What Are the Beliefs and Misconceptions about Climate Change of Students Pursuing Careers in Civil and Construction Engineering?

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Abstract

The overwhelming consensus in the scientific community is that anthropogenic climate change will irreversibly affect future generations. Engineering professionals who design and construct our built environment can protect society against the effects of global warming through implementation of building strategies that reduce climate changing emissions. There is little research to assess if students who intend to pursue careers in the design and construction of our built environment hope to address such important environmental and societal challenges. To advance understanding, a survey instrument was developed and validated to measure undergraduate engineering students' climate change literacy, career motivations, and agency to address climate change in their career. Preliminary results compare responses of engineering students intending to pursue a career in civil and construction industries to those of engineering students intending to pursue other engineering careers. The results indicate that civil and construction engineering students are more likely to take sustainability courses and learn about climate change in the classroom, but they do not excel above other engineers in their knowledge of climate science. The educational gap in engineering sustainability courses must be closed to ensure those who will design and construct our built environment are properly equipped to succeed in the sustainability-related careers they desire.

INTRODUCTION

Climate change caused by humans will irreversibly affect future generations and is one of the most urgent issues facing society (Cook et al., 2013; National Research Council, 2010; Nino, 2015; Stocker et al., 2013). Consequences of climate change will likely include reduced global food production, reduced water supplies, sea level rise, and ocean acidification (Karl, 2009). Engineers who construct the built environment and maintain infrastructure systems will play a critical role in combatting these consequences. In particular, construction engineers must devise new methods and processes to fortify infrastructure systems. Implementation of actions to combat and protect against climate change should be incorporated into scheduled plans for infrastructure upgrades or replacements. These actions include incorporating extra foundational supports, erecting protective barriers around critical roadways, elevating bridges and structures, modifying the curvature of drains and roads, and

developing natural areas to provide buffer zones. Engineers and construction professionals must recognize the need for such changes in practice and take action.

Recognizing a need for such changes in construction practice stems from education. Civil and construction engineering students must be taught to ask questions about climate change like: how severe will the consequences of the climate impact be, how soon may this occur, and how likely is the potential climate impact? The vast majority of experts agree the climate is changing (Cook et al., 2013), but there is little research to assess if civil and construction engineering students are ready to address such challenges in their career. Engineers play an essential role in combatting the effects of climate change, so, as students, engineers must be made aware of the issues and empowered to reduce human impact on the built environment. Students exposed to climate change issues through education are more likely to want to address these issues in their career (Klotz et al., 2014; Shealy et al., 2015).

This paper investigates students' experiences in undergraduate engineering programs by surveying their beliefs about climate change, their understanding of climate science, and their agency to address the issue in their careers. Preliminary results from a pilot study are reported in this paper (n=224). An explanation of next steps for a national survey is also included. The goal of this paper is to receive feedback about the survey instrument, explain the validation methods, and expand the usefulness of the survey to other researchers who are interested in engineering student agency to address climate change and sustainability in their careers.

BACKGROUND

Human impact on the climate system is unequivocal (Stocker et al., 2013), but only 50% of Americans believe in anthropogenic climate change (Leiserowitz et al., 2012). Climate change is likely to increase the frequency and severity of natural disasters necessitating more resilient infrastructure systems. Engineers who are responsible for the maintenance of our infrastructure systems will play a vital role developing more robust systems to address climate change impacts. Unfortunately, at a lower percentage than the general U.S. population, only 30% of professional engineers (n = 1077) believe climate change will cause significant public risk (Lefsrud & Meyer, 2012). Misconceptions about climate change are also evident in first-year college students. For example, more than 50% of students intending to major in engineering do not believe in climate change (Shealy et al., 2016). One possible reason for this misconception is a lack of education about the impact of climate change. The educational development of engineers and students studying construction during undergraduate programs provides an opportunity to correct misconceptions about climate change. Engineering education curricula should help students develop their skills for engineering and for construction careers that help mitigate climate change and raise sustainability awareness.

Need for a National Survey

A national survey for senior engineering students' will help assess U.S. readiness to address the impacts of climate change. The survey will quantitatively measure the relationships between understanding of climate change, how this develops critical engineering agency to address these topics, and how this translates to career plans. We desire to understand if students who will construct our built

environment and infrastructure systems hold different beliefs or understanding of climate change than other engineers, and if their beliefs and understanding are related to their undergraduate education.

To develop the pilot survey, we drew from existing knowledge on topics including belief about climate change (Leiserowitz et al., 2012), engineering course content and standards (ABET, 2013; Allenby et al., 2009), sustainability (Davidson et al., 2007; Huntzinger et al., 2007; Mihelcic et al., 2006), critical engineering agency (Godwin et al., 2013; McNeill & Vaughn, 2010), and career choice (Hazari et al., 2010; Kaminsky et al., 2012; Shealy et al., 2015). The survey was modeled after prior national surveys such as Sustainability and Gender in Engineering (Klotz et al., 2010), the Yale Project on Climate Change Communication (Leiserowitz et al., 2012; Leiserowitz et al., 2010) and the Climate Literacy Survey from Clarkson University (DeWaters et al., 2012). The survey included anchored, numerical, multiple choice, and categorical questions divided into six sections: (1) career goals, (2) college experiences, (3) about you, (4) climate science, (5) people and the planet, and (6) demographic information.

RESEARCH QUESTIONS

1. What are engineering students' beliefs about climate change?
2. Do engineering students who intend to design and construct the built environment have different beliefs about climate change than other engineering majors?
3. Do these students…
   a) talk about sustainability and climate change in their courses?
   b) understand the impacts of global warming on themselves and others?
   c) understand the causes of climate change and methods to reduce or slow it?

METHODS

In the next phase of research, data will be collected through a national survey of 5,000 senior undergraduate students. Advanced statistical techniques will be used for analysis. This study will be the first of its kind to explore how experiences in college impact students' climate change beliefs and their agency to address related sustainability challenges. This approach can provide generalizable trends about how undergraduate education affects students' self-beliefs and long-term goals, but it cannot provide causal information. Even so, it can provide powerful information about the most influential experiences on students' attitudes through multilevel models and effect size calculations. The data of this national survey will be openly available to researchers when data collection concludes in May 2018.

The results reported in this paper are pilot data to establish evidence for reliability and validity. The survey was distributed to 224 students in their senior year of engineering at Virginia Tech. Students were asked to complete the survey online, and ten percent of those who completed the survey were randomly selected to receive a cash prize for participating. The survey took, on average, 17 minutes to complete. The civil engineering students discussed in this study include three subsets of academic focus: non-structural (n=59), structural (n=6), and construction (n=14). Civil engineering students' responses to the survey were compared to the responses of students studying other engineering disciplines including mechanical engineering,

environmental engineering, materials science engineering, and aerospace engineering (n=111). Responses were compared utilizing the student's pooled t-test. If the t-test rendered a p-value less than 0.05, the null hypothesis was rejected. Since the t-tests were conducted on two independent samples with unequal variance, the Welch-Satterthwaite equation was utilized to calculate the degrees of freedom. Fourteen questions from sections 4 and 5 of the survey, related to climate science and sustainability education, were analyzed to determine statistically significant difference between the two groups (civil engineers and other engineers).

RESULTS & DISCUSSION

The majority of survey questions received similar response from both demographics (civil engineers and other engineers) with ten questions demonstrating statistically significant differences. Two questions related to sustainability education rendered a significant difference (p=0.000). The first question asked: "Compared to your peers, how likely are you to take sustainability related courses in your area of academic interest," on a scale from 1 to 5 with 1 being "Not at all likely" and 5 being "Extremely likely." The results indicated that civil engineers were more likely to take sustainability related courses than other engineering disciplines (Table 1A). The second question asked: "Which of the following has contributed the most to your understanding of global climate change?" Respondents were given six choices and asked to rank each on a scale from 1 to 5 with 1 being "Not at all" and 5 being "A lot." The choices were independently ranked. Both demographics responded similarly to all answer choices except for the choice listed as "College courses." Civil engineers were more likely to cite college courses as a source of information about global climate change than other engineering disciplines (Table 1B).

Table 1. Descriptive statistics: Civil engineers are more likely to….

		Other Engineering Majors			Civil Engineering Majors			Comparison		
		N_1	X_1	S_1	N_2	X_1	S_2	t-test	DF	p
A	… take sustainability related courses.	111	3.1	1.4	79	3.8	1.2	-3.85	182	0.000
B	… gain understanding of global climate change from college courses.	106	3.1	1.4	73	4.1	1.2	-5.27	167	0.000
C	…want to spread sustainability awareness in their community.	104	3.1	1.4	72	3.7	1.2	-2.66	169	0.009
D	… work alongside local government to mitigate climate change.	105	2.8	1.4	73	3.2	1.1	-2.02	173	0.045

*N=sample size, X=sample mean, S=sample standard deviation, DF= degrees of freedom

Even though civil engineers are more likely to take sustainability related courses and gain an understanding of global climate change from college courses, they do not recognize themselves as a component of the natural environment when asked about the immediacy of global warming impacts. Respondents were asked to evaluate the immediacy of global warming impacts with the statement, "Global warming will start to have serious impacts on…" with a five-point timeline scale from "Now" to "Never." They were given nine identities to evaluate in regards to this statement (Table 2). Of the nine identities, "Me personally" was used as the control case to compare engineering students' perceptions of global warming impacts on themselves to the eight other identities. Engineering students viewed the immediacy of impacts on themselves as similar to the immediacy of impacts on other people. However, engineering students, including civil engineers, perceived global warming impacts to be much more immediate on plant and animal species ($t= 3.684$, $p=0.000$) and the natural environment ($t=3.616$, $p=0.001$) than on themselves or other people (Table 2). The p-values for both of these results meet Bonferroni correction requirements where $p<0.006$. Evaluation revealed that all engineering disciplines, including civil engineers, hold the belief that global warming will impact plant and animal species and the natural environment before impacting them.

Table 2. T-test results comparing responses with regards to "Me personally" for the question "Global warming will start to have serious impacts on…"

Answer Choice	t-test	p-value
Me personally (control)	N/A	N/A
My family	-0.16575	0.869
People in my community	0.150407	0.881
People in the U.S.	1.455321	0.150
People in other modern industrial countries	1.266233	0.209
People in developing countries	1.071409	0.287
Plant and animal species	3.684428	0.000
The world's poor	1.429306	0.157
The natural environment	3.616195	0.001

Civil engineers' response to the question "Global warming will start to have serious impacts on…"are isolated from other engineers' responses in Figure 1.Civil engineers perceive more of an immediate global warming impact on plant and animal species and the natural environment than on themselves. However, all engineering disciplines who participated in the survey have this similar mindset. This inconsistent perception about global warming impacts is ironic because humans are, in fact, a component of the natural environment and are biologically considered an animal species. It is surprising that civil engineers' perceptions do not differ from other engineering disciplines considering they are more likely to take sustainability courses and learn about climate change in the classroom (Table 1A, 1B). This issue could indicate an educational gap in engineering sustainability courses.

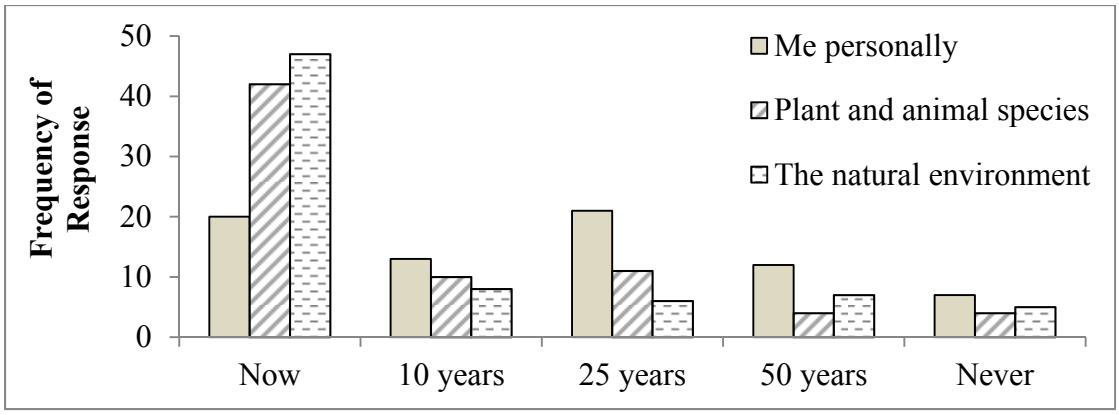

Figure 1. Civil engineers' responses to "Global warming will start to have serious impacts on…"

A possible educational gap in engineering sustainability courses was also indicated by the results of survey questions asking about the causes of climate change and methods to reduce or slow climate change. A total of 21 true-false questions were asked in relation to these topics and only 10 of these questions were answered correctly by the majority of civil engineers (Figures 2, 3). Figure 2 demonstrates that the majority of civil engineers believed all listed options were actual causes of climate change, or they were unsure if they were causes. Civil engineers are more likely to desire working with the community to spread sustainability awareness and with the government to mitigate climate change (Table 1C, 1D), so it is necessary that they are properly educated about the causes of climate change. Therefore, it is concerning that the majority of civil engineering students answered six of ten questions incorrectly about the causes of climate change.

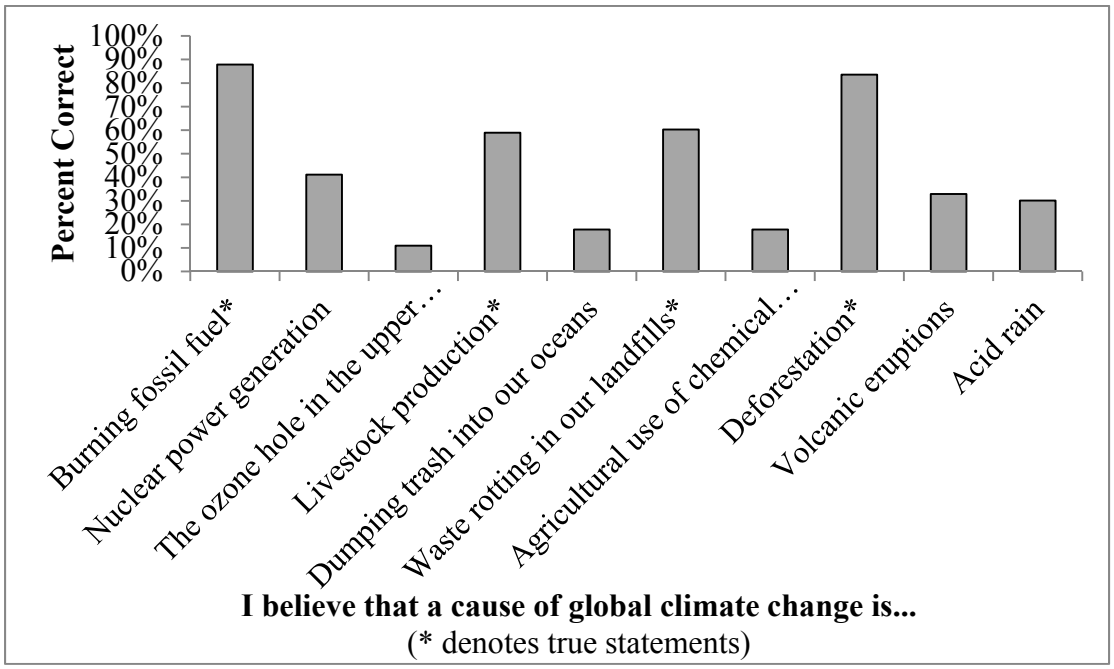

Figure 2. Civil engineers' responses about the causes of climate change

A similar trend surfaced when civil engineers were asked about methods to reduce or slow climate change. Of the eleven questions asked related to this topic, five of the questions were answered incorrectly by the majority of students (Figure 3). The majority of students did not understand eating less meat was a feasible method to slow climate change, and they thought all other methods listed in the survey were ways to reduce or slow climate change, although only seven methods were in actuality (Figure 3). Sending civil engineers into the workforce who misunderstand the basics of climate science would be a great disservice to the community. Civil engineers must be properly educated about methods to combat climate change if they are to be successful in careers where their goal is to spread sustainability awareness or legislatively mitigate climate change. Other engineers responded similarly to civil engineers for most of the questions detailed in Figures 2 and 3 except for three questions. Civil engineers answered more incorrectly than other engineers for the following questions: "I believe a cause of global climate change is nuclear power generation" (F, t= -2.431, p=0.016); "I believe a cause of global climate change is the ozone hole in the upper atmosphere" (F, t=-2.045, p= 0.042); "I believe a way to help reduce or slow down climate change is building more nuclear power stations instead of coal power stations" (T, t=2.379, p=0.019). It is concerning that civil engineers do not excel above other engineers in their knowledge of climate science even though they are more likely to take sustainability courses and learn about climate change in the classroom. The educational gap in engineering sustainability courses must be closed to ensure civil engineers are properly equipped with knowledge to succeed in the sustainability-related careers they desire.

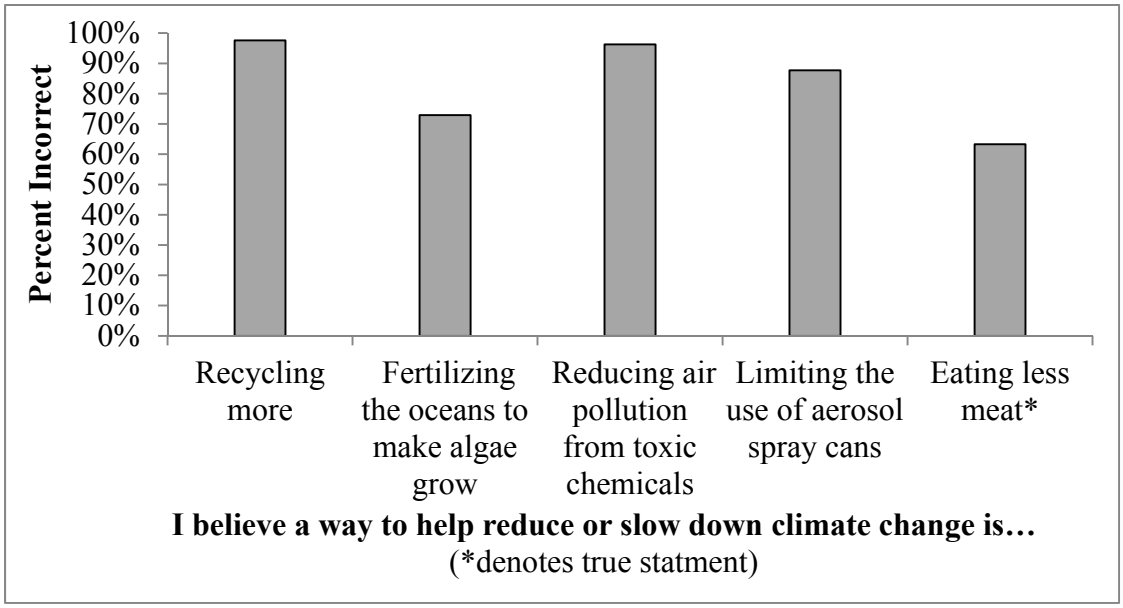

Figure 3. Civil engineers' incorrect responses about the reduction of climate change

Results demonstrate that civil engineering majors including construction engineering majors may not be properly equipped with an understanding of climate science. Civil engineers have a greater desire to raise sustainability awareness within the community and to combat climate change by working alongside the government,

yet their knowledge of climate science is no better, and, in some cases, worse than other engineering majors. Further, the majority of engineering students think that sustainably completing projects costs more. This is fundamentally inaccurate as sustainable building and infrastructure projects must cater to the triple bottom line which includes being economically beneficial. The belief that sustainability costs more is especially concerning since civil engineering majors claim they are more likely to gain understanding of climate change from college courses. Engineering students who plan to design and construct our built environment are lacking in their knowledge of climate science, yet they desire to work in sustainability fields more than other engineers. Gaps in engineering sustainability education must be identified to combat this issue.

CONCLUSION

Second and third order consequences of climate change include strain on infrastructure systems and depletion of environmental resources. These are issues that civil and construction engineers will combat in their careers regardless of their views about climate change. Engineering education about climate change should represent these challenges with sustainability implications spanning community, environment, and economy (*The Climate Change Educational Partnership*, 2014). Those studying how to design and construct vital infrastructure systems must consider questions such as: what resources are available, how severe will the consequences of the climate impact be, how soon may they occur, and how likely is the potential climate impact? If civil engineering students are not well educated about climate science, they will not be able to answer these questions knowledgeably. Results convey a gap in engineering sustainability education because there is a disconnect between civil engineering students' knowledge of climate science and their career goals to work in sustainability fields.

Our long-term vision is that this research becomes a catalyst for teaching on topics related to climate change and its implications for sustainability because teaching can support students' critical engineering agency (e.g., empowerment and identity in engineering contexts) and beliefs about sustainability. Students' agency and beliefs may influence their career choice and expected career outcomes. As a result, we hypothesize that more engineering students will pursue careers to solve societal challenges that mitigate and prepare for climate change and its global implications for sustainability.

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