# AC 2010-405: WERE THE INNOVATIVE TECHNIQUES EFFECTIVE? ASSESSMENT OF THE CIVIL ENGINEERING COURSES – CIVIL ENGINEERING MATERIALS AND TRANSPORTATION ENGINEERING

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# Were the Pedagogical Techniques Effective? Assessment of the Civil Engineering Materials and Transportation Engineering


## Abstract

The author had presented an innovative technique in civil engineering materials and transportation engineering at the past ASEE conferences. In the civil engineering materials course, lectures were modified to address the concepts required to conduct laboratory experiments and its practical applications. The objectives of the laboratory experiments were well defined; however, the students determined the process of conducting the experiment. The information provided to the students focused on the rationale behind developing standardized laboratory procedure and their broad ranging applications on the civil engineering industry.

The transportation course, which is traditionally a lecture course, was redesigned to ensure that every student actively participates and understands 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, the faculty was available to answer any questions they may have. At the end, after solving the problem in class, the solution was distributed. This allowed the students to see how they thought through the problem as well as provided them with a correct solution for future reference.

The purpose of this paper is to present a detailed assessment data of both these courses over a period of five years. The assessment period includes before and after the innovative techniques was implemented. The paper also presents the metrics that were used for assessing these courses. The paper demonstrates the following two aspects; 1) the assessment tool, and 2) the effectiveness of the innovative techniques. This will help identify the advantages and disadvantages of the technique.

## Introduction

The author had presented an innovative technique in civil engineering and transportation engineering at the past ASEE conferences[1,2]. Each of the techniques are described in detail below.

## Civil Engineering Materials

Civil engineering (CE) materials laboratory is taught in the junior year as a required course for all CE students. This is a two-credit course with a seventy-five minute class and a two-hour forty-minute laboratory every week. The typical enrollment is around 20 to 25 students and no teaching assistants are permitted. The limited laboratory space and equipment does not provide sufficient hands-on experience for all the students. Several universities have a situation similar to that of Rowan University, and this makes teaching core courses like civil engineering materials very challenging. The author re-designed the course to ensure that every student actively participates in the laboratory and understands the material behavior. The number of topics covered in this class was divided into four major areas, timber, aggregates, asphalt concrete and cement concrete. The course was modified to address the concepts required to conduct laboratory experiments and its practical applications. The objectives of the laboratory experiments were well defined, but it was up to the students to determine the process based upon fundamental principles taught in statics, structural analysis, solid mechanics. Each of the four groups were required to have their process approved from the instructor before conducting the laboratory. The methodology was very effective and the information was organized and flowed better. The information covered was extensive because the rationale behind developing standardized laboratory procedure had broad ranging applications on the civil engineering industry as a whole. This technique could be used in primarily teaching institutions that have limited space and equipment resources and do not allow multiple sections of laboratory

## Transportation Engineering

Transportation engineering is taught in the junior year as a required course for all civil engineering (CE) 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. Throughout the course, the faculty conducted a simulating 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, the faculty was available to answer any questions they may have. 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 students had to assimilate the information provided and translate it to the problem at-hand. This activity initially frustrated the students because they are traditionally used to following example problems. However, this exercise forced them to take the theoretical concepts and directly apply them to transportation engineering analysis and design problems. 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 visualize 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. For example, the faculty would explain the vertical curves and then immediately following the theory of vertical curves they had to design the curve according to typical constraints in the field. Individual short quizzes were assigned to ensure that they read and followed the material. All exams were take home team-based exams to be submitted within 48 to 72 hours, in which the team-members could discuss their effort as they presented their solutions to complex design and analysis problems. In this paper, the assessment tool utilized to assess these courses and the impact on student outcomes is presented.

**Assessment Tool**

**Before Fall 2004**

The assessment tool before Fall 2004 was primarily based on the following metrics:

1. Capstone senior design reports and presentations
2. Engineer-in-training exam
3. Senior exit interviews

The main disadvantage was that the assessment was based on metrics that were obtained long after the students had completed the courses.

**After Fall 2004**

The department developed a new rubric in summer of 2004 that would assess each course according to the ABET outcomes so that the assessment could be conducted throughout the four-year curriculum. The sample rubric for civil engineering materials is shown in Figure 1a, 1b, and 1c. If the particular outcomes were assessed, a response of Yes or NO was added, and explanation was provided in the case of Yes. The rating was based on a five point scale, 5 being 100% of the students achieved that outcome and 0 being none of the students achieved the outcome. The numbers were quantified based on the deliverables submitted by the student. The "Outcome" column is the interpretation of the ABET goals. The interpretation was developed by the faculty members in the CEE program.

After all the scores from all the courses taught in the semester were averaged, the outcomes where the average was less than 3 were flagged and discussed on how to improve a particular outcome. For example, for ABET Goal 4 (Objective 1) *The Civil Engineering Program at Rowan University will produce graduates who demonstrate an ability to communicate effectively (ABET G)*, one of the outcomes was *Graduates will demonstrate oral presentation skills*. IF, the average for all courses taught in a given semester was less that 3, ways of introducing presentations in the courses would be discussed. In addition to the rubric, the three previously utilized tools were also used in assessment.

| Course | Civil Engineering Materials | | | |
|---|---|---|---|---|
| Term | Fall '04 | | | |
| | | Addressed | Describe | Rating |
| **Goal 1 - Objective 1:** The Civil Engineering Program at Rowan University will produce graduates who demonstrate an ability to apply knowledge of mathematics, science, and engineering (ABET A) and, specifically, demonstrate a proficiency in mathematics through differential equations; probability and statistics; calculus-based physics; and general chemistry (ABET L). | **Outcome 1:** Students and alumni will demonstrate the ability to apply mathematics, science, and engineering principles to solve engineering problems. | y | Applied solid mechanics concepts to determine the flexural strength of wood beams | 3 |
| **Goal 1 - Objective 2:** The Civil Engineering Program at Rowan University will produce graduates who recognize the need for and the ability to engage in lifelong learning. (ABET I). | **Outcome 1:** Students and graduates will participate in activities that enhance their ability to remain current in their field. | y | Did a paper on sustainable material and new emerging technology | 4 |
| **Goal 1 - Objective 3:** The Civil Engineering Program at Rowan University will produce graduates who have the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (ABET K). | **Outcome 1:** Students will use techniques, skills, and modern engineering tools to facilitate the problem solving process. | y | students used excel | 2 |
| **Goal 1 - Objective 4:** The Civil Engineering Program at Rowan University will produce graduates proficient in a minimum of four (4) recognized major civil engineering areas (ABET M). | **Outcome 1:** Students and alumni will demonstrate the ability to perform analysis and design tasks in at least four (4) recognized major areas of civil engineering. | y | infrastructure materials | 2 |
| **Goal 2 - Objective 1:** The Civil Engineering Program at Rowan University will produce graduates who demonstrate an ability to design and conduct experiments as well as to analyze and interpret data (ABET B) and are able to conduct experiments as well as to critically analyze and interpret data in at least two recognized major areas of civil engineering (ABET N). | **Outcome 1:** Students will design and conduct experiments necessary to obtain the desired experimental data. | y | conducted four labs | 5 |

Figure 1a. Sample Assessment Rubric (ABET Goal 1)

| Course | Civil Engineering Materials | | | |
|---|---|---|---|---|
| Term | Fall '04 | | | |
| | | Addressed | Describe | Rating |
| **Goal 3 - Objective 1:** The Civil Engineering Program at Rowan University will produce graduates who have an ability to function on multidisciplinary and diverse teams (ABET D). | **Outcome 1:** Students will learn to function effectively on multidisciplinary and/or diverse teams. | y | Students worked in diverse teams | 2 |
| **Goal 3 - Objective 2:** The Civil Engineering Program at Rowan University will produce graduates who have an understanding of professional and ethical responsibilities (ABET F). | **Outcome 1:** Students will take pride in the profession of civil engineering and recognize their professional and ethical responsibilities. | n | | |
| **Goal 2 - Objective 2:** The Civil Engineering Program at Rowan University will produce graduates who demonstrate an ability to design a system, component, or process to meet desired needs (ABET C) and are able to perform civil engineering design by means of design experiences integrated throughout the professional component of the curriculum (ABET O). | **Outcome 1:** Students will design a system, component, or process to meet desired needs. | y | Concrete mixture design | 2 |
| **Goal 2 - Objective 3:** The Civil Engineering Program at Rowan University will produce graduates who demonstrate the ability to identify, formulate, and solve engineering problems (ABET E). | **Outcome 1:** In classroom, design and laboratory activities, students will identify known variables, formulate key relationships between them and solve engineering problems. | y | Students conducted laboratories to characterize wood, aggregates, cement, cement concrete and asphalt | 5 |
| | **Outcome 2:** Students will identify, formulate, and solve problems in technical areas in which they have not received formal training | n | | |
| **Goal 3 - Objective 3:** The Civil Engineering Program at Rowan University will produce graduates who have the broad education necessary to appreciate contemporary issues (ABET J) and understand the impact of engineering solutions in a global/societal context (ABET H). | **Outcome 1:** Students will develop an awareness of how the practice of Engineering impacts, and is impacted by, other disciplines, societal factors, and contemporary issues. | y | Limited discussion on use of recyled materials | 2 |

Figure 1b. Sample Assessment Rubric (ABET Goal 2 and Goal 3)

| | | Addressed | Describe | Rating |
|---|---|---|---|---|
| **Goal 3 - Objective 4:** The Civil Engineering Program at Rowan University will produce graduates who understand professional practice issues such as: procurement of work; bidding versus quality based selection processes; how the design professions and the construction professions interact to construct a project; the importance of professional licensure and continuing education; and/or other professional practice issues (ABET P). | **Outcome 1:** Graduates will enter the workplace cognizant of professional practice issues. | y | Discussed construction issues in civil engineering materials | 3 |
| | **Outcome 2:** Graduates will have an awareness of the licensure process and the impact of professional licensure on their career. | y | Discussed about EIT exam | 4 |
| **Goal 4 - Objective 1:** The Civil Engineering Program at Rowan University will produce graduates who demonstrate an ability to communicate effectively (ABET G). | **Outcome 1:** Graduates will write effectively. | y | students wrote lab reports and paper | 4 |
| | **Outcome 2** Graduates will demonstrate oral presentation skills. | y | Students presented on a a paper topic | 4 |

Figure 1c. Sample Assessment Rubric (ABET Goal 3 and Goal 4)

**Assessment Results**

**Civil Engineering Materials**

The author has identified the following five outcomes most relevant for the Civil engineering materials 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 design and conduct experiments necessary to obtain the desired experimental data.*
3. Students will develop an awareness of how the practice of Engineering impacts, and is impacted by, other disciplines, societal factors, and contemporary issues.
4. Graduates will write effectively.
5. Graduates will demonstrate oral presentation skills.

Figure 2 shows the assessment results for Civil Engineering Materials Course over the semesters. In the civil engineering materials course, beginning fall 2004, the lectures were modified to address the concepts required to conduct laboratory experiments and its practical applications. The objectives of the laboratory experiments were well defined; however, the students determined the process of conducting the experiment. The information focused on the rationale behind developing standardized laboratory procedure had broad ranging applications on the civil engineering industry as a whole. Since there was no specific assessment required for each of the courses before fall 2004, a quantitative comparison before and after the revised pedagogical technique was implemented is not available. Nevertheless, the results show that within two years of implementing the course, 60% of the students achieved the first outcome listed above. Within

three years, 60% of the students achieved all the five outcomes listed above. The students are doing a paper and a presentation on recycled materials and conducting cost-benefit analysis of using these "green" construction materials. This deliverable has significantly increased the number of people achieving the third outcome where "Students will develop an awareness of how the practice of Engineering impacts, and is impacted by, other disciplines, societal factors, and contemporary issues."

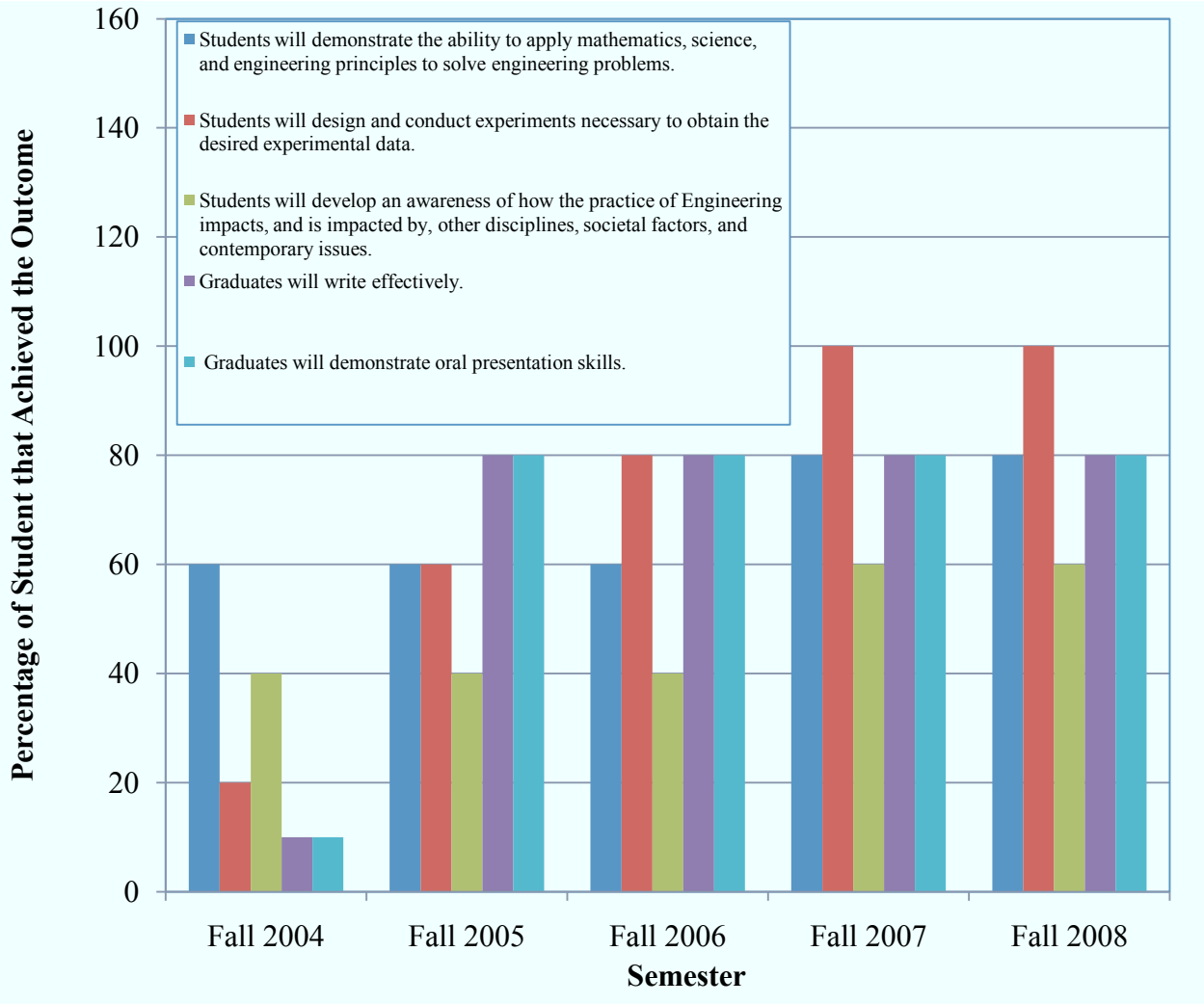


**Figure 2 Assessment Results for Civil Engineering Materials Course**

**Transportation Engineering**

The transportation course, which is traditionally a lecture course, was redesigned in spring 2005 to ensure that every student actively participates and understands 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, the faculty was available to answer

any questions they may have. At the end, after following through the solution in class, the correct solution was distributed. This allowed them 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 2 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.

**Summary**

Based on the data presented the following can be summarized:

1. The new rubric was effective in assessing the courses.
2. A steady increase in the percentage of students that has achieved the key outcomes was observed after the innovative techniques were adopted in the two courses.

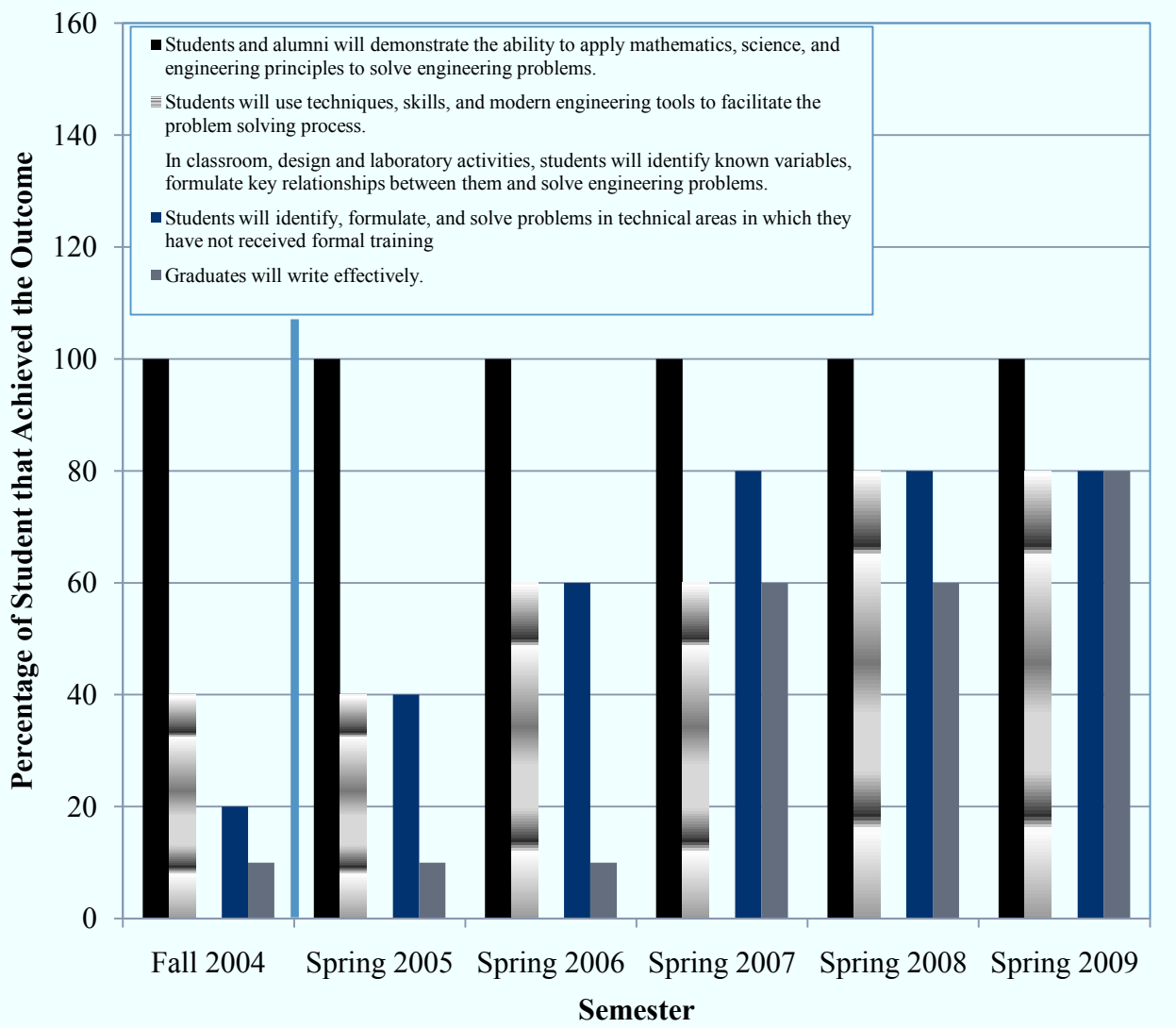


**Figure 3 Assessment Results for Transportation Engineering Course**

## BIBLIOGRAPHICAL INFORMATION

1. Mehta, Y. A. "Innovative Techniques To Teach Civil Engineering Materials Laboratory," Proceedings of the ASEE Annual Conference, Salt Lake City, UT 2004.
2. Mehta, Y. A, "Innovative Techniques to Teach Transportation Engineering," Proceedings of the ASEE Annual Conference, Chicago, IL 2006.