AC 2012-4337: ANALYSIS OF THE SUSTAINABILITY CULTURE IN CIVIL AND ENVIRONMENTAL ENGINEERING AND MECHANICAL ENGINEERING PROGRAMS

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Analysis of the Sustainability Culture in Civil and Environmental Engineering and Mechanical Engineering Programs

Abstract

This paper describes a study of the sustainability culture of 390 students in civil and environmental engineering and mechanical engineering. A sustainability knowledge survey was administered to all students included in the study to ascertain the level of foundational sustainability knowledge of students in both majors. In addition, questions to determine the sustainability attitude of students in both majors were given. The results of the survey were analyzed to determine the relative knowledge and affinity of the students to sustainability. The relative impact of the attitude on major selection was determined. The results indicate that there is not a discernible difference between the knowledge and interest between the two disciplines. There is some indication that freshman and sophomore students are more interested in the subject of sustainability than juniors and seniors. Most students indicate that if sustainable design makes them more marketable or is required for employment they would embrace such practices.

Introduction

In current discourses regarding environment, global climate change, and other sustainability issues, one common assumption is that humans will be able to rely solely on engineering solutions to solve environmental predicaments. However, even though the discipline of engineering has been charged with creating solutions to global environmental problems, the culture of engineering is not currently, singularly focused on or equipped for innovating solutions to sustainability challenges. Some "green" focused engineers are working on designing new technologies with an emphasis on sustainable engineering and design, however they are currently a minority. If technological advances in infrastructure, energy production, fossil fuel reduction, and waste are going to be part of society's solution to sustainability, engineers are going to have to change the way they identify themselves as active participants in solving this problem. Because new engineers are socialized to the profession through their education in an engineering department, examining the culture of an engineering department will identify in what ways students are being socialized into their role as sustainable designers. Additionally, due to the differing design mandates presented to civil and mechanical engineers, the researchers believe there is value in comparing and contrasting the cultures of both a Civil and Environmental Engineering Department and a Mechanical Engineering Department to explore the influence of attitude towards sustainability on choice of major.

The University of Utah recognizes that sustainability is a concept that needs more focus at the school. President Young signed the Presidents Climate Commitment (PCC) a commitment to increase sustainability at the University along with 500 other university presidents. To fulfill that promise the Office of Sustainability was created in 2007 as a resource that oversees improvements to facilitates, outreach programs to students, and green initiatives on campus[2]. Additionally, the school is working on achieving its STARS (Sustainability Tracking Assessment and Rating System) rating. STARS is a system created by a network of universities so that progress toward sustainability can be quantified and compared with other institutions[3]. Work is

being directed towards developing sustainability curriculum programs, and the engineering programs described herein are part of this effort.

Because one of the researchers holds a position at the University of Utah in which she interacts with multiple departments within the College of Engineering, she has had the privilege to observe engineering classes ranging from first year to graduate level. In the processes of observing multiple departments and class levels, the differences in cultures within the Civil and Environmental Engineering and Mechanical Engineering Departments regarding sustainability became evident. Therefore, a research study was devised and conducted to examine the organizational culture of the University of Utah Civil and Environmental Engineering and Mechanical Engineering Programs. The goal is to determine if the identification of environmentally or sustainability focused engineering is part of the current organizational structure. From this standpoint the objective in this paper is to build a more comprehensive view of the sustainability curriculum and sustainability culture of the students and faculty in these departments. Exploring how students and faculty currently identify themselves and what the role of engineers is regarding sustainability at this school at this time will provide interesting information both to scholars interested in identity and to scholars interested in how different disciplines are reacting to sustainability. By understanding the culture of these departments at this time, meaningful curriculum could be developed at the University of Utah and elsewhere to help place more emphasis on the importance of sustainability in the disciplines of Civil and Environmental Engineering and Mechanical Engineering.

Teaching Sustainability in Engineering

Engineering curriculum is packed with math, design, physics, and science classes to help students build skills in problem solving and design. Engineering students sometimes feel that working on soft skills such as communication, writing, and sustainability are not directly important to the tasks of their future[4]. However, the Accrediting Board for Engineering and Technology (ABET)[5], the organization that develops standards for college programs to meet, requires that sustainability is addressed in engineering curriculum. Hence it is necessary for accredited university programs to incorporate the issue of sustainability in its curriculum.

The first step to this is to define sustainable design. Pappas & Olga note [6] that sustainable design practices in engineering have their roots in two engineering fields, green engineering which focuses on designing to be more in tune with the earth and environmental engineering that has to do with cleaning up the effects built systems have had on the environment. Sustainable design "focuses on design that requires fewer natural resources, produces less (or no) waste, and reduces, reuses, or recycles waste produces (p. F1c-2)." One university defines sustainable design as having four components, technical, financial, environmental, and societal and these are reinforced throughout the students' career in a series of courses spanning freshman to sophomore year[7]. James Madison University defines environmental sustainability as

> an approach to the engineering of processes, products, and structures which has, indefinitely, a less negative, neutral, or benign effect on all environmental systems. Sustainable engineering design tends to produce products and processes in which nature is not subject to continual 1) increases in the use of natural resources, 2) increases in goods produced by society, and 3) increases in waste products and effects of their degradation[6].

Once a definition of sustainability has been established the program can begin to implement the courses to teach sustainability. Fox et al.[8] suggest that there is a support network created by the National Science Foundation and existing engineering sustainability programs that will help educators incorporate lessons of sustainability into existing classes. Focusing engineering lessons on renewable energy and conservation practices can be folded into design classes. However, it is difficult to teach because it is such a large interdisciplinary issue that requires the expertise of many fields. Dincer & Rosen[9] highlight some obstacles to creating conservation technology development programs: technical, institutional, financial, managerial, pricing, and information diffusion. Educational engineering programs that do not emphasize sustainable practices are an example of an institutional obstacle to sustainable engineering. Throughout the educational process students are being socialized into their role as engineers and if sustainability is not part of the curriculum, it will not be part of their identity as practicing engineers.

Traditional teaching methods are used to teach sustainability and examples have included, problem solving, case studies, and thinking and reasoning challenges[6]. The Rose-Hulman Institute of Technology implemented aspects of sustainable design into classes in which students had to pay attention to the sustainability aspects of designs as they created prototypes and computer models[4]. One program made a large commitment to sustainable design and offered a great time commitment to the lesson plan. In a fundamentals of engineering course the instructors adopted two hours of lecture and four hours of lab use to concentrate on ideas of global climate change instead of traditional engineering curriculum. The instructors use the Al Gore book *An Inconvenient Truth*[10]as a text to educate students about global climate change. By pre and post testing the students in the class, it was determined that the design of curriculum that particularly addressed global climate change helped the students understand global climate change[11].

The goal of a college education is to prepare the individual for a career in their chosen field and this includes the development of knowledge and skills that they will need to be competent when hired. It also includes socializing students to be members of the professional community they are preparing to be a part of. This includes learning values, beliefs, norms, and customs of the professional culture. When they are socialized into that culture they have created an identity with the profession. By including sustainability curriculum into engineering education, students will be socialized to value sustainable design.

Methodology

Our research methods were driven by the desire to investigate the differences in culture between the Civil and Environmental Engineering and Mechanical Engineering Programs at the University of Utah. We sought to understand if it is a set of ideals that students believe before they become members of a program or is it socialized into the students throughout their tenure in the department. We administered knowledge and attitude surveys and conducted interviews to understand the cultures more effectively and to see if some students who are more sustainably minded are predisposed to environmental practices choose Civil and Environmental Engineering or Mechanical Engineering.

This study is a qualitative multi-method ethnographic examination of the culture of sustainability in the University of Utah's Civil and Environmental Engineering and Mechanical Engineering Departments. Ethnography offers a method in which the researcher is able to gain understanding about a culture of a group by doing field research and building close connections with the group being studied[12]. Using mixed methodology to collect data from a number of sources will offer a rich data set in which to draw conclusions. Data will be collected through a variety of channels including; surveys, semi-structured open ended topical interviews with students and professors, participant observation, material culture and document analysis. This paper presents the initial results of the first steps of the study.

Ellingson's[13] crystallization approach to making claims offers a methodology that allows for multifaceted, interdisciplinary ways to gather and understand data. Using the metaphor of a crystal, that is growing, multi-layered, and complex, crystallization offers a method of investigation for difficult transdisciplinary problems. Crystallization combines multiple forms of analysis and multiple genres of representation into a coherent text or series of related texts, building a rich and openly partial account of a phenomenon that problematizes its own construction, highlights researchers' vulnerabilities and positionality, makes claims about socially constructed meanings, and reveals the indeterminacy of knowledge claims even as it makes them (p. 4). It is a nontraditional approach to research that allows for the weaving of different genres of information into themes of life. Because the issue of sustainability and the development of new ways of thinking about design are issues that require many disciplines, crystallization offers an appropriate methodology for investigation.

Participant Recruitment

Lindlof and Taylor[14] explain that a sponsor facilitates gaining access to individuals by introducing the researcher to potential participants. In this project, the sponsor is provided by supported faculty in both the Civil and Environmental Engineering and Mechanical Engineering Departments. These professors provide opportunities to distribute surveys in class, introduce students and faculty to the researchers and encourage students and faculty to become involved in this project. Through these connections, snowball sampling helps locate other interviewees. This is a process in which the researcher uses social networks so that after a participant is interviewed they then introduce the researcher to others to participate.[15] The first steps of this process have been completed, but more will come in the future as the snowball effect continues to have an impact.

Design & Study Procedures

The foundation of the part of the study reported in this paper is based on 365 surveys completed by freshman (150), sophomore (129), junior (30), and senior (86) Civil and Environmental Engineering and Mechanical Engineering students. Additional information will be gathered in subsequent parts of this study through interviews, participant observation of classes and faculty meetings, and document analysis.

Surveys

Surveys are an excellent way to poll many students at once, and to briefly understand how they are feeling at a particular moment in time about an issue. For that reason, this study uses surveys as the foundation of gathering information. Surveys were conducted in several large seminar classes in the Civil and Environmental Engineering and Mechanical Engineering Departments. The Mechanical Engineering surveys were gathered electronically. The 1000 (freshman) level Introduction to Robotic Systems Design class (126) and the 2000 (sophomore) level Introduction to Sustainable Energy Systems (75) used Moodle, a computer program that had been facilitating those two classes. Participants in the 4000 level Senior Design Class (58) were taken using Canvas, a computer program that facilitated many of the class activities. The Civil and Environmental Engineering classes completed the surveys by hand on paper and those answers were transcribed for analysis. The Civil and Environmental Engineering classes surveyed were Introduction to Civil and Environmental Engineering (30), Statics (20), Hydraulics (26), and Project Practice and Design (30), which cover the freshmen to senior levels as was accomplished for the Mechanical Engineering students.

The surveys ask students questions about their knowledge and opinion regarding sustainable design. Using open ended and likert scale questions the surveys provided a fast and effective way to collect a great deal of data regarding students' attitudes, knowledge and opinions about issues of sustainability in the field of engineering. The surveys will gather both qualitative and quantitative information, for the purposes of this paper the quantitative data will not be subject to statistical analysis but instead will be one of the texts used explore this case study. A copy of the survey is attached as Appendix A.

Qualitative Methods, Data Analysis and Interpretation

To analyze the data for this project, we will be using grounded theory to identify the answers to the research questions. Lindlof and Taylor[14] describe the use of grounded theory as a popular method for analyzing qualitative data. Grounded theory offers a methodology to build theory from data[15]. The process of grounded theory is to first code the data in a wide variety of categories. The next step is to create memos that identify themes of the research and important actors, implications, and interesting questions. The last steps are integration and dimensionalization, in which a set of codes will be created to make new categories. Grounded theory offers the researcher a clear way to code, organize and explain the data. It also allows the researcher the freedom to be free of hypothesis while examining data and drawing conclusions through the data analysis process. By using this method the researcher is free to let the data indicate the theoretical phenomena that is occurring.

Results

Participants in the survey were asked to list the top five things they consider when beginning a design process. Through this question the researchers were trying to ascertain how important sustainability is when beginning a design process. Table 1 lists the results that demonstrate how often environmental or sustainability factors were listed as one of the top 5 considerations. These results indicate that Civil and Environmental Engineering students prioritize ideas of

sustainability and environmentalism as they are creating designs more than Mechanical Engineering students.

Table 1. Summary of student responses that listed sustainability as a top 5 design consideration.

Year/Department	Number of participants	Number that listed sustainability or environmental concerns	Percent that consider sustainability or the environment in design process
Freshman/CE	30	7	23%
Sophomore/CE	20	6	30%
Junior/CE	26	6	23%
Senior/CE	30	10	33%
Freshman/ME	126	3	2%
Sophomore/ME	75	6	8%
Senior/ME	58	6	10%

Students were also asked if they thought that sustainability would be an important factor in the future of engineering. Table 2 lists on a scale of 1 to 7, 1 being not important at all and 7 being extremely important, how students felt that sustainability would factor into their careers. The data indicates Civil and Environmental Engineering student respondents of this survey felt that sustainability would be a more important part of their career. Additionally, students at the beginning of their programs indicated that sustainability would be more important than did students further along.

Table 2. Ranking of importance of sustainably in their field in the future.

Year/Department	Score of importance on a 1-7 scale 1 being not important and 7 being very important
Freshman/CE	6.6
Sophomore/CE	6.4
Junior/CE	6.6
Senior/CE	5.9
Freshman/ME	6.0
Sophomore/ME	5.8
Senior/ME	5.7

To determine if students that were more invested in ideas of sustainability were more likely to choose Mechanical Engineering or Civil and Environmental Engineering, the researchers tried to ask questions that would allow the students to reveal how ideas of sustainability impacted their decision making. The first question in the survey that addresses this issue was; what is the relative importance of sustainability being a part of Mechanical (Civil and Environmental) Engineering practice in your decision to choose Mechanical (Civil and Environmental) Engineering as a career? This question was asked on a 7 point scale, 1 being not important and 7

being very important. The answers to this survey question, shown in Table 3, indicate that being able to make a difference in sustainable design was not a major factor in choosing a career path. Freshman and sophomore Civil and Environmental Engineering students indicated that becoming involved in ideas related to sustainability were more important to them than the rest of the participants.

Table 3. Ranking of importance of sustainably in their decision to become an engineer.

Year/Department	Score of importance on a 1-7 scale 1 being not important and 7 being very important
Freshman/CE	4.9
Sophomore/CE	5.1
Junior/CE	4.3
Senior/CE	4.3
Freshman/ME	4.7
Sophomore/ME	4.1
Senior/ME	4.2

The second set of questions asked the students to rank factors that helped them to choose a career in Mechanical Engineering or Civil and Environmental Engineering. These factors were; job security, high salary, appeal of technical work and problem solving, potential to improve sustainability, potential to improve quality of life, potential to live anywhere, enjoy learning, and status of being an engineer. The students ranked their answer on a 1-3 scale 1 being not important, 2 being important, and 3 being very important. Consistently the top two answers were job security and enjoyment of technical work, although the potential to improve the quality of life was noted by the Mechanical Engineering freshman, and the senior Mechanical Engineering students ranked the enjoyment of learning second highest. Table 4 represents the average answer for the top two indicators and where the average answer for sustainability fell. It appears that with the exception of a slight degree of more interest from freshman and sophomore in both programs, students are not choosing to go into these fields because of the contribution to sustainability they can make. Job stability and the appeal of technical work rate higher across both fields and class rankings. When asked to expand upon why they chose the major they did answers range from, I don't know what sustainability is, to I want to design rockets and engines. From, sustainability does not factor into my decision to it being an important factor and changes in designs to motors can radically change how resources are used. In both Mechanical Engineering and Civil and Environmental Engineering barring a few outliers that indicated that sustainability was the reason they choose this field, most of the participants indicated that sustainability was not a significant factor in why they choose to become engineers.

Table 4. Factors for choosing a major.

Year/Department	Factors that were important in choosing a major	Average score
Freshman/CE	Job security	2.4
	Appeal of technical work	2.3
	Sustainability	2.1
Sophomore/CE	Job security	2.6
	Appeal of technical work	2.5
	Sustainably	2.2
Junior/CE	Job security	2.5
	Appeal of technical work	2.5
	Sustainability	2.0
Senior/CE	Job security	2.4
	Appeal of technical work	2.3
	Sustainability	1.8
Freshman/ME	Appeal of technical work	2.6
	Potential to improve quality of life	2.6
	Sustainability	2.2
Sophomore/ME	Job security	2.7
	Appeal of technical work	2.7
	Sustainability	2.0
Senior/ME	Appeal of technical work	2.5
	Enjoy learning	2.4
	Sustainability	1.6

To determine the differences in sustainability aspects in the curriculum and courses offered between Mechanical Engineering and Civil and Environmental Engineering and the sustainability knowledge of students in each program we asked two sorts of questions, one was for the students to list classes that had been helpful to them in learning about concepts of sustainability, and the other was to test the student's knowledge about concepts of sustainable design. First, participants were asked what classes in the program have helped them understand the concepts of sustainability most. The survey responses are listed in Table 5. Most students listed the class in which the survey was being conducted, some stated on their surveys that since the survey was being done in that class, sustainability must be important to the class. E LEAP is a program that freshman engineering students take that teaches them study skills, writing skills, and social aspects of engineering such as environmental concerns. This class appears to be the most significant contributor to knowledge about sustainability for both Civil and Environmental Engineering and Mechanical Engineering students.

Table 5. Classes that have taught sustainability (listed in order of frequency of answer).

Year/Department	Class that taught them the most about sustainable design
Freshman/CE	E LEAP CVEE 1000
Sophomore/CE	E LEAP Environmental Engineering I
Junior/CE	E LEAP Environmental Engineering I
Senior/CE	Environmental Engineering I & II E LEAP Senior Design
Freshman/ME	ME 1000 E LEAP
Sophomore/ME	ME 2500 E LEAP
Senior/ME	Senior Design Sustainable Energy Thermodynamics Heat Transfer

The next way we investigated what the students were learning in class was to test their knowledge about concepts of sustainability. The first concept we wanted to investigate was how students defined sustainable design. Table 6 contains the top concepts that were identified by the students in their definitions. The definitions tended to center around the same concepts of minimalizing environmental impact, saving resources for the future, creating a design that is long lasting, and being energy/fuel conscious. There was one definition of sustainability that was constantly given by students from every grade and program. This definition was "Meeting our needs without compromising the needs of our children and those in the future." This definition is the classic definition of sustainable development produced by the UN Committee on Environment and Development (i.e., the 1987 Brundtland Commission).

Table 6. Analysis of student definitions of sustainability.

Year/Department	Concept of sustainability identified in definition	Number of answers
Freshman/CE	Designing with future generations in mind	13
	Long lasting design	5
	Low Environmental impact	2
	Mindful of resources	2
Sophomore/CE	Long lasting design	6
	Low Environmental impact	4
	Designing with future generations in mind	2
Junior/CE	Long lasting design	8
	Low Environmental impact	7
	Energy/fuel conscious	3
Senior/CE	Designing with future generations in mind	10
	Low Environmental impact	7
	Mindful of resources	5
	Long lasting design	4
Freshman/ME	Low Environmental impact	41
	Long lasting design	19
	Energy/fuel conscious	8
	Designing with future generations in mind	8
Sophomore/ME	Low Environmental impact	20
	Energy/fuel conscious	17
	Mindful of resources	14
	Long lasting design	10
Senior/ME	Long lasting design	17
	Low Environmental impact	13
	Reduce waste	10
	Recycled materials	7

The second test of knowledge that the researchers choose was to ask students to identify two common concepts of sustainable design. First, we asked the students to identify the 5 r's of sustainable design and the other question asked students to define triple bottom line. The five r's are reduce, reuse, recycle, replace, and reinvent. The concept of triple bottom line is that companies, projects, etc. should be concerned and evaluated with three outcomes – profit (economics), people (social), and planet (environment). The researchers accepted, economic, social, and environmental as an alternative answer. It appears that in both Mechanical Engineering and Civil and Environmental Engineering the students are fairly uninformed of some foundational ideas of sustainability. The results indicate that ME students are slightly more informed as to concepts of sustainability. As would be expected students provide more accurate and comprehensive answers as they proceed through the program. None the less, the highest competency of the group was the senior Civil and Environmental Engineering and all Mechanical Engineer students being able to identify triple bottom line. These results would

indicate that none of these groups of students demonstrate comprehension of simple ideas of sustainable design.

Table 7. Number of correct answers for 5r's and triple bottom line.

Year/Department	Number of Participants	Number of correct answers for 5 r's	Number of correct triple bottom line	Percent of correct answers
Freshman/CE	30	0		0%
			2	6%
Sophomore/CE	20	1		5%
			3	15%
Junior/CE	26	0		0%
			3	12%
Senior/CE	30	5		17%
			19	63%
Freshman/ME	126	11		9%
			18	14%
Sophomore/ME	75	22		29%
			25	33%
Senior/ME	58	16		28%
			16	28%

Discussion

The most important finding in this study is that students in both Mechanical Engineering and Civil and Environmental Engineering believe that incorporating ideas of sustainability into their designs will be important to their future careers. A common sentiment is that individuals do not want to be involved with projects that are not quality and will not last for a long time. However, another popular response was that the ethos of the company they work for or the customer they serve will be the main determining factor in how much sustainability has an effect on how much influence sustainability has on a design.

There is no indication that Civil and Environmental Engineering students are more committed to sustainability than Mechanical Engineering students. It appears that younger students, freshman and sophomores answers indicate that they are more enthusiastic about incorporating sustainability into their practices. Because of this both Civil and Environmental Engineering and Mechanical Engineering Departments should understand that students feel that sustainable design will have import in their careers, and are choosing this course of study because they can be involved in designing sustainable systems more so than past students. Departments that recognize this will be able to offer curriculum that serves these students more effectively.

Conclusion

Both the Civil and Environmental Engineering and Mechanical Engineering Departments at the University of Utah need to do a better job of informing students about the concepts of sustainable design. Many students indicated that being invested in sustainability based technologies will offer new job opportunities, design challenges, and opportunities. Participants also noted that environmental regulations will make their job more difficult and design more expensive. A common sentiment expressed is that individuals do not want to be involved with projects that are not quality and will not last for a long time. However, another popular response was that the ethos of the company they work for or the customer they serve will be the main determining factor in how much influence sustainability has on a design. The Mechanical Engineering and Civil and Environmental Engineering Departments both have a tremendous opportunity to incorporate new curriculum at all levels of the program that will prepare students for skills that they themselves believe they need.

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APENDEX A.

Please complete the following questionnaire to the best of your ability, if you do not have an answer to a question, leave it blank. Thank you.

Part 1. Demographics

Sex: Male Female

Age: _____

Class Standing: Freshman Sophomore Junior Senior

Engineering GPA:

Do you currently work/hold an internship? Yes No

What is your position?

Part 2. Design

What are five aspects of design you consider when beginning a design project?

1.

2.

3.

4.

5.

What does sustainable design mean to you?

Please list three concepts or ideas associated with sustainable design:

1.

2.

3.

Please list the 5 R's of environmentally conscious design:

1.

2.

3.

4.

5.

Please list the three elements of the Triple Bottom Line of Sustainable Design:

1.

2.

3.

What U of U classes have taught you about sustainability? *Please write NA if no classes have addressed sustainability.*

To what extent do you think that ideas of sustainable design will be important in your role as a practicing engineer?

1	2	3	4	5	6	7
Not at all important						Very important

Please explain.

What is the relative importance of sustainability being a part of civil engineering practice in your decision to choose Civil Engineering as a career?

1	2	3	4	5	6	7
Not at all important						Very important

Please explain.

To what level is sustainability important to you in your personal life?

1 2 3 4 5 6 7
Not at all important Very important

Please explain.

Do you think global climate change is happening?

1 2 3 4 5 6 7
1- No, I do not think it is Without a doubt
4 It is probably not caused by human
5 I am not sure
6 I think it is
7 Without a doubt

Do you think global climate change is caused by humans?

1 2 3 4 5 6 7
No, I do not think it is Without a doubt

Rate the level of importance each of the following factors were in your decision to become a civil engineer by checking the level of importance that represents how much this impacted your choice of major:

Factor:	Not Important	Important	Very Important
Job Security			
High Salary			
Appeal of Technical Work and Problem Solving			
Potential to Improve Sustainability			
Potential to Improve Quality of Life			
Potential to Live Anywhere			
Enjoy Learning			
Status of Being an Engineer			
Other _____			