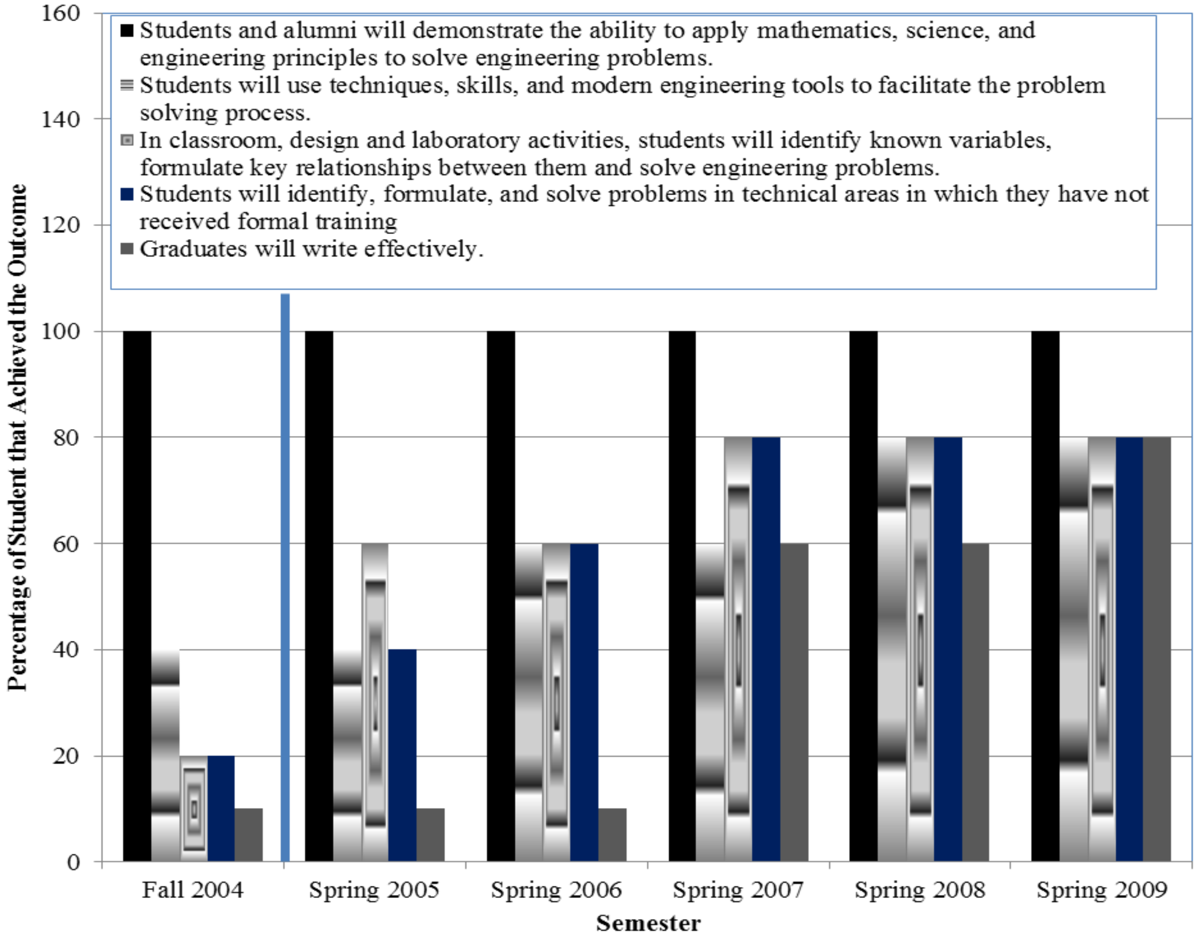


Figure 3: Assessment results for Transportation Engineering course [5].

Applicability to Other Engineering Courses

The proposed technique is effective in courses which require problem solving to enhance the understanding of the theory, such as Fluid Mechanics, Geotechnical Engineering, Environmental Engineering, Pavement Design [3], Surveying and Engineering Graphics [6], and Structural Analysis. On the other hand, the material covered in the Civil Engineering Materials course covers physical, mechanical behaviour of aggregates, asphalt, cement concrete and aggregates [7]. The information requires a more conceptual understanding of the materials and, hence, may not be appropriate to use this technique.

Increase in Class Sizes

The author found that this technique created a few unexpected problems, which were especially due to the increase in class size in the last couple of years. When the course was designed, there were 10-14 students; it was easy for the author to follow-up on the effort of students in class problems, where the most learning is happening. With the increase in class size to 28-30, it has become harder to pay close attention to all the students within the allotted time as they solve the in-class problems. However, the technique has still been effective. The author has supplemented the course with tutorial sessions beyond normal class time to supplement the in-class problems. It has been very hard because no teaching assistants are assigned for the classes at Rowan University. It is unclear at this time what the critical class size is before this technique becomes ineffective.

## CONCLUSIONS

Based on the four courses, the author strongly believes that the new technique is beneficial for both the instructor and the students. The methodology has been very effective; the students are very involved in the learning process and many have pursued careers in transportation engineering.

The author strongly believes that teaching is a learning process for the faculty. The author is continuously evolving and improvising the technique to ensure that the students stay current with the latest developments and have a fruitful learning environment.

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## BIOGRAPHY

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