Civil Engineering Outreach with Middle School Age Students

Rod E. Turochy[1]

Abstract – This paper describes an outreach effort to introduce civil engineering to middle school aged children. A course consisting of nine 75-minute sessions was developed in which basic concepts of civil engineering were explained and reinforced with a wide variety of activities. While "presentations" or "slide shows" played an important role, other activities included were demonstration of materials and structures, hands-on learning through simple construction and experimentation, reinforcement of concepts through a field identification and observation, and writing activities. This range of activities was intended to help students learn through many modes and understand course concepts at many levels. The course was then evaluated by examining changes in student attitudes toward civil engineering as a learning subject and as a career. Students were also asked a series of open-ended questions to obtain their impressions of what they learned.

Keywords: civil engineering, outreach, K-12

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INTRODUCTION

The need to raise public awareness and dispel misconceptions of engineering is well-established. Also well-documented is the need to attract young people to engineering as a career choice. These notions served as foundations for the goals and content of a civil engineering outreach course, as well as providing its motivation. The content briefly placed civil engineering in context within engineering at a broader level and then quickly delved deeper, defining and providing examples of the major subdisciplines of civil engineering. The bulk of the course sessions were then devoted to each of the subdisciplines, covering the basic concepts and purposes of each, supported with selected detail. The final course session was devoted to a course summary and review (using a game activity) and obtaining information from the students on how their perceptions and understanding of civil engineering changed during the course. A series of basic questions to obtain this information was asked before and again after completion of the course; differences in the responses were evaluated and interpreted. This paper then closes with some "lessons learned" through this course, associated suggestions for future instructors, and conclusions about the course.

BACKGROUND AND MOTIVATION

The need to raise public awareness and understanding of what engineers do is well-established, such that it has received significant attention at the national level in recent years, supported by publications such as *Raising Public Awareness of Engineering*, published by the National Academy of Engineering [NAE, 2002]. Common misconceptions of engineering abound among both adults (that are not engineers) and youth. In an editorial in "Issues in Science and Technology", William A. Wulf, then-President of the National Academy of Engineering, wrote that "Something is wrong with the public perception of engineering" [Wulf, 1998]. Part of the misperception is simple misunderstanding. Wulf noted a poll that found more people associated engineers with train operators than with key engineering traits such as "inventive" and "creative". A more recent study involving 504 schoolchildren in grades 1–5 found that repairing cars, installing wiring, and operating machines were more likely to be perceived as work done by engineers then were efforts to "design ways to clean water, design things, and improve machines" [Cunningham et al., 2005]. Therefore, there is a clear need for outreach from engineers and engineering educators to correct these misperceptions.

The Engineering K-12 Center of the American Society for Engineering Education published a set of guidelines for improving K-12 engineering education and outreach [ASEE, 2004]. These six guidelines pertain to: hands-on learning, interdisciplinary approach, relationship to state learning standards, use of K-12 teachers, making engineers "cool", and partnerships among groups interested in outreach [ASEE, 2004]. Given that the course described herein was specific to civil engineering and was given to homeschooled children, some of these guidelines were not applicable. However, two of these guidelines were particularly relevant to the ICE course described herein: hands-on learning and making engineers "cool". In most of the course sessions, one or two opportunities were created for hands-on learning through simple activities or experiments. Making engineering "cool" was accomplished through careful selection of course instructors that not only had reputations as "good" teachers but also a genuine interest in working with children. A total of six instructors delivered sessions in the course. Every instructor was either a faculty member or a graduate student in the Department of Civil Engineering at Auburn University. Attention was also paid to making sure that civil engineering was presented as a career open equally to boys and girls; two of the six instructors selected were female.

This course came about when a homeschool cooperative based in Auburn, Alabama, initiated the idea of exposing their children to civil engineering for the purposes of creating an awareness of what civil engineers do and of civil engineering as a career. The fact that the students in the Introduction to Civil Engineering (ICE) course were homeschooled had no consequence on decisions regarding course goals and content. However, this fact did provide some advantageous circumstances for course administration. Two of particular note were an ability to schedule course sessions and field trips at a variety of times and locations and an opportunity to work with students in a small group, which allowed for more interaction and questions. The course was presented to two groups; one composed of twelve students aged 7–10 (grades 2–5), and one composed of twelve students aged 11–14 (grades 6–9) participated in the course. The older group consisted of six boys and five girls; nine girls and three boys were in the younger group. Only the older group was used for the purposes of evaluating student perceptions and attitudes toward civil engineering.

COURSE DEVELOPMENT

A series of classes was developed to introduce the middle school aged and elementary school aged children to civil engineering with the following goals:

- Create an awareness of what civil engineers do
- Create a recognition of civil engineering works
- Create an understanding of how civil engineers improve our quality of life

In creating an awareness, the intention was to uncover and dispel misconceptions about what civil engineers do and create an awareness of civil engineering as a career choice for all. Recognition refers to developing an ability to identify the products of civil engineering that we use in our daily lives. Course content emphasized the ubiquity of civil engineering accomplishments from providing safe drinking water to highways and bridges. This also relates to creating an understanding of the role civil engineers play in affecting nearly every aspect of our quality of life. The goal was to foster an ability to describe how civil engineers have improved our quality of life by making it healthier, safer, more efficient, etc.

Several useful curricular materials exist, which can allow for development of a curriculum almost exclusively from each source, or support the creation of course content in which the course developer/instructor may already have defined basic goals and course topics. In this case a new set of curricular materials was developed, although portions of many existing resources were integrated into the course. Key sources in this effort were materials obtained from the American Society of Civil Engineers, including a notebook based on the "Building Big" series featured on public television and an ASCE slideshow on civil engineering as a career choice.

The course consisted of nine sessions; two were held at classrooms and laboratories at Auburn University. A field trip was taken to a pavement testing facility associated with Auburn University but located about 15 miles from campus. The flexibility of homeschool families, coupled with accommodating the schedules of the various instructors, allowed for course sessions to occur in several places and at several time slots.

Regarding course delivery, many modes of learning were used. The use of Powerpoint slideshows laden with pictures and occasional video clips was a key component; however, this was only one of several tools in course delivery. Other tools included hands-on activities involving simple construction, experiments, or writing activities to reinforce key vocabulary. Observational techniques, field identification, and simple pass-around items were used to reinforce concepts and to reach the students through seeing materials first-hand and through the sense of touch.

COURSE CONTENT

Objectives of the course were to present all subdisciplines of civil engineering including the basic concepts in each supplemented with detail on selected subtopics through a variety of activities. The opening session introduced civil engineering and its subdisciplines. The second session covered basic concepts of forces and moments. The third through eighth sessions addressed each of the civil engineering subdisciplines. The next meeting was a field trip to an accelerated pavement testing facility, and the final session consisted of a brief review, a game intended to reinforce concepts and well-known civil engineering landmarks, and a discussion group with the students to elicit changes in their perceptions of civil engineering. Table 1 shows the basic syllabus for the course.

Table 1. Course Syllabus

Session	Topic
1	Introduction and Overview
2	Forces and Moments
3	Civil Engineering and Construction Materials
4	Construction Management, Equipment, and Safety
5	Geotechnical Engineering / Soils Magic
6	Traffic Engineering and Highway Safety
7	Structures and Bridges
8	Environmental Issues and Water Resources
9	Summary and Closing

The purposes of the first session were to place civil engineering in context within all branches of engineering and then introduce each of the subdisciplines. This was accomplished with a slideshow that focused on both famous and ordinary examples of civil engineering works in each subdiscipline. An abbreviated version of a slideshow provided on the outreach section of the website of American Society of Civil Engineers on careers in civil engineering concluded the session [ASCE, 2008].

The second session, rather than being focused on a particular area of civil engineering, was used to provide necessary background on mechanics of materials so that future discussions on structures, construction, and other areas could be more productive and provide opportunities to reinforce force and moment concepts. The session began with a brief slideshow defining and showing pictures of forces and moments. The students were then paired up in a physical activity to demonstrate compression, tension, bending, and torsion. A second brief slideshow then defined and showed examples of common structural components. Most of the pictures used in this slideshow were of famous civil engineering works that the students would recognize (e.g., the Golden Gate Bridge, the Eiffel Tower, Jordan-Hare Stadium), providing an opportunity to reinforce and deepen their prior knowledge of these structures. During this presentation the students had opportunities to build trusses using toothpicks and gumdrops; afterwards, the differences between solid and hollow columns were demonstrated using toilet paper tubes which were later filled with sand.

The third session focused on common materials used in construction of civil engineering works. For most of the common building and paving materials, samples were brought in for the students to see and touch. This presentation was followed with a walk around the building and property where the class met so the students could not only identify the materials used but also *how* they were used, and whether they were carrying load, and if so, what forces were involved. Students also had an opportunity to learn about the unique properties of asphalt cement, specifically, its time-sensitive loading properties. First, each student took a turn striking a pan of asphalt binder material (asphalt cement) with a hammer. After the students found the material very resistant to compression in this manner, they then were able to see, by slowly pressing a finger into the pan, that the material deforms under a lighter, but much longer, loading. This activity therefore provided a tie to the previous session regarding mechanics of materials. Short video excerpts on the making of Portland cement and of asphalt pavements were shown to conclude the session.

The fourth session focused on construction equipment, safety, and methods. Pictures and brief videos of a dozen common pieces of equipment found on a construction site showed students not only the names but the uses and roles the equipment served. The students were then given an opportunity to touch, feel, and try on several pieces of workplace safety gear including hard hats, scaffold harness, and protective wear for eyes, ears, etc. This session wrapped up with a sequence of pictures showing the stages of construction of the new Student Center at Auburn University followed by short videos of demolition by implosion of the Seattle Kingdome, a tall office building, and a decommissioned nuclear reactor. It was expected that the demolition videos would be a favorite part of the course.

The fifth session presented focused on geotechnical engineering. The instructor showed a slideshow of various geotechnical works, both success and failures. This was followed by a discussion of the role of soil mechanics and foundations for all structures, and some of the reasons why foundations can fail. This session with demonstrations of soil strength and of liquefaction. More detail on the demonstrations can be found in the ASCE publication “Soils Magic” [Elton, 2001]; the author of Soils Magic presented this session.

The sixth session addressed transportation engineering and the role its plays in our daily lives. The topic was made relevant to the students by a discussion on “rules of the road” and underscoring that transportation systems are used every time they leave their homes. This was followed by a presentation and slideshow on traffic control devices, focused mainly on signs. Many samples of sign and pavement marking materials were circulated among the group. A short video entitled “Careers in Transportation”, produced by the Institute of Transportation Engineers, was shown to conclude the session [ITE, 2004].

The seventh session featured structures and bridges. This began with a slideshow on structures and then one on bridges. These presentations provided an opportunity to reinforce concepts of forces and moments as well as structural components. The students were then divided into groups and given the task of building bridges with minimum amount of materials not normally used the build bridges, such as modeling clay and manila file folders. Resistance to bending was reinforced by creating several different cross-sections with the file folders.

The eighth session covered an introduction to environmental issues with a focus on water and wastewater. The group then discussed the uses of water and why an effort is made by civil engineers to ensure that it is safe for drinking. A short video on the water cycle was shown, followed by a presentation on water supply and treatment facilities for water and wastewater.

The students (along with many of their parents) went on a field trip to the pavement test track for the National Center for Asphalt Technology. The center is located at Auburn University and its accelerated pavement testing facility is located about 30 minutes from the university campus. The pavement test track consists of a 1.7-mile loop comprised of 46 different test sections, each with its own unique combination of design and materials. A team of heavy trucks travel the test track five or six days per week to accomplish in about two years the loading that a typical pavement on a major highway might endure in 20 years. The site visit allowed the students to see the asphalt laboratory, the trucks, and the test track itself. The group traveled the track (on a day when the trucks were not operating), stopping at several sections that exhibited various types of pavement distress. These stops were intended not only to allow the students to see, touch, and feel pavement first-hand, but also to reinforce many of the concepts discussed over the duration of the course.

The ninth and final session provided a final opportunity to reinforce basic concepts and tie together the material covered in the previous sessions. A quick slideshow review and outline of the course was presented, followed a game activity in which the students were divided into groups of three or four and then quizzed on their recall of vocabulary and of civil engineering landmarks. The game was conducted using a presentation on which each slide would show either a definition or a landmark for which each team was given up to thirty seconds to correctly identify. Following the game, a group discussion was facilitated in which the students were asked to answer a few questions regarding their perceptions of civil engineering as a subject and as a career. This activity took place with the older group (sixth through ninth grade) and is reported on below.

COURSE EFFECTS ON STUDENT PERCEPTIONS AND KNOWLEDGE OF CIVIL ENGINEERING

As noted previously, creating an awareness of civil engineering as a profession and recognition of its works were among the goals of the ICE course. A series of questions posed in a discussion with the 11 students in grades 6–9 in the final sessions was intended to evaluate how their attitudes changed. Information was also obtained on the topics covered. While the sample size obviously does not lead directly to generalizations about youth perceptions of civil engineering, it did allow for engagement of all course participants during the sessions and for all to participate and add comments during the discussion group at the close of course, during which the following information was obtained.

With the first pair of questions, students were asked to select a response on a Likert-type scale, shown in Table 2, to gauge the range of perceptions of civil engineering as a topic and as a career both before and after the course. The first question was “How did you feel when you learned that you were going to be taking this class?” The parallel ‘after’ question was “How do you feel about civil engineering now?” The average score was 3.3 for question 1 and 4.4 for question 2. The ensuing discussion brought out comments that give insight into the change of more than one whole point in the average response. The comments reflected student recognition that “the class gave us the chance to point out in our environment what we learned…” and “…once people learned about we thought it was more fun.” Among the girls in the group, 3 of 5 indicated that, prior to the course, they thought civil engineering was a career primarily for males; however, after the course, all felt it was a career option open to both men and women.

Table 2. Available Responses to Questions 1–4

Response	Score
Very interested	5
Somewhat interested	4
Neither interested nor disinterested	3
Somewhat disinterested	2
Very disinterested	1

The second pair of questions was "What was your impression of careers in civil engineering before this course?" and "What was your impression of careers in civil engineering after this course?" Responses were selected according to the scale in Table 2. Representative responses in the discussion that followed include "it seemed more interesting [after the course]", "I know…that there are girls.", and "engineers are not as nerdy as I thought". A substantial shift appears to have occurred in the students perceptions of civil engineering as a topic and as a career. Table 3 provides a summary of the first four questions and average responses.

Table 3. Student Perceptions of Civil Engineering

Question	Average Response
1. How did you feel when you learned that you were going to be taking this class?	3.3
2. How do you feel about civil engineering now?	4.4
3. What was your impression of careers in civil engineering before this course?	2.2
4. What was your impression of careers in civil engineering after this course?	3.5

The students were then asked a few questions what they learned and what they enjoyed about the course. In this series of questions, responses were completely open rather than from an established list. Question 5 reads "What are the top three things you have learned about?"; Answers ran the gamut of civil engineering topics, from "roads, signs, and forces" to "bridges, water cycle, and heavy equipment". Question 6 asked "What topic have you enjoyed the most?" in which each student was asked to name a topic. Responses were signs (4), forces (2), heavy equipment (2), roads (2), and water cycle (1). In the seventh and final question, students were asked "What do you think is most useful thing you learned about?". Responses were roads (4), signs (4), water cycle (1), and forces (1).

INSTRUCTIONAL LESSONS LEARNED

While conducting the course, the author of this paper (instructor of five of the sessions) learned many things about effective approaches to course delivery when working with children at the elementary school and middle school ages. While most of these ideas would likely not surprise a K-12 instructor, the following is a list of suggestions or "lessons learned" when introducing engineering concepts to school children. Regarding course delivery styles, the key lesson learned is to "mix it up." Obviously, it is not optimal to deliver a "presentation" or "lecture" but instead allow for a variety of activities enabling more interaction, questions and discussion. A course session of any combination of several of the following types of activities would be effective:

- Do something hands-on – let the students get their motor skills going and let them "see" the concept to be illustrated. This is also a great opportunity for teamwork.
- If possible, let them get up, walk around, and identify and observe what has just been discussed.
- A self-directed learning/writing activity (such as word find or crossword puzzle to reinforce key vocabulary) or an opportunity to write a paragraph about how products of engineering the student use in their daily lives relate to what has been discussed.
- Bring items to pass around
- A presentation as one of the learning modes can be effective. Presentations, such as Powerpoint slide shows, can have a role, if they do not require the students to sit for too long at one time. Engineering, particularly civil engineering, is easy to show: materials being produced, structures being built (and unbuilt), etc. As opposed to a typical presentation in a college course, which may be heavier on words than pictures due to the complexity of concepts being taught, these presentations can be loaded with pictures and video clips as well as words (such as definitions of key terms) in an engaging manner.

Many resources exist for the creation of an engineering outreach course. Many professional organizations and industry organizations have an interest in outreach and have developed materials for such purposes, ranging from videos to slideshow presentations to curricular guidebooks. In developing the ICE course, such resources were obtained from the American Society of Civil Engineers, the Institute of Transportation Engineers, and the National Asphalt Paving Association.

CONCLUSIONS

A course to introduce civil engineering to middle and elementary school age students was developed and presented to schoolchildren in the Auburn, Alabama area. The course consisted of nine 75-minute sessions and a field trip. The course sessions introduced civil engineering and its subdisciplines, covered the basics of forces and moments, followed by a session devoted to each subdiscipline, and closed with a summary session which included an evaluation component. Special attention was given to allowing for substantial hands-on learning, making engineering "cool", and presenting civil engineering as a career path open to women and men.

Instructors in the course met with small groups of students at a time to increase interaction and the ability to engage students individually. A series of basic questions was asked of the middle school age students to elicit their perceptions and understanding of civil engineering before and after the course. From the questions, it appears that the course had a substantial positive impact on how the students viewed civil engineering as a topic and as a career choice. These results are encouraging; however, due to the small sample sizes, the findings noted herein can not necessarily be generalized to the larger population. It does appear the students came away from the course with a greater appreciation of how civil engineers affect the quality of lives and the broad extent to which everyday activities are enhanced by the work of civil engineers.

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