Pedagogical Techniques Employed in an Engineering Management Course

Simon T. Ghanat and William J. Davis
The Citadel, Charleston, SC

Abstract

To enhance the Engineering Management course at The Citadel and improve the student learning environment, a wide variety of active learning techniques were employed. These included incorporating learning objectives directly into the teaching of the course material, employing web-based pre-class responses, student presentation of chapter topic, team building activity, parking proposal study project, administrating daily quizzes and formative assessments, group problem solving, case studies, debates, and a number of other active learning activities. A pre- and post-test was developed based on key concepts in engineering managements to assess the knowledge gained over the course of the semester. The pre-test was administered to measure student's prior engineering management knowledge at the beginning of the term. The same short-answer test (post-test) was administered on the last day of semester to assess knowledge gained as a result of the course experience. This paper discusses the active learning techniques employed and the analyses of pre- and post-test results.

Keywords

Pedagogy, Engineering Management

Introduction

Curriculum that includes engineering management provides beneficial learning experiences for undergraduate engineering students including expanded skills sets, preparation for successful careers, and bridging of the competency gaps[1]. Development of professional and leadership skills has been shown to progressively improve through the college experience when included in the curriculum [2]. Placing an emphasis on "softer" engineering skills can be used to compliment traditionally required technical curriculum, where most of the course material is focused on teaching students' analytical methods[3]. Competencies of graduates to be prepared to function as engineering managers is an important topic for engineering educators and department assessment procedures to address[4]. Engineering management is an important course in the curriculum to engage students in developing lifelong learning skills, considering global economic issues and understanding the role of professional societies, beyond traditional analytical course material[5]. To prepare graduates with expanded professional skills, undergraduate programs are modifying curriculum and course material to meet the needs of the engineering profession[6].

Engineering Management course is a required three-credit hour course for undergraduate civil engineering students during their junior or senior year at The Citadel. The course focuses on professional skills needed to prepare graduates for careers in consulting engineering, public works administration, and construction management. The course has been offered over the previous 25-years, and in recent years has been modified to incorporate expanded professional skill outcomes as identified by American Society of Civil Engineers (ASCE) in "A Vision for Civil Engineers 2025,"and ASCE Body of Knowledge (BOK) 2 [7,8,9]. These professional society policy documents have influenced undergraduate engineering curriculum to include a more specific list of professional skills needed to meet career challenges and identification of target levels of cognitive development required to prepare students for professional practice.

Engineering Management Course at The Citadel

ASCE's "Vision for Civil Engineers in 2025" states that graduates should be prepared to lead society in establishing a sustainable world and improve the global quality of life. Future practicing civil engineers are envisioned to be master builders, stewards of the environment, innovators, managers of risk, and leaders of public policy. The ASCE Body of Knowledge (BOK) 2 provides a significant foundation for how engineering programs should prepare civil engineering students to meet ever increasing societal demands[10]. Based on this vision for future engineers set forth in ASCE BOK 2, faculty in the Department of Civil and Environmental Engineering (CEE) adopted 22 student outcomes, eight (8) of which are directly focused on developing student professional skills and competencies. As shown in Table 1, all eight (8) of these outcomes are included as course objectives in Engineering Management, identified with adopted levels of Bloom's Taxonomy.

Table 1 – Engineering Management Course objectives and Bloom's Taxonomy

Course Objective	Bloom's Taxonomy
1. Explain lifelong learning skills needed for successful engineering careers.	3-Application
2. Apply key aspects of project management, and scheduling within an engineering context.	3-Application
3. Demonstrate the ability of multidisciplinary teams to effectively examine engineering solutions.	3-Application
4. Use key business concepts to illustrate effective approaches to business development, project relationships, proposal submittal, and consultant selection.	4-Analysis
5. Relate characteristics of effective communication to project design, alternatives evaluation, and recommended solutions.	4-Analysis
6. Recognize fundamental influences of public policy on engineering standards, design requirements, and professional practice.	2-Comprehension
7. Explain legal and ethical responsibilities of professional engineers.	2-Comprehension
8. Identify leadership principles and proficiencies use to address challenges within the engineering profession.	2-Comprehension

Pedagogical Techniques Employed

Students learn more effectively by actively analyzing, discussing, and applying content in meaningful ways rather than by passively absorbing information[11,12], therefore, students benefit when instructors employ pedagogical strategies that promote active learning. Various teaching and learning techniques were employed to improve the student learning of key concepts in engineering management. These included incorporating learning objectives directly into the teaching of the course material: employing short YouTube videos; student presentation of chapter topic; team building activity; employing “real world” homework assignments (parking proposal study); administrating daily quizzes and formative assessments; debate; and a number of other techniques.

Web-based pre-class reading responses[13, 14] were used to motivate students to prepare for class regularly. Students were required to respond to one, open-ended question on the course website prior to each lesson. Before each lesson, student responses were examined and the in-class activities were tailored to meet their actual needs. At the beginning of each lesson, pre-class reading responses were summarized on the board and common errors were discussed**.** Students were provided with daily handouts, which contained a partially completed outline of the lesson and a number of qualitative questions, with blank spaces for answers. Mini-lectures were used to correct the misconceptions and allow the students to fill-in-the-blank in their handouts.

To assist students with learning of the course material and to promote active learning, each student was required to teach a lesson during the semester. This method can benefit both those students who are being taught and the peer teachers[15]. Peer teachers can reinforce their own learning by instructing others and students feel more comfortable when interacting with a peer[15]. Daily quizzes on assigned reading were administered at the beginning of the class. These quizzes were given to increase students’ attendance, preparation, participation, study habits and to improve the exam scores. Short YouTube videos were shown daily to facilitate and stimulate some introductory discussions on each day’s topic.

One-Minute paper[16] was used to monitor student learning and address students’ misconceptions and preconceptions. Students were typically asked to write a concise summary of the presented topic, write an exam question for the topic, or answer in 60 seconds a big picture question from the material that was presented in the current or previous lesson.

In-class debates cultivate the active engagement of students, placing responsibility of comprehension on the shoulders of the students[17]. Debates afford many benefits besides promoting active engagement and mastery of the content[17]. Because debates require listeners and participants to evaluate competing choices[7], they develop higher order critical thinking skills by moving up Bloom’s Taxonomy [17,18.] For these reason, debates of ethical dilemma case studies were employed to further facilitate active learning and promote critical thinking skills. Students were provided with three ethical dilemma case studies. The class was divided into six teams; two teams were assigned to each case. The members of each team worked together to prepare a solution to their ethical dilemma, which they presented to the class. Students were required to devise a solution, explain and defend their solution through an ethnically-based argument. Each team was required to prepare a presentation consisting of three slides (Slide #1 summarizing the case study, and Slides #2-3 presenting the group's solution to the ethical dilemma problem). One group presented a summary of the case and the other group provided their solution to the problem. Finally, the first group gave a critique of the second group's solution, at the end of which they briefly stated their solution. Following this, there was a brief discussion period open to the entire class. The second group was asked to provide a critique of the first group's argument, not simply presenting their own argument. Therefore, the first group was required to use the second group's slides to structure their critique, rather than using their own. Teams were assessed based on the strength and delivery of their ethical argument. Everyone was responsible to be familiar with all cases.

An ice breaker activity was used to facilitate the team work prior to beginning of the parking study project. Each team was asked to build the tallest free-standing structure in18 minutes, out of 20 sticks of spaghetti with one-yard of tape, one-yard of string, and one marshmallow. This activity was a great way for each team to get acquainted and dive-in to the planning of their team project.

To further deepen the understanding of the engineering management concepts, students were asked to conduct an in-depth study of The Citadel campus parking. Students were told that the demand for parking at The Citadel has significantly increased the last few years and often the parking facilities cannot serve the parking demand. Students were asked to prepare an engineering proposal on The Citadel parking study to be submitted to Citadel decision makers and transportation engineering faculty in the Civil Engineering Department. Each team prepared a proposal which contained a detailed scope of work; management plan; and schedule of tasks.

Assessment Measure

A ten-question pre- and post-test was developed based upon the key concepts in engineering management course (see Table 2). The pre-tests were administered to measure students' prior engineering management knowledge and to identify student misconceptions at the beginning of the semester. The same short-answer test was administered on the last day of the semester to assess knowledge gained as a result of the course experience. Each question was scored against an established correct answer. When grading the pre- and post-test instruments, instructor was looking for key words and phrases. It is important to note that neither the pre-test nor post-test counted toward the course grade.

Figure 1 analyzes students' performance on each question on the pre-test and post-test. Student performance (at below 50% level) on all questions except Question #9 of the pre-test is an extremely poor performance, indicating little to no prior experience with these concepts. The strongest score on the pre-test was Question 9 (engineering ethics question), which is an important theme in the engineering management course that the students successfully mastered. Student's high pre-test performance on Question 9 suggests that they are sufficiently able to apply their prior knowledge to certain aspects of engineering management. The scores increased on all of these questions for the post-test, although the scores for Question 6 were still slightly low. The strongest scores on the post-test were Questions 1, 5 and 7; these questions were all fundamental course concepts that are highly emphasized throughout the semester. The weakest score on the post-test was Question 6 (consequences of uncompensated scope creep).

Figure 1 illustrates the distribution of the pre-test and post-test mean scores for the students in this study (n =14), respectively. The pre-test scores ranged from zero to five out of ten possible points. Fifty-eight percent of students scored zero or one on the pre-test. Ten percent of students scored a three or four on the pre-test. The results of the pre-test indicate that the students are entering the engineering management course with little prior knowledge. The mean increased significantly from pre- to post-test and the standard deviation also increased, indicating more scatter in post-test results.

Table 2. The short-answer questions on the pre- and post-test

No.	Question
Q1	Describe what critical path is in project management.
Q2	Define acronym RFP in engineering management.
Q3	What are the characteristics of a project? What are the three key project constraints?
Q4	Explain the need for lifelong learning and describe skills required of a lifelong learner
Q5	Describe the term multiplier, which is commonly used in the consulting business.
Q6	What are the consequences of uncompensated scope creep?
Q7	Explain the role of a leader and list important leadership principles and attitudes
Q8	What is the difference between Quality Control and Quality Assurance?
Q9	A licensed professional engineer was convicted of felony totally unrelated to his consulting engineering practice. What actions would you recommend be taken by the state registration board?
Q10	What is Tort?

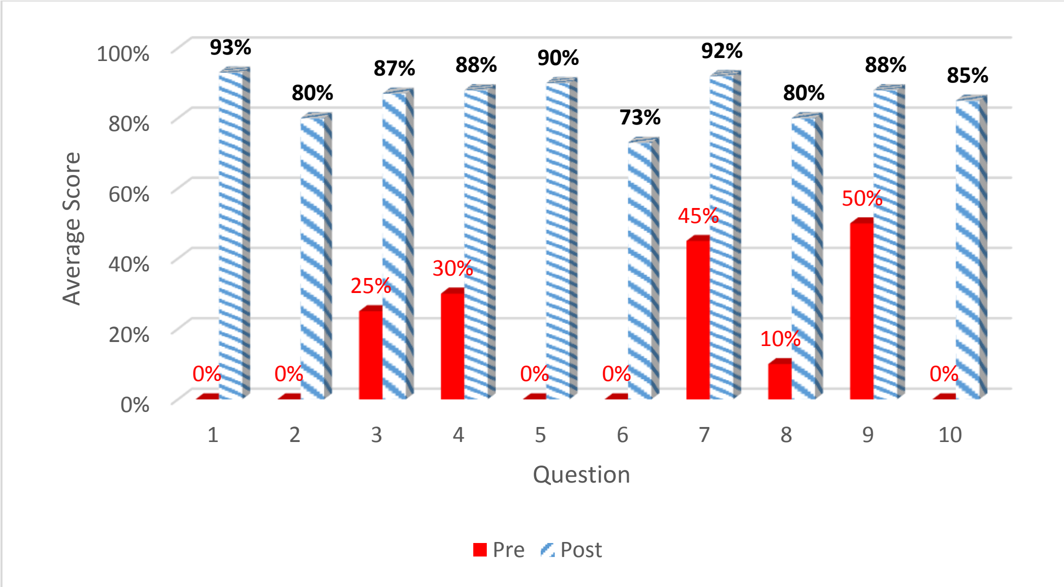

Figure 1. Mean score for each question on the pre- and post-test

Statistical analysis was conducted on the pre-test and post-test data to detect changes in students' understanding of the concepts over the course of the semester. Comparison of the pre- and post-test scores was completed using the paired t-test at five percent level of significance, and the results are shown in Table 3. The difference between the means was statistically significant showing substantial improvement from pre-test to post-test at five percent level of significance. The results showed that there was a significant difference in scores for pre-test and post-test. There was an increase from an average score of 1.29 out of 10 points equivalent to 12.9 % on the pre-test to an average score of 7.0 out of ten points equivalent to 70 % on the post-test (mean paired diff = 5.71, SE = 0.32; t (14) = 17.79, p-value < 0.001) (see Table 3). The difference between pre- and post-test means was statistically significant (p <0.001), revealing substantial knowledge gained.

Table 3. Results of Paired-t test

	Pre-Test		Post-Test				
N	Mean	St Dev	Mean	St Dev	Mean Diff	t	p-value
14	1.29	0.73	7.0	1.47	5.71	17.79	<0.001

Conclusions

Students entered the engineering management course with little prior knowledge. The difference between the means of pre-test and post-test was statistically significant, showing improvements from pre-test to post-test. There was an increase from an average percentage correct of 12.9% on the pre-test to an average percentage correct of 70% on the post-test. The pre-test to post-test changes in overall scores was influenced by the various pedagogical techniques used in engineering management course.

References

1 Unal, R., Keating, C., & Kauffmann, P., & Peterson, W., “Engineering Management The Minor of Choice,” Proceedings of the American Society of Engineering Education Annual Conference, Montreal, Canada, 2002

2 Dunn, P., Pearce, B., “Introducing Project Management to Senior Civil Engineering *Students,”* Proceedings of the American Society of Engineering Education Annual Conference, Chicago, IL, 2006.

3 Pascarella, E. T., Terenzini, P. T. (Eds.). (2005). *How College Affects Student : Volume 2 A Third Decade of Research*. *: Volume 2 A Third Decade of Research*.

4 Merino, D. “*A Proposed Engineering Management Body of Knowledge (Embok)”* Proceedings of the American Society of Engineering Education Annual Conference, Chicago, IL 2006.

5 Murray, S., Raper, S., “Encouraging Lifelong Learning For Engineering Management Undergraduates. Proceedings of the American Society of Engineering Education Annual Conference, Honolulu, Hawaii, 2007.

6 Davis, W., K. Bower, R. Welch, D. Furman, “Developing and Assessing Student’s Principled Leadership Skills: to achieve the Vision for Civil Engineers in 2025,” Proceedings of the 120th. American Society for Engineering Education Annual Conference, Atlanta, GA, 2013.

7 The Vision for Civil Engineering in 2025, American Society of Civil Engineers, Reston, VA, June 2006.

8 Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession, American Society of Civil Engineers, Reston, VA, 2009.

9 Civil Engineering Body of Knowledge for the 21st Century, Preparing the Civil Engineer for the Future, Second Edition, Committee on Academic Prerequisites for Professional Practice, American Society of Civil Engineers, Reston, VA, 2008.

10 Walesh, Stuart G., "The Raise The Bar Effort: Charting The Future By Understanding The Path To The Present – The BOK and Lessons Learned," Proceedings of the American Society for Engineering Education Annual Conference, Austin, TX, 2012.

11 Bonwell, C., and Eison, J. Active learning: Creating excitement in the classroom. Washington, D.C. Jossey-Bass, 1991.

12 Mayers, C., and Jones, T. Promoting active learning: Strategies for the college classroom. San Francisco: Jossey-Bass, 1993.

13 Novak, G.M., Patterson, E.T., Gavrin, A.D., and Christian, Just in Time Teaching: Blending Active Learning with Web Technology, Prentice-Hall, Upper Saddle River, N.J, 1999.

14 Ghanat, S.T., Kaklamanos, J., Ziotopoulou, K. , Selvaraj, I , and Fallon, D. A Multi-Institutional Study of Pre- and Post- Course Knowledge Surveys in Undergraduate Geotechnical Engineering Courses,” Proceedings of ASEE, New Orleans, LA, 2016.

15 Whitman, N.A. & Fife, J.D. *Peer Teaching: To Teach Is To Learn Twice*. ASHE-ERIC Higher Education Report No. 4. 1988.

16 Angelo, T.A. and Cross, K.P. *Classroom Assessment Techniques* A Handbook for College Teachers: 2nd ed, 2nd ed, Jossey-Bass Publishers, San Francisco, CA, 1993.

17 Snider, A., and Schnurer, M. Many sides, Debate across the curriculum. New York: International Debate Education Asscitation, Upper Saddle River, N.J, 1999.

18 Freeley, A., and Steinberg, D. Argumentation and Debate: Critical thinking for reasoned decision making, 11th ed, Belmont, CA, 2005.

Dr. Simon T. Ghanat, P.E.

Simon T. Ghanat is an Assistant Professor of Civil and Environmental Engineering at The Citadel in Charleston, South Carolina. He received his Ph.D., M.S. and B.S. in Civil and Environmental Engineering from Arizona State University. Dr. Ghanat's research interests are in the areas of Engineering Education and Geotechnical Earthquake Engineering. He previously taught at Bucknell University and Arizona State University.

Dr. William J. Davis P.E.

William J. Davis is a Professor in Civil & Environmental Engineering at The Citadel in Charleston, SC. He received his Ph.D. in civil engineering from Georgia Tech and is a registered professional engineer. His research interests focus on transportation infrastructure planning and design, highway safety, and active living by design. He teaches courses in transportation engineering, geographic information systems, pavement design, land surveying, and engineering management. He has served on numerous technical committees for ASCE, TRB, ITE and ASEE