Exploring Gender Differences in Students' Sustainability Beliefs in Upper-level Engineering Courses

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Abstract

Sustainability has increasingly become a more prevalent topic in engineering as the need for global solutions that holistically improve the environmental, enhance quality of life, and are economically feasible have become more pressing. However, few studies have examined students' sustainability related career outcome expectations for upper-level engineering students, and, in particular, how these interests can be used to broaden participation in engineering. This time point is a critical one as students will be transitioning from college to industry where they may be positioned to solve pressing societal and environmental problems. To fill this gap, in this paper we answer the question, "What differences exist between men and women's attitudes about sustainability in upper-level engineering courses?" in order to better understand how sustainability topics may promote women's interest in and desire to address these needs in their future careers. We used data from a pilot of the CLIMATE survey given to 228 junior and senior civil, environmental, and mechanical engineering students at a large East Cost research institution. We asked the same questions as a previous study, called Sustainability and Gender in Engineering (SaGE), focused on first-year engineering students, "Which of these topics, if any, do you hope to directly address in your career?" with a list of ten sustainability outcome expectations. We used Pearson's Chi-squared test with Yates' continuity correction to compare men and women's answers. We found significant gender differences in students' desire to address energy, terrorism and war, water supply, food availability, and opportunities for woman and/or minorities in their careers. Some of these differences persist from first-year through upper-level classes, as compared to the results from SaGE in first-year students, while others develop during students' undergraduate education. Our results begin to help us understand the particular differences that men and women, even far along in their undergraduate engineering careers, may have in their desire to address certain sustainability outcomes in their careers.

Introduction

Issues such as climate change, resource availability, and social inequities affect future generations and are some of the most urgent issues facing society, our planet, and future global economies [1]–[4]. For example, results of climate change are likely to include a reduction of global food production and water supplies, sea level rise, and ocean acidification [5]. Global markets are expected to experience abrupt shifts in investment types and financial institutions will hold increasingly more risky assets that could cause destabilization insurance markets [6]. Engineers will play a critical role in solving these challenges. However, there is little research to assess if engineering students are ready to address and interested in working on these problems in their career, especially later on in students' undergraduate education.

To date, most education research about students' attitudes and knowledge about climate change and sustainability focus on middle and high school students' conceptual models without considering the link between understanding and interest to address such issues in their career [7]. Prior to college, global implications for a changing climate or other particular sustainability issues are not well understood by students in the U.S. [8]–[10]. Both an understanding of climate

science and its implications for sustainability require a systems thinking approach [11]. Far less is known about how misconceptions or ways of thinking may be corrected during college and how these sustainability beliefs may influence engineers' career goals. Additionally, prior research on early career undergraduate students' beliefs in human caused climate change indicate concerning numbers. Over half of freshmen undergraduate students interested in studying civil engineering in a national survey (53%) did not believe in anthropogenic climate change [12]. These trends in research highlight a need to understand what students think about climate and sustainability and how they relate to student career pathways in engineering.

In addition to the need to produce engineering students who are interested in addressing sustainability challenges in their careers, this topic may aid in the recruitment of underrepresented students in engineering, especially women. There has been much research into ways to attract women into engineering. Past studies have studied the effect of familial influence on student's career goals in engineering to study the impact of family members on student's choice to pursue a particular field of study [13]. Through a mixed method study, Bieri Buscho and colleagues [14] found that, in line with prior research, "women who decide to enter the field of STEM show a very strong expectation that they can make the world a better place" [p. 168]. Engineering decisions are most often made at the latter stages of high school, where many do not choose engineering pathways in college. There is also a significant drop in participation at the transition from university to engineering industry [26, 33]. One topic that has increasingly become popular is the idea of using sustainability to increase the participation in engineering. This topic is particularly appealing as it ties to outcome expectations like helping others and making the world a better place, both of which have been shown to be important reasons for choosing careers for women.

Prior research by Klotz and colleagues [15] showed that sustainability as a topic in engineering education is a positive way to increase women's interest in STEM at the transition from high school to college. In a study of first-year engineering and non-engineering students, Klotz and colleagues found that, overall, students interested in majors other than engineering were more likely to select that they hope to address poverty, distribution of resources, or opportunities for women and minorities in their career compared to engineering students [3]. However, within the engineering population, students interested in engineering majors were more likely to want to address energy (supply or demand), climate change, environmental degradation, water supply (shortages, pollution), terrorism and war, and opportunities for future generations. In addition, engineering women were even more likely to want to address disease, poverty and distribution of resources, and opportunities for women and minorities than their male engineering peers. In other words, engineering students were less likely than other students to want to address many sustainability issues, and male engineering students were even less likely (compared with female engineering students) to want to address them, especially disease, poverty, and distribution of resources. These results point to particular attitudes that first-year engineering students hold about the role sustainability in their future careers. It is imperative to understand these attitudes and how to develop engineers ready to solve sustainability problems in the future.

Our work begins to understand this question by focusing on students in their upper-level classes to see how attitudes may have shifted over time during an undergraduate education. We do have longitudinal data to compare prior work to our study, but we can draw qualitative comparisons to

see if there are shifts in attitudes over time. Examining upper-level students' attitudes is a critical time point as students' are beginning to transition from college to the engineering industry or other careers where they are positioned to solve some of these pressing problems. By understanding upper-level students' sustainability career goals, we can start to understand how engineering education may influence career goals and what difference exist at the end of college, as well as what students hope to address in their career to better understand what students see as available or not available through an engineering career.

Framework

We use the framing of outcome expectations from social cognitive career theory [16] to understand upper-level engineering students' interests in addressing particular issues related to climate change and sustainability in their careers. Outcome expectations are defined as "beliefs about the outcomes of various courses of action" [15, p. 458] and differ from goals, which are related to one's intentions to pursue a course of action. For example, a student might have a particular career interest in an engineering field (e.g., civil engineering, environmental engineering, etc.) because she has a particular outcome expectation (e.g., solving societal problems). Outcome expectations have been important in several frameworks used to understand students' career choices and pathways. It is a key feature in social cognitive career theory [16], [17] and expectancy-value theory [18]. In social cognitive career theory, outcome expectations along with self-efficacy beliefs and particular experiences are mediating factors in students' career choices. In expectancy-value theory, outcome expectations are similar to utility value [18]. Utility value can characterize the perceived future importance that is related to a particular career choice, such as making money or helping to solve societal problems [19].

This framing has also been linked directly to sustainability related outcome expectations and the choice of engineering for students. Klotz and colleague [15] investigated outcomes expectations that first-year students wanted to address in their engineering careers and those they did not connect with their engineering careers. This analysis allowed them to identify particular connections and disconnects for engineering students that may be important in recruiting diverse students, especially women, who are motivated by outcomes that they mistakenly perceive are not available through an engineering career. This prior work provides a foundation for our study. We are interested in examining not first-year students' engineering choice, but the connections students make in their upper-level courses to outcome expectations.

Research Question

In this paper, we answer the question, "What differences exist between men and women's attitudes about sustainability in upper-level engineering courses?" The purpose of this work is to better understand how interest in sustainability topics may differ among men and women engineers and how these persist and change between first-year and senior engineering students. The results also provide an understanding of student pathways from engineering to industry and include information about which sustainability topics resonate most with engineering students and how this differs based on gender.

Methods

This study is the first step in developing an instrument to measure students' career pathways, attitudes, beliefs, and knowledge about sustainability and climate change. We developed a survey based on prior work used with freshmen engineering students and in consultation with sustainability education experts. This survey was piloted in upper-level engineering courses at a single institution. In this paper, we present the preliminary results of students' sustainability related outcome expectations by gender and compare the results to prior work with early career students [15].

Participants

The CLIMATE survey was given to 228 junior and senior civil, environmental, and mechanical engineering students at a large, public Southeastern research institution during the Spring 2017 semester. The students surveyed included 62 third-year students, 96 fourth-year students, 29 fifth-year students, and one sixth-year student (as the question asked students how many years have you been at the current institution). The remaining students did not indicate how many years they were enrolled at the institution on the survey. These students were representative of the student population at the institution within these majors in both demographic characteristics and distribution of years at the institution in required upper-level courses. Many students at this institution engaged in cooperative education, and this participation helps account for the students who had beyond four years of enrollment. A total of 129 students indicated that they were male (56.7%), 45 students indicated that they were female (19.7%), three students indicated that they were a non-binary gender (1.3%), and the rest preferred not to answer. Students were also asked to report their self-identified race and/or ethnicity. A total of 141 students indicated they were white (49.0%), two students indicated that they were Black or African-American (0.9%), 15 students indicated that they were Asian (6.6%), one student indicated that s/he was American Indian or Alaska Native, 16 students indicated that that were Hispanic/Latino (7.0%), 10 students indicated more than one race (4.4%), and the remaining students preferred not to answer.

Instrument

The instrument was administered electronically during class via Qualtrics. Students voluntarily agreed to respond to the survey. This survey included questions about students' career goals, college experiences, beliefs about engineering, and demographic information. For this paper, we focused on student responses to one question, "Which of these topics, if any, do you hope to directly address in your career?" In order to compare our results of upper-level students' attitudes about sustainability, we asked the same questions as the previous study focused on first-year engineering students [15]. The list of topics included energy (supply or demand), climate change, environmental degradation, water supply, terrorism and war, opportunities for future generations, food availability, disease, poverty and distribution of resources, and opportunities for women and/or minorities. The answer to this question was either "Yes" or "No."

Analysis

As the answer to the question of interest was binary, either "Yes," or "No," Pearson's Chi-squared test with Yates' continuity correction was performed on each topic for this question, comparing men and women's answers. This test was chosen as it applies to categorical data and evaluates how likely any observed difference between sets arose by chance. For this analysis, we used an α of 0.05 and the R statistical software [20].

Results

A chi-square test was conducted on each of the sustainability related outcome expectations comparing the frequencies of indicated desired outcome expectations for men and women. The results of these tests are shown in Table 1. We included results from both significant and non-significant tests to show our complete findings. We also calculated the effect size, Cramer's φ, to examine the practical significance of our significant results. A value of 0.1 is considered a small effect, 0.3 a medium effect and 0.5 a large effect [21].

Table 1. Gender differences in upper-level engineering students' sustainability related career outcome expectations.

Sustainability Related Outcome Expectation	**Percent Male Agreement**	**Percent Female Agreement**	**Chi-square**	***p*-value†**	**Effect Size φ**
Energy (supply or demand)	**74.0**	52.6	5.30	0.021*	0.15
Disease	11.8	10.5	1.80×10^{-31}	1.000 (n/s)	--
Poverty and distribution of wealth	18.1	21.1	0.03	0.865 (n/s)	--
Climate change	37.8	42.1	0.08	0.773 (n/s)	--
Terrorism and war	**38.6**	10.5	9.31	0.002**	0.20
Water supply	**33.1**	52.6	3.97	0.046*	0.13
Food availability	7.1	**23.7**	6.67	0.010**	0.17
Opportunities for future generation	59.8	65.8	0.22	0.638 (n/s)	--
Opportunities for women and/or minorities	11.0	**55.3**	31.66	<0.001***	0.37
Environmental degradation	41.7	60.5	3.44	0.064 (n/s)	--

† n/s represents a non-significant result, ** a statistical significance between 0.01 and 0.001, and *** a statistical significance of less than 0.001.

We found that women are significantly more likely to want to address water supply ($\chi^2(1) = 3.97$, $p < 0.05$; 53%) than their male peers (31%). There was also a significant interaction for students' responses to the sustainability related outcome expectation of addressing food availability ($\chi^2(1) = 6.67$, $p < 0.01$). Women were more likely to want to address food availability in their careers (24%) than men (7%). Finally, there was a significant difference in women's desire to address opportunities for woman and/or minorities in their careers ($\chi^2(1) = 31.66$, $p < 0.001$; 55%) than their male peers (11%). The effect sizes for differences in women's desires to address water supply and food availability than men, 0.13 and 0.17, respectively, are small. The effect size for

the women's desire to address opportunities for women and/or minorities in their future career than men is moderate at 0.37. Of all the differences found, this different in sustainability career outcome expectations was the largest.

Men were significantly more likely to want to address energy supply or demand ($\chi^2(1) = 5.30$, $p < 0.05$; 74%) than their female peers (53%). There was also a significant interaction found ($\chi^2(1) = 9.31$, $p < 0.01$) for terrorism and war. Men were more likely to want to address terrorism and war in their careers (39%) than women (11%). Both of these effects were small, but significant in determine career differences between men and women.

Discussion

Our results begin to help us understand the differences that men and women, even far along in their undergraduate engineering careers, may have in their desire to address certain sustainability outcomes in their careers. We found significant differences in many of the types of sustainability related topics that men and women hope to address in their careers. Women were more likely than men to want to address water supply, food availability, and opportunities for women and/or minorities. Men were more likely to want to address energy and terrorism and war. We found no significant differences in students' desires to address disease, poverty, climate change, opportunities for future generations, and environmental degradation.

Our work is consistent with other prior literature that shows that connections to societal problems are important for women in engineering. One of the top barriers for women entering engineering is a perceived lack of connection of engineering with societal problems [22], [23]. The subject of sustainability may be one message that provides an engineering focus that may be more attractive to engineering, especially a focus on resource availability and social inequity. This finding is consistent with results from the "Academic Pathways Study" (NSF ESI #0227558), which showed that female undergraduates saw projects in the broader context of social and environmental impact while males typically focused on more technical details [24]. In order to develop engineering students prepared to address particular sustainability challenges, it is necessary to diversify the types of outcome expectations of students in engineering. If students who choose engineering are not interested in solving these types of problems, the future solutions developed by those students will be limited. Additionally, particular topics both at the beginning and end of a university degree may open pathways for underrepresented groups like women to enter engineering at the university and in the workforce.

In the prior study, "Sustainability and Gender in Engineering," by Klotz and colleagues [20] of 6,772 students from across the U.S., students who chose engineering at the beginning of university, both male and female, were less likely than students who planned to pursue non-engineering degrees to have outcome expectations related to disease, poverty, and opportunities for underrepresented groups. However, for many of the outcome expectations that engineering students were less interested (i.e., disease, poverty, and opportunities for underrepresented groups), engineering women were significantly more likely to want to address those outcomes in their careers than their male peers. These findings point to a system in which engineering students are less likely than non-engineering students to want to address these societal problems in their careers, and engineering men were even less likely to want to address them than

engineering women. These results point out particular concerns about what students' value and how that may affect their preparation and career pathways to address pressing sustainability issues.

This prior work from the "Sustainability and Gender in Engineering," study [20] was for students in their first-year English courses. We were interested in what types of differences might occur in engineering students' outcome expectations after their educational pathways through engineering programs, especially those in sustainability related fields like civil and environmental engineering. Exploring differences in upper-level students' sustainability related outcome expectations by gender is a first step in beginning to understand the interconnected ways in which students interests, goals, and expectations may influence their educational and workforce pathways in engineering. Our results indicate some differences than the results found with first-year students. We found more differences in students' outcome expectations by gender, with women being more interested in water supply and food availability and men more interested in energy and terrorism and war than their peers. This finding may show that the particular experiences that men and women have in their engineering courses may further divide interests in particular topics throughout their undergraduate career.

The one consistent result across the two studies was women's desire to address opportunities for women and minorities. Both the previous study [15] and our current study found significant differences with *p*-values less than 0.01 with moderate to large effect sizes. This results may be a particularly interesting place to focus recruitment and retention efforts in engineering for women. If women are interested in a topic, like addressing opportunities for women and minorities in engineering, and perceive engineering as career pathway that fits with that goal, they may be more likely to persist in engineering [25]–[29], especially at the transition from university to the workforce. This transition is often a troublesome point for retention, with only 11% of women working in engineering industry sectors [26] in comparison to almost 20% of women who earn engineering bachelor's degrees [30].

In other studies from the "Sustainability and Gender in Engineering" project, results for particular disciplines and the intersection of race and gender were investigated. A paper from the "Sustainability and Gender in Engineering" study examined students' sustainability career outcomes by both race and gender [31]. All women were more likely than men to want to address disease and opportunities for women in their careers, but there were differences among the female groups for many of the other outcome expectations. These results show that the intersection of both race and gender are important for understanding students' perceptions of sustainability and connections made to future career. In general, gender tended to be more influential on sustainability related outcome expectations than race and ethnicity, but differences did exist.

Again, results from the same study "Sustainability and Gender in Engineering" study showed significant differences in students' intended engineering majors based on their sustainability related career outcome expectations [32]. The results of this prior work showed that environmental engineering students had a stronger desire than their peers to address almost all of the sustainability career outcome expectations, and were not isolated to simply environmental issues. These students may be better informed about sustainability-related issues or may be cued

to specific jargon. Environmental engineers were the only discipline to report a desire to address poverty and wealth distribution and food distribution which are more social aspects of sustainability. Civil engineering students want to address fewer sustainability topics than their peers (only terrorism and war). Mechanical engineering students most wanted to address energy in their careers. This group was also the only group to indicate a lower desire than average to address opportunities for women and minorities as well as future generations. They were no different from the average in other sustainability attitudes. The results from these three sets of results from this prior work illustrate that first-year students' sustainability outcome expectations do have an impact on their desired career pathways and may be different by gender and race/ethnicity. We did not have the sample sizes to conduct more nuanced analyses like the intersection of race and gender or particular differences by engineering major but plan to do so in our future work (see below). This paper reports only the preliminary results from our piloting of the CLIMATE survey.

Our results may indicate particular sustainability related topics that attract women to engineering and may persist through the engineering degree pathway. Opportunities abound to emphasize the human impact of engineering through sustainability issues. Our results suggest that women are particularly interested in addressing issues related to the quality of life and future opportunities for underrepresented groups. These topics are often underemphasized in the engineering curriculum and more broadly as problems that engineers help solve in society. Our results also indicate that the interest of women may change over the course of their engineering curriculum. We acknowledge that we cannot make direct comparisons between our findings and prior studies, but the influence of particular university experiences and courses on students' knowledge of and attitudes about sustainability is an under-researched and potentially useful area of study for future interventions. We plan to better understand the change that occurs in students' attitudes, interest, and knowledge related to students' undergraduate engineering experiences related to sustainability to highlight particular types of curricular and co-curricular programs that may improve students' engagement and preparation for engineering work.

Limitations and Future Work

There are limitations to our work. For one, our data are cross-sectional rather than longitudinal comparisons. We did not survey the same students over a four year time period. In addition, there were limited choices of topics for students to pick without additional understanding of *how* they will be used in future career plans. Our future work will include looking at particular student experiences in and out of the classroom to understand how these sustainability outcome expectations develop. We plan to examine how particular expertise and topics taught in university experience may influence students understanding of and interest in addressing sustainability and climate in their future careers. If possible, it would be interesting to explore how global issues versus domestic issues might explain some of the differences, to add another dimension/layer. That is, what characteristics are different in the women that are interested in water supply, food supply, and other sustainability related outcome expectations versus the women interested in energy and terrorism and war. Additionally, we would like to examine the data by other demographic variables than just gender. The small sample by race and ethnicity, particularly, precludes us from doing so. We have recruited faculty in senior design courses across all engineering majors across the U.S. to participate in our full deployment of the

CLIMATE survey during Spring 2018. We aim for approximately 4,000 survey responses to better characterize student's sustainability attitudes and climate change beliefs when they are close to the transition between college and their future careers.

Conclusion

The need to diversify the field of engineering is critical to creating an atmosphere of diverse thinkers in industry prepared to address pressing global needs such as addressing climate change and its implications for long-term sustainability. This topic of sustainability could be used as a tool to increase female participation in engineering entering the workforce. The results of our study show that women in engineering have different sustainability related career outcome expectations. These findings may provide practical ways in which all students can engage in engineering courses and activities that better align with their needs and goals, as well as implications where we might see higher numbers of engineering women working in certain industry sectors in the future. Our future work will include looking at particular student experiences in and out of the classroom to understand how these sustainability outcome expectations develop and change.

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