AC 2011-746: DEVELOPMENT OF AN INTRODUCTION TO INFRASTRUCTURE COURSE

Matthew W Roberts, University of Wisconsin, Platteville

MATTHEW ROBERTS is an Associate Professor in the Department of Civil and Environmental Engineering. Dr. Roberts earned his B.S. in Civil Engineering from Brigham Young University in 1993 then spent four years in the U.S. Air Force as a civil engineering officer. He received his Ph.D. from Texas A&M University in 2002 and has been teaching structural engineering topics at the University of WisconsinPlatteville since then.

Philip J. Parker, University of Wisconsin, Platteville
Michael K Thompson, University of Wisconsin, Platteville

M. Keith Thompson teaches Structural Mechanics and Reinforced Concrete Design at the University of Wisconsin - Platteville. His interests are in design of reinforced concrete structures and he is a member of the ACI Committee 408 "Bond and Development of Reinforcement." He received his PhD from the University of Texas at Austin and had previously worked as a bridge engineer for Figg Engineering in Tallahassee, Florida.

Barb A Barnet, Univeristy of Wisconsin - Platteville

Barb Barnet, PhD, Statistics, has served as a faculty member at UW-Platteville for 12 years.

Development of an Introduction to Infrastructure Course

Abstract

An "Introduction to Infrastructure" course has been developed in the Civil and Environmental Engineering Department at [institution]. The course is intended for sophomore students and serves two main purposes:

1. To introduce the students to civil and environmental engineering and the subdisciplines, and
2. To begin the development of an awareness of infrastructure and the challenges facing the United States with respect to infrastructure overcapacity and degradation.

A particularly noteworthy aspect of the course is that students completed assessments of various infrastructure components, inspired by the assessments completed for the "Report Card for America's Infrastructure" published by the American Society of Civil Engineers.

The course was developed as part of a National Science Foundation grant in the Course, Curriculum, and Laboratory Improvement (CCLI) program. A pilot offering of the course was offered in Spring 2010 and a second offering of the course is scheduled to be offered for Spring 2011. Preliminary direct assessment efforts from the pilot offering indicate that the course was successful in meeting instructional goals. Indirect assessment gives further indication that the course was successful in preparing students for their studies in civil and environmental engineering, in helping the students gain appreciation of infrastructure problems facing the United States, and in developing teamwork skills.

Background

The infrastructure of the United States is exceeding its design capacity and is aging, requiring maintenance and renovation. In order to meet this challenge, a need exists to produce civil and environmental engineers who have a broad understanding of the pressing needs of the infrastructure of the United States. With this in mind, the faculty of the Civil and Environmental Engineering (CEE) Department at [institution] reviewed the program curricula (for the first time in at least 20 years) and decided to redesign the curricula with an infrastructure theme. A Department Level Reform planning grant from the National Science Foundation (NSF) was used to plan an overhaul of the curriculum that infuses an infrastructure theme throughout.

Once the curriculum planning was accomplished, further funding was secured under the Course, Curriculum, and Laboratory Improvement (CCLI) program of NSF to implement an "Introduction to Infrastructure Engineering" (hereafter referred to as 'I2I') course, which is intended to serve as the first CEE course for undergraduates in the Civil and Environmental Engineering degree programs. The I2I course was first offered in Spring 2010.

Overview

The I2I course is intended for sophomore students, and will most likely be the first course the students take from the CEE Department. The general goals of the course are:

1. To introduce the students to civil and environmental engineering and the subdisciplines, and

2. To begin the development of an awareness of infrastructure and the challenges facing the United States with respect to infrastructure overcapacity and degradation.

3. To teach students about teamwork and to help them to function effectively in teams.

This last goal is an important part of the course because the students will be working extensively in teams in future courses of the curriculum. One of the course modules covers the general attributes of effective teams[1] and the personal skills and attitudes that students need to be excellent team members. The personal attributes are based on the teamwork framework developed by the Comprehensive Assessment for Team-Member Effectiveness (CATME) instrument.[2]

There are other goals of the course, but this paper will be restricted to discussing the success of the course in meeting these three goals.

During and after the pilot offering of the course, assessment efforts were undertaken to determine how well these three course goals were met. The initial assessment results, as discussed below, indicate that the pilot offering of Introduction to Infrastructure Engineering successfully met the course goals. Furthermore these assessment results and observations by the instructor have suggested areas where the course could be improved.

Course Development

The success of the course was in large part due to the involvement of department faculty in developing course modules. Many of the ideas for the course originated from a brainstorming session during the summer of 2007. All faculty from the CEE Department participated, and the brainstorming was led by a member of the department's Advisory Board. The two questions for which the faculty brainstormed answers were: What are the attributes of the ideal engineer in 2020?; What curriculum additions/revisions are necessary to produce the ideal engineer of 2020?

Following this brainstorming, a grant from the National Science Foundation Course, Curriculum, and Laboratory Improvement program allowed the I2I course to be developed. Through discussions among the entire department, it was decided that the basis of the course would be an introduction to the five sub-discipline areas of civil and environmental engineering offered by the UWP CEE department (construction, environmental, geotechnical, transportation, and structural). As part of this introduction, each sub-discipline area would assign students to assess a portion of the local infrastructure.

All faculty in the CEE department participated in developing the materials for the modules, with one module created for each sub-discipline area. Faculty worked in their area(s) of expertise. The result is a set of materials that is targeted directly at sophomore students. Each sub-discipline area was instructed to devote one lesson of their module to introducing their sub-discipline and three lessons to explaining one (or more) facet of the sub-discipline. For each module, students had to gain knowledge and obtain skills that would allow them to complete a culminating infrastructure assessment assignment. This assignment is inspired by the infrastructure assessments carried out by the American Society of Civil Engineers (ASCE) Report Card on America's Infrastructure.[3]

For each topic, module developers had to:

- Provide background reading – background reading was very important, as the instructor of the class will not have expertise in all subdisciplines of civil and environmental engineering.
- Provide lesson objectives.
- Provide in-class activities (including lecture notes) – developers were encouraged to incorporate active learning practices into their class periods.
- Provide in-class assessments (e.g. minute papers, muddiest point evaluations).
- Provide out-of-class activities (e.g. homework assignments).
- Address selected cross-cutting themes.

A total of 20 cross-cutting themes were included. To reinforce these important concepts, they were each revisited in at least two modules. The themes were: analysis vs. design; sustainability; public financing; societal impact; ethical considerations; economic impacts; historical perspective; security; constructability; political considerations; systems approach; maintenance and rehabilitation; planning; forecasting/modeling; operations; access; risk; teamwork; link to more complex material; and interrelationships between sub-disciplines.

Assessment of Course Goals

Pre- and Post-Test

One of the assessment tools designed for use with the course was a pre- and post-test. (The I2I assessment instrument, which was used for both the pre- and post-test, is included as Appendix A.) The purpose of this test was to gauge students' knowledge about infrastructure prior to taking the course and then comparing to what they knew at the end of the course. This exam was developed by asking the faculty involved in developing the modules to write questions pertaining to that unit of material. The questions were then assembled, edited, critiqued by the faculty project members and pilot tested on a group of volunteer students. After the pilot test, the results were analyzed and the final questions for the test were selected. The final version of the test contains 20 questions, some multiple choice and some open-ended. The students were given a full class period in which to complete the test.

The results were analyzed using non-parametric statistics, due to the low sample size. Figure 1 shows the p-values for each, where the null hypothesis is that no difference exists between the pre- and post-test scores and the alternative is that the post test score was higher. In evaluating student answers it was felt that Question 7 did not adequately measure student knowledge, so it is not displayed in Figure 1. Question 10 is not displayed on the chart as the average scores for the pre- and post-test were equal. Question 20 was the only question where the pre-test average score was slightly higher than that of the post-test. For the remaining questions, the post-test score was higher and for 7 questions, it was significantly higher.

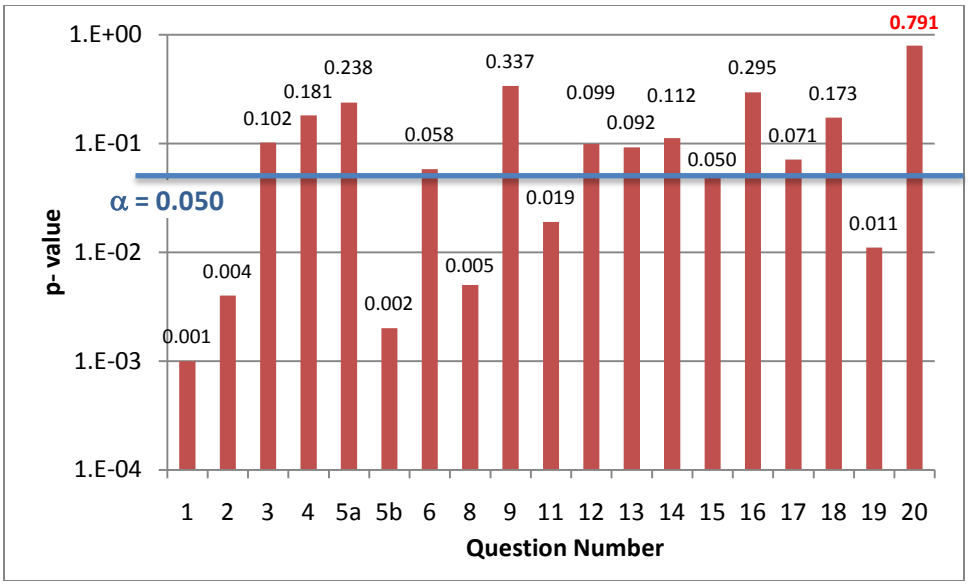

Figure 1 Statistical analysis of pre/post test results.

The pre- and post-test questions that corresponded to the three goals are shown in Table 1.

Table 1 – Relationship of Course Goals to pre- and post-test assessment questions

Goal #1 (introduction to civil and environmental subdisciplines)	Questions 3, 4, 5a, 5b, 6, 7, 8, 9, 11, 14, 15, 16, 17, 18, 19, 20
Goal #2 (awareness of infrastructure issues)	Question 2
Goal #3 (teamwork)	Question 10

The questions not listed in Table 1 were used to assess other aspects of the course that are not covered by the three goals.

With respect to Goal #1, the assessment results are encouraging. With the exception of question 20, the students improved from pre- to post-test. In many cases (questions 5b, 8, 11, and 19), the gains were statistically significant; given the small sample size, this is very encouraging.

Only one question was included on the assessment instrument pertaining to Goal #2. Specifically, the question asked the students to identify the state of the infrastructure, as measured by the *Report Card for America's Infrastructure*.[3] Interestingly enough, the students' answers on the pre-test indicated that the students' perception of the infrastructure was *worse* than the grades assigned in the *Report Card*. Five of the eleven students thought the *Report Card* was mostly D's and F's, instead of the actual C's and D's, while three students thought the grades were better (B's and C's). On the post-test, all but one student correctly answered that the grades are mostly C's and D's.

Unfortunately, as mentioned above, we were not able to learn anything about attainment of Goal #3 because the scores from the pre- and post- test for question 10 were equal.

The results of the pre- and post-test assessment indicate that the course was particularly successful in meeting Goal #1. There is an indication that Goal #2 was met as well, but no information regarding the attainment of Goal #3 was learned.

Student Surveys

To determine the students' attitudes about the course in general and the teamwork portion of the course in particular, a survey was designed and administered after the semester ended. The results were very favorable about the course. All of the students agreed that they enjoyed the course and ninety percent agreed the material was presented clearly, the material would be applicable in their job or future courses, and that they have a greater understanding of U.S. infrastructure problems. The full survey results are included as Appendix B.

Survey results that helped to assess Goals #1, #2, and #3 are shown in Figure 2. Students answered the questions using a 5-point Liker scale: 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree.

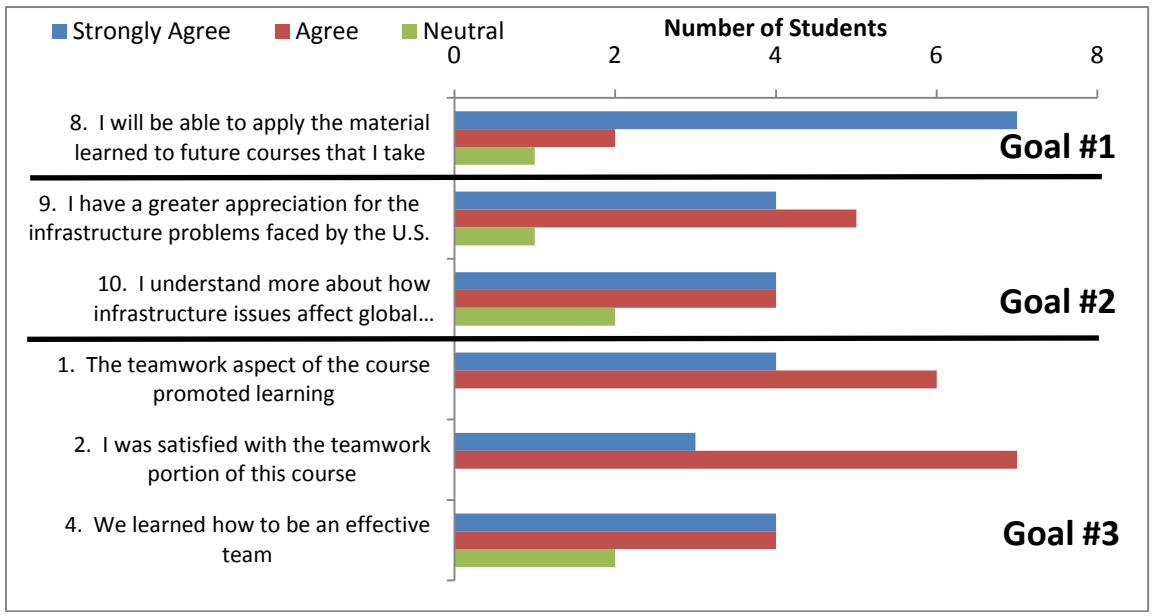

Figure 2 – Student survey results that were related to course goals.

As indicated by Figure 2, the student survey further confirmed that the course was successful in Goal #1 (introduction to civil and environmental subdisciplines). The students also perceived that they better understood infrastructure issues, indicating that the course had some success in meeting Goal #2. Lastly, the questions related to teamwork indicate that the students felt working in student groups helped the course, giving some indication that the course met Goal #3.

The students were also asked for general feedback on the course. No assessment was attempted on the general comments. However, one comment from a senior was especially gratifying to read:

> "In general I feel the class was a major success. Being in my fourth year, I wish we had the information and the class in my freshman year as a required class. It would have really opened my eyes to the beauty of engineering earli-

er, and would have been a significant help in my course work in other classes."

Lessons Learned (So Far)

While the pilot offering was generally successful in meeting the course goals, there are many ways in which the course development and presentation of materials could have been improved. Some of the more important lessons learned:

- A collective effort at creating a course can result in an exciting and inspiring course.
- A course developed by the entire faculty of the department results in everyone having buy-in.
- The rigor of the modules varied, with some modules being over-ambitious, while other modules did not include enough rigor.
- Brainstorming, with appropriate rules, is amazingly productive.
- Many of the lectures within modules are not connected very well and better transition material is needed. Perhaps in the mind of the module developer, the transitions are obvious. However, to the non-experts, the transitions are not as obvious.
- Module developers would have benefitted from having an example module to follow.
- The creativity of a group is much greater than the sum of the creativity of the parts!
- Faculty members are very talented at creating interesting and inspiring topics in their sub-discipline areas.
- Faculty members follow good directions about as well as do students.
- Faculty members follow poor directions as poorly as do students.
- Faculty members heed deadlines as well as do students.
- For the most part, faculty members did not provide enough background reading to help the non-experts teach even introductory material. In many cases, the background reading was too closely aligned with the notes, thus missing the main point of the reading which is to give the lecturer some insight into the breadth of the topic.
- Two new themes were introduced in the pilot offering: engineers as researchers and redundancy. Material needs to be prepared for these topics.
- Many of the themes need introductory material. Some themes are introduced by an entire lecture (ethical implications), but many of the others have no unique lecture material to support them.
- The integration of safety into the course is very well done. Students take it very seriously, and the requirement to complete a Job Safety Analysis for every site inspection helps to reinforce the importance of safety. Students see the relevance and authenticity of such an assignment.
- Student checkout of equipment for infrastructure assessment was haphazard at best. In the future, the equipment will be stored in the same room that houses the surveying equipment, and student workers will be utilized to check the equipment out to students.

Lessons were also learned with respect to the assessment instrument used. As mentioned previously, analysis of the pre- and post-test results led the authors to question whether some students fully understood the questions as they were intended by the course developers. In addition, the vast majority of the questions cover Goal #1 (Introduction to civil and environmental subdisciplines) at the expense of the other goals and more "big picture" aspects of the course that are

important. During the second pilot offering of the course, which will be in Spring 2011, a new version of the pre- and post-test will be tried. Questions will be open ended short answer or brief essay type. The questions will also be less reliant on specific engineering terminology to read or to provide an answer. Hopefully this will allow students to demonstrate more fully whether they understand a concept in general terms even if they do not know the engineering "lingo" that goes with the concept. In determining value added between the pre- and post-test, the authors will use rubrics that assign points based on various features of the answer including: how often do they use correct terminology or avoid incorrect terminology in their answer (indicating basic knowledge gained); can a student cite appropriate examples to support an answer (also indicating knowledge gained); and how many and how well does a student connect ideas together (indicating that they have developed a coherent organization of the knowledge they have gained – the connections they make should be appropriate and meaningful to count). The philosophy of the rubric for the new pre- and post-test questions is to look for key features that distinguish experts from novices as discussed in *How People Learn*.[4]

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 0837530 (CCLI). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

References

1. **Smith, Karl A and Imbrie, P K.** *Teamwork and Project Management.* Boston : McGraw Hill, 2004.

2. **Ohland, Matthew W., et al.** Developing a Peer Evaluation Instrument that is Simple, Reliable, and Valid. *Proceedings of the 2005 ASEE Annual Conference.* 2005. CD ROM.

3. **American Society of Civil Engineers.** Home. *Report Card for America's Infrastructure.* [Online] 2009. http://www.infrastructurereportcard.org/.

4. **National Research Council.** *How People Learn: Brain, Mind, Experience, and School.* Washington DC : National Academy Press, 2000.