Effects of Classroom Pedagogies Used in a Freshmen Course on Students' Perception of the Sub-Disciplines of Civil Engineering

Dimitra Michalaka[1], Simon T. Ghanat[1], Mary K. Watson[1], Kevin Bower[1], Ronald W. Welch[1]

[1]The Citadel, The Military College of South Carolina

Abstract

Civil Engineering is a very broad field that includes several sub-disciplines: Structural, Geotechnical, Transportation, Environmental, and Water Resources. Freshmen who join Civil Engineering programs are most often not aware of all these sub-disciplines. The instructors of the introductory course to Civil Engineering at The Citadel, a teaching focused engineering program, incorporated lectures and activities in the design of the course. The purpose of this pedagogy was to assist students to gain a better understanding of the field of Civil Engineering and their future career options. Questionnaires were distributed to students on the first day of class and at the end of the semester, which included questions about what each Civil Engineering sub-discipline is and which sub-discipline students were considering. In this paper, the pre and post questionnaire answers are analyzed to examine the effect of the classroom activities. The results showed that the majority of students are interested in structural engineering and that the distribution of the sub-disciplines did not significantly change at the end of the semester.

Keywords

Civil Engineering, Pedagogy, Structural, Geotechnical, Transportation, Water Resources

Introduction

Civil Engineering includes several sub-disciplines: Structural, Geotechnical, Transportation, Environmental, and Water Resources. Freshmen who join civil engineering programs are often not aware of all sub-disciplines. Many engineering programs around the country offer an introductory engineering course during the first year of studies[1] because it has been shown that exposing students to engineering the first year may improve retention[2-5]. To support freshmen student development, Ray Landis has introduced a model "Introduction to Engineering" course. Ray Landis is widely known for his expertise in developing minority engineering programs, as well as freshmen curriculum development[7]. In fact, his text "Studying Engineering: A Road Map to a Rewarding Career"[7] has been used by over 100,000 students at more than 300 institutions[6]. Through this course, students gain a clear picture of what success in engineering study will bring to their lives[8-9]. They learn about the various sub-disciplines of civil engineering, how to study in engineering, and the engineering design process. Through this knowledge, they become articulate in telling others about civil engineering[7-8]. They can also learn about opportunities for pre-professional employment in engineering and the benefits of such employment. Regarding introducing students to the different civil engineering sub-disciplines which is the focus of this paper, it has been shown that hands-on activities improve

understanding[10-11] and retention in the field[5]. At the same time, students feel more confidence about their major selection[12].

The first semester introduction to the civil engineering course at The Citadel was recently redesigned to expose students to civil engineering early in the curriculum, as well as equip them with other essential skills needed for success[13]. Among others, it includes several hands-on activities on the different civil engineering sub-disciplines to make them aware of all the specialty areas of civil engineering. In order to examine the influence of those activities to student preferences, questionnaires were distributed on the first day of class and at the end of the semester.

Surveys

The survey included questions about what each civil engineering sub-discipline is and which of the sub-disciplines the students are considering. This paper analyzes the results of the pre and post surveys. The survey used a five-level Likert-type scale for responses as is shown in the Appendix.

Civil Engineering Sub-disciplines Classroom Activities

In-class activities related to all the five major sub-disciplines were incorporated into the course design. Throughout the semester, students worked collaboratively on small projects to explore the five specialties of civil engineering (Table 1).

Table 1. Summary of mini-projects used to illustrate the five major civil engineering sub-disciplines.

Sub-Discipline	Mini-Project
Structural Engineering	Designing a virtual bridge using the West Point Bridge Design Software
Geotechnical Engineering	Conducting Soil Analysis
Transportation Engineering	Designing a parking lot Conducted traffic analysis
Environmental Engineering	Using a spectrophotometer to determine the contamination of water Creating a water filtration system
Water Resources Engineering	Analyzing a hydraulic jump

The above projects were employed to inform and excite students about the different civil engineering sub-disciplines and civil engineering field as a whole. Instructors wanted to make students aware of all the different possibilities within civil engineering. Also, the same activities were used in similar courses in the past and the majority of the students seemed to have enjoyed them.

The following contains a description of the activities:

Structural Engineering

The principles of tension and compression in structural engineering were emphasized by guiding students in designing bridge models using West Point Bridge Design Software[14], a free software program. A snapshot of the software is given in Figure 1.

Figure 1. Snapshot from the West Point Bridge Design Software[14]

The following criteria and constraints were given to the students:

- The bridge deck had to be at least 12 meters above ground.
- The bridge had to be able to support the standard 225 kN, two lane truck load.
- The cost of the bridge had to be minimized. The client does not have unlimited funds to support design of the bridge; however, the client might be willing to spend more money on an exceptional design.
- The client would like one complete, successful, and detailed design with minimized costs; however, the client would like alternative designs to be included in case "a new requirement emerges." These designs did not need to be refined as rigorously, but should meet all requirements and be significantly different than the original. Each team had to have one alternative design per number of team members.

Students were allowed to work on their bridge design project for three class periods and also utilize time outside the classroom. After a week, they had to submit a report including the following information:

- A memo reporting the final cost of their bridge and the reasons they believed it was an exceptional design.
- A flow chart of the engineering design process that documented what their design team did at each step.
- A printed copy of the Load Test Results Report for their final design.

- A printed copy of the Cost Calculator Report for their final design.
- A printed image of their final design.
- An appendix that contained the printed Load Test Results Report, Cost Calculator Report, and image for each design alternative. For example, Appendix A had to contain those items for one alternative design. Appendix B had to contain those items for a different alternative design, and so on.

Geotechnical Engineering

To illustrate key concepts in geotechnical engineering, students conducted a sieve analysis. Students received very detailed instructions on how to conduct the sieve analysis and were provided the following Geotechnical project:

October 31, 2014

RE: Geotechnical consulting, Riverside Plaza (North Charleston, SC)

Dear CEE Faculty:

On behalf of Terzaghi, LLC, I am writing to inform you that "Introduction to Civil Engineering" Consultants Group has been awarded the contract for geotechnical services in support of commercial land development at the future Riverside Plaza in North Charleston, SC. We look forward to working with you and your team on this project.

The site map (Figure 2) attached to this letter illustrates the proposed layout of the facility. Terzaghi is in the process of evaluating the borrow soil that will be excavated from the detention pond area. We need to determine if the soil is suitable as (1) structural fill under the proposed parking lots and building foundations or (2) general (non-structural) fill or (3) clay liner. The following are the grain size distribution for each application:

Property	Structural Fill	General Fill	Clay Liner
Minimum Fines Content (%)	---	---	35
Maximum Fines Content (%)	15	50	-
Minimum Gravel Content (%)	10	N/A	-
Maximum Gravel Content (%)	---	N/A	10

We have obtained a test pit sample of the borrow soil and have shipped the sample to you. We request that you perform the appropriate test to evaluate the potential use of the soil for the applications described above. Please send us a memo containing your findings and recommendations by November 12, 2014. If you have any questions regarding this letter, feel free to contact me at (843) 888-1234.

Sincerely,
Terzaghi, LLC

Karl Terzaghi.
Project Manager

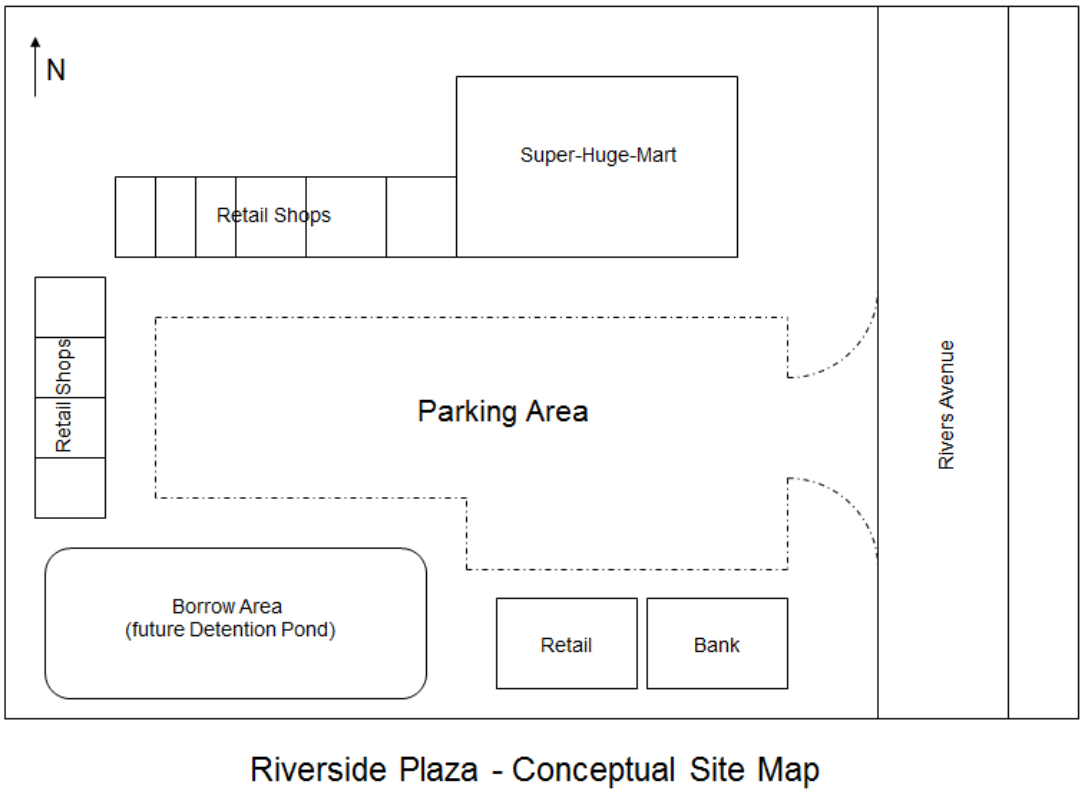

Figure 2. Layout of the facility

Deliverable:

1. Memo: Memo needs to contain your findings (% of gravel, sands and fines) and recommendations (should the soil be used as structural fill, general fill, clay liner or none of these)?
2. Plot of percent finer vs. particle diameter.

Transportation Engineering

Related to transportation engineering, students developed a scaled design of a parking lot to meet several criteria, including number of spaces, accommodations for expectant mothers and disabled drivers, as well as area of green space. The objective of the design was to minimize cost while designing a functional parking lot with the following requirements:

- A design with entrances and exits on two roads.
- A minimum of 60 parking spaces.
- Landscaping on at least 20% of the surface.
- At least 5 trees in the parking lot. Trees require a 10’ x 10’ area.
- At least 10 bushes in the parking lot. Bushes require a 5’ x 5’ area.
- At least 5% of the total number of spaces must be handicap.
- At least 1% of the total number of spaces must be for expectant mothers.

- At least 4 spaces must be for shopping carts.

Students were given a week to submit a complete and accurate design, prepare a memo, a complete cost estimate, as well as a short presentation for their design.

To introduce transportation engineering, students also collected traffic data and identified the percentage of turning vehicle movements and pedestrian movement at a given intersection (see Figure 3).

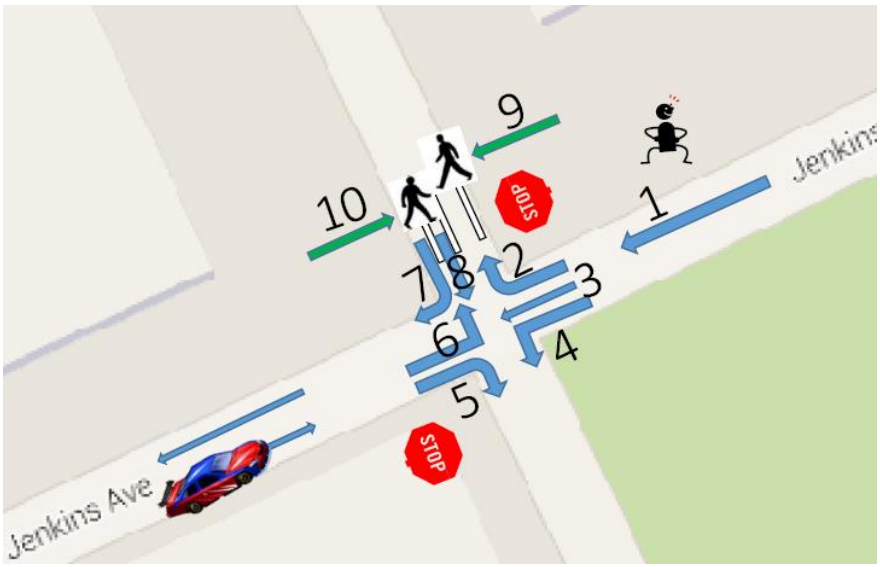

Figure 3. Intersection where students collected traffic data

Environmental Engineering

As an introduction to environmental engineering, students measured contaminated samples of water using a spectrophotometer. Students also designed, constructed, and tested water filters using basic materials such as: sand, gravel, charcoal, rubber bands, and coffee filters. Students worked in groups to design, construct, evaluate and rebuild water filters. After the process, they were required to submit a schematic of their water filters and a memo explaining how they would design a water system if they were required to duplicate the design process again.

Water Resources Engineering

For the water resources activity, students learned about dams and spillways, and they conducted a related experiment to analyze a hydraulic jump (see Figure 4). Then, they measured and calculated several components of the hydraulic jump such as the height of the water, the velocity of the water, the Froude Number and others.

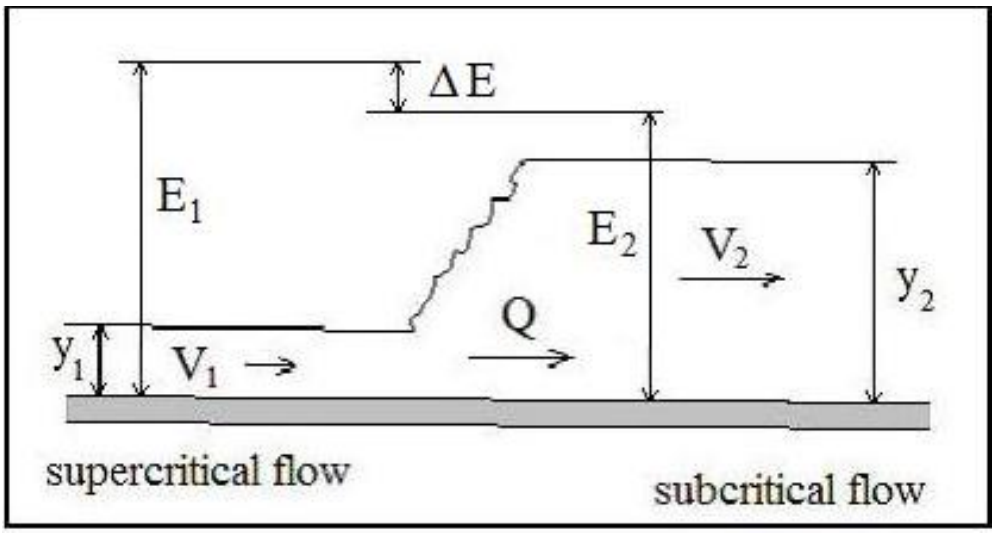

Figure 4. Hydraulic Jump created in the lab

Data Analysis and Results

The data from the pre and post surveys were compiled and statistical analysis was performed to examine if students interest in the different sub-disciplines changed after taking the introduction to the civil engineering course.

The SPSS Software was employed to conduct the data analysis on all completed surveys to detect any changes in student's civil engineering sub-disciplines preferences over the course of the semester. Quantitative comparison of pre- and post-survey mean scores for each sub-discipline was completed using a paired t-test. Significant shifts in scores were identified for $p \leq 0.05$ (95% confidence interval). In other words, in the paired t-test the null hypothesis is that the pre- and post- survey averages between the civil engineering sub-disciplines were the same. If the calculated p-value was less or equal to 0.05 (95% confidence interval), it was concluded that the average difference was statistically different. The sample size was 59 students and the degrees of freedom 58. The results and statistical analysis are summarized in Table 2.

Assuming a 95% confidence interval, the results indicated that the mean difference of the student preferences for the structural engineering and environmental were not statistically significant (p value greater than 0.05) while the mean difference for all the other disciplines was significant (p values less than 0.05). Surprisingly, the data showed that students gave lower scores to all sub-disciplines after completion of the course. A possible reason for this could be that students became interested in more than one sub-discipline making them unsure of which sub-discipline they are planning to pursue. Overall, it seems that the hands-on activities were not enough to alter student preferences too much.

Table 2. Results and t-test

		Mean	Std. Deviation	Std. Error Mean	t	p-value
Pair 1	Structural (pre)	4.27	0.91	0.12	1.106	0.273
	Structural (post)	4.10	1.30	0.17		
Pair 2	Geotech (pre)	3.10	1.05	0.14	2.215	0.031
	Geotech (post)	2.71	1.18	0.15		
Pair 3	Transportation (pre)	3.08	1.04	0.14	2.266	0.027
	Transportation (post)	2.68	1.04	0.14		
Pair 4	Environmental (pre)	3.55	0.97	0.13	1.755	0.084
	Environmental (post)	3.29	1.29	0.17		
Pair 5	Water Resources (pre)	3.15	1.03	0.13	2.837	0.006
	Water Resources (post)	2.66	1.12	0.15		

Since the scores at the post- surveys were lower than the pre-surveys, the student evaluations were studied to examine students' perception of the projects related to the five sub-discipline of civil engineering. The comments are summarized in Table 3.

Table 3. Summary of students' perception of the Introduction to Civil Engineering Projects

Liked about Projects	Disliked About Projects
The fun activities and projects we get to do	Need more hands on stuff
it introduced me to my major	The class felt like a waste of time and credit
Getting well rounded with CE as a whole and not just one specific part	The information is a little basic, need for more projects
learning about the 5 sub disciplines of civil engineering	some of the elementary concepts we had to go over
I liked most learning about the different branches of Civil engineering and picking which one I hope to focus on	More demonstrations of the sub-disciplines of CE
Hands on learning of all the different disciplines of civil	Make the class more geared to college rather than a middle school level of learning
hand on engineering experiments which showed me he purpose in why we do the things we do and also why group work is essential	Make the class more goaled to showing what the what the engineers do in day to day life more
it helped me figure out which branch of civil engineering I want to pursue	didn't like how long it took to start doing the sub-discipline projects
actual CE activities we did were awesome	Give us some real world stuff

Conclusions

The results of this study indicate that student preferences toward the different civil engineering sub-disciplines did not change much after the completion of this course. More specifically, no significant differences were observed for one of the sub-disciplines at a 0.05 level of significance. Even though hands-on activities were included for all sub-disciplines and students enthusiastically participated, there were no notable findings concluded.

To further examine how student preferences change over a four-year period, we propose to include the same questionnaire questions on the students' exit survey, a survey that students complete few days before their graduation. This will show if students' initial preferences changed after taking several courses focused on the different disciplines.

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Dimitra Michalaka, PhD

Dr. Dimitra Michalaka is an Assistant Professor at the department of civil and environmental engineering at The Citadel. Dr. Michalaka received her undergraduate diploma in civil engineering from the National Technical University of Athens (NTUA), after which she entered into the transportation engineering graduate program at UF. She graduated with a Master's of Science in May 2009 and with a Ph.D. in August 2012. Her research is primarily focused on traffic operations, congestion pricing, traffic simulation, and engineering education.

Simon T. Ghanat, PhD

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.

Mary Katherine Watson, PhD

Dr. Mary Katherine Watson is currently an Assistant Professor of Civil and Environmental Engineering at The Citadel. Prior to joining the faculty at The Citadel, Dr. Watson earned her PhD in Civil and Environmental Engineering from The Georgia Institute of Technology. She also has BS and MS degrees in Biosystems Engineering from Clemson University. Dr. Watson's research interests are in the areas of engineering education and biological waste treatment.

Kevin Bower, PhD, P.E.

Dr. Kevin Bower is an Associate Professor and Head of the Department of Civil and Environmental Engineering at The Citadel, Charleston, South Carolina. Dr. Bower's teaching research interests are in improving active learning environments and the development of classroom pedagogy to improve moral development in engineering students.

Ronald W. Welch, PhD, P.E.

Ron Welch (P.E.) received his B.S. degree in Engineering Mechanics from the United States Military Academy in 1982. He received his M.S. and Ph.D. degrees in Civil Engineering from the University of Illinois, Champaign-Urbana in 1990 and 1999, respectively. He became the Dean of Engineering at The Citadel on 1 July 2011. Prior to his current position, he was the Department Head of Civil Engineering at The University of Texas at Tyler from Jan 2007 to June 2011 as well as served in the Corps of Engineers for over 24 years including eleven years on the faculty at the United States Military Academy.

APPENDIX

I am considering pursuing the following civil engineering sub-discipline (Circle the appropriate number):

1- Strongly disagree	2- Disagree		3-Neutral	4- Agree	5- Strongly Agree
Structural Engineering	1	2	3	4	5
Geotechnical Engineering	1	2	3	4	5
Transportation Engineering	1	2	3	4	5
Environmental Engineering	1	2	3	4	5
Water Resources Engineering	1	2	3	4	5