Civil engineering students' beliefs about the technical and social implications of global warming and when global warming will impact them personally and others

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Abstract

The United Nations recognizes reducing the effects of global warming as a Sustainable Development Goal (SDG) (#13). This goal is interconnected and critical to improving health and education, reducing inequality, and spurring economic growth globally. Civil engineers will play a vital role in meeting this goal. To understand how civil engineering students perceive global warming, we surveyed a national sample of civil engineering students in their final semester of college (n = 524). We asked them (a) if they recognize both the technical and social issues associated with global warming and (b) when they believe global warming will start to have a severe effect on themselves, others, and the planet. Civil engineering students are significantly more likely to recognize the technical issues associated with global warming than social issues. In particular, the majority of students understand global warming is an immediate issue for the environment, engineering, health, and science, but less than half recognize global warming presents social justice, poverty, and national security issues. Moreover, civil engineering students hold an inverse relationship between spatial distance and the timing of the effects of global warming. The majority of students believe global warming is currently having a severe impact on plant and animal species, the environment, people in developing countries, and the world's poor but do not recognize themselves in this group. Instead, civil engineering students predominantly believe the effects of global warming will start to have a serious impact on themselves, their family, and people in their community in 25 to 50 years. These results are troubling because if those beliefs translate into students waiting to address climate change for another two to five decades locks in more emissions and increases the chance of future and more severe global humanitarian crises. Educational interventions are needed to change these perspectives about time and impact.

Introduction

Climate change caused by humans is irreversibly affecting future generations and is one of the most urgent issues facing society [1]–[3]. The effects of climate change are already reducing global food production and water supplies, increasing sea level rise, and ocean acidification [4]. The majority of greenhouse gas emissions contributing to climate change are from the built environment. Residential and commercial buildings account for nearly 40 percent of total U.S. greenhouse gas emissions [5], and the transportation sector contributes about 30 percent of total U.S. greenhouse gas emissions [6].

Civil engineers who support the design and construction of these physical systems need to play a more central role in helping reduce greenhouse gas emissions and preparing for its effect on society. The impact of climate change is both technical and social. For example, civil engineers need to use stronger materials to combat roadway buckling from increased temperatures, washouts from precipitation, and settling from thawing permafrost [7]. Smart infrastructure is also needed to better detect air quality challenges and combat polluters [8], [9]. Communities are also feeling the social impact of climate change. For example, residents in Louisiana and

Maryland are leaving their homes and retreating inland to escape rising floodwaters [10], [11]. Additionally, the U.S. Military is concerned about climate change because of increased human migration and the risk of geopolitical war [12].

The issue of climate change is inherently a challenge for sustainability, broadly defined as meeting the "needs of the present without compromising the ability of future generations to meet their own needs"[13] and recognized in the most recent United Nations (UN) Sustainable Development goals. The effects of climate change will undoubtedly make many of the UN Sustainable Development goals more challenging to meet.

Education in civil engineering should represent these dynamic challenges spanning both technical and societal problems [14]. Engineers exposed to issues related to global warming and its effect on climate change through education are more likely to want to address these issues in their careers [15], [16]. How educators expose students to problems related to climate change may influence what technical or social aspects they want to address. For example, recognizing the social implications of climate change and its impact on sustainability leads to wanting to address these issues [17]. Students interested in social sustainability topics like ensuring opportunities for future generations, economic equality, and quality of life, are more likely to be female, non-White, and speak English not as their first language [18]. In other words, presenting both the social issues related to climate change to engineering students may help attract a more diverse and underrepresented group of students to tackle these challenges in the future.

In addition to recognizing the technical and social implications of climate change, students also need to acknowledge the temporal (e.g., this decade compared to a century from now) and spatial (friends and family compared to only people in developing countries) effects of climate change that is occurring all around them. Greater temporal and spatial distance about the impacts of climate change leads to less support for mitigation efforts [19]. Recognizing the effects of climate change are already causing challenges for infrastructure is especially critical for civil engineering students whose future design decisions can make our built environment and citizens more or less vulnerable to climate change. It is not just enough to recognize both the technical and social issues but realize the need to address these challenges now [20], [21].

The purpose of the research presented in this paper is to measure how civil engineering students perceive climate change as either a technical or social issue and how civil engineering students perceive the temporal and spatial distance of the effects of climate change on themselves, others, and the planet. The background provides a summary of recent literature about education related to climate change and the consequences of perceived temporal and spatial distance to address climate change. The research questions follow, and the methods explain the data collection process. The results and discussion offer new insight into the perceptions of climate change among civil engineering students nationally and highlights the need to change perceptions of climate change among students in undergraduate civil engineering programs.

Background

Only half of the students interested in studying civil engineering believe in human-caused climate change [22]. Understanding perceptions of climate change is critical to motivating successful adaptation and mitigation efforts [23], [24]. Opinions about climate change are

inherently difficult to change, in part, because the concept is challenging to understand [25] and is susceptible to systematic misconceptions [26], [27]. For example, students with the highest general science literacy are not necessarily the most concerned about climate change [28], [29]. Students must recognize the mechanisms driving climate to believe in its long-term effects [30], [31].

How students learn about climate change can also affect their perceptions. Educational interventions are widespread [30] and studies in classrooms [32] and outside school [33] have examined whether specific interventions can lead to improved understanding of climate change. For instance, students interacting with scientists to explore local climate conditions and collect data [34] or implementing an energy conservation program in their school [35]. Programs that focus on the personally relevant and meaningful information and activities that engage learners are more effective than merely presenting the facts and also the actions [36].

Understanding how climate change is a social issue, not just a technical issue, can help change motivation to take action. For example, focusing on the positive effects on society rather than averting climate risks on the environment can increase willingness to adopt mitigation measures [37], [38]. Social factors such as the process and culture of education can shift willingness to adopt mitigation measures for climate change [17]. However, focusing on the social implications of climate change is only helpful if students see themselves and their community as likely to be affected. Lack of personal risk perception of climate change is a barrier to taking action [39]. Also, greater psychological distance from the problem is associated with less concern about climate change [19]. People who hold higher levels of personal responsibility also hold temporal and spatial perceptions about climate change that are consistent with science [40].

Understanding the immediate effects of climate change is especially critical for students studying civil engineering because these students' decisions in their careers will lock in energy use for decades. Civil engineering students will make forward-looking decisions in their careers that not only account for current costs but also more accurately weigh future consequences of their choices on community well-being and quality of life. Unfortunately, too many decisions about infrastructure are overly nearsighted and are suboptimal for community well-being and quality of life [41]–[45]. These decisions may be reflective of the beliefs and perceptions of the nation. Only half of the people in the U.S. believe global warming is harming people in this country, and less than half believe global warming will harm them personally [46]. In other words, there are less perceived repercussions for short-term decisions.

Students that believe the effects of climate change as either too far in the future or not related to them or their community [47] may be more likely to discount the benefits. For example, to extend floodplains in response to rising sea levels because the future benefits in reduced storm damage will not be realized for generations to come [48]. Thus, they value these decisions with some excessively discounted rate [49].

Research Questions

The purpose of this study was to understand how civil engineering students perceive climate change as a technical or social issue and when they believe the effects of climate change will start to have a serious impact on themselves, others, and the planet. The research questions are:

1. Do civil engineering students recognize both the technical and social issues associated with global warming?
2. When do they believe global warming will start to have a serious effect on themselves, others, and the planet?

Methods

A national sample of senior engineering students completed a survey in Spring and Fall of 2019. The sampling frame included four-year institutions chosen from the National Center for Education Statistics institutional database. A stratified random list was created by categorizing institutions by undergraduate engineering enrollment, including small (< 5,400), medium (5,400-14,800), and large institutions (> 14,800). Capstone instructors at the institution selected at random were contacted and asked to distribute the survey. A total of 83 capstone instructors distributed surveys to students in their class. No incentives were given to students for completing the survey. Capstone instructors received paper surveys by mail, along with instructions to distribute the surveys to their class. Sixty-six instructors responded with completed surveys for a total sample of n = 4,605 senior engineering students. A total of 636 students from our sample were civil engineering students. Of those 636 students, 524 were retained as completed cases for the purposes of the analyses.

Survey questions and analyses

We used two questions from the survey to understand whether civil engineering students recognize both the technical and social issues associated with global warming and when students believe global warming will start to have a severe effect on themselves, others, and the planet. These questions were:

1. I believe that global warming is a(n)… environmental issue, religious issue, social justice (fairness issue), political issue, scientific issue, engineering issue, health issue, economic issue, national security issue, agricultural (farming, food) issue, or poverty issue. The options were an anchored numeric five-point rating scale from 0-"Strongly disagree" to 4-"Strongly agree."
2. Global warming will start to have serious impacts on...me personally, my family, people in my community, people in the United States, people in other modern industrialized countries, people in developing countries, plant and animal species, the world's poor, and the natural environment. The options were categorical: now, 10 years, 25 years, 50 years, and never.

We removed students who skipped more than 10 percent of the total questions and students who did not answer either of these two specific questions on the survey from the analysis. The final number of civil engineering students included in the study was 524.

To understand whether civil engineering students recognize both the technical and social issues associated with global warming, we created two separate consolidated factors with exploratory factor analysis (EFA). The results of the EFA for items related to the first research question–what kind of issue is global warming–generated two factors with six survey items loading on factor one and five items loading on factor two. We called these two factors "technical issues" and "social issues," respectively. The technical issue items were environmental, scientific,

engineering, health, economic, and agricultural. The social issue items were religious, social justice, political, national security, and poverty. The factor loadings are reported in Table 1. The Root Mean Squared Error of Approximation for the model is 0.085, and the Tucker-Lewis Index is 0.935, which suggests a moderate to a good fit of the model.

Table 1. Factor loading variance explained

	Factor 1	Factor 2	Uniqueness
Environmental	0.776	.	0.460
Religious	.	0.679	0.638
Social justice	.	0.744	0.451
Political	.	0.403	0.669
Scientific	0.879	.	0.300
Engineering	0.903	.	0.204
Health	0.705	.	0.328
Economic	0.563	.	0.367
National security	.	0.605	0.463
Agricultural	0.686	.	0.380
Poverty	.	0.689	0.409

With these two factors, we calculated a "technical issue" score and a "social issue" score for each respondent by taking the arithmetic mean of all of the individual items in the factor. In addition to comparing social and technical issues, we also report student responses for each item. Reporting items individually enables more insight into the particular items that students associate with global warming.

To understand when students believe global warming will start to have a serious effect on themselves, other humans, and the planet (research question two), we examined the distributions of civil engineering student beliefs for each of the items in the question. We also clustered students into several groups based on their patterns of beliefs. By patterns of belief, we mean a consistent collection of beliefs about when, if at all, global warming may affect different groups. These patterns of belief allowed us to identify popular sets of beliefs among civil engineering students regarding the potential spatial and temporal effects of global warming. For example, whether students who believe global warming will have an impact on them personally in 50 years also believe global warming will affect people in other modern industrialized countries similar to themselves. We clustered students to identify patterns of beliefs about when and where global warming may affect each item.

We performed this cluster analysis in multiple steps. To start, we recoded the answers to the survey items transforming them from a five-point scale to three-point trichotomous variables. Responses of “now” or “10 years” were grouped as one variable (treated as “sooner”). Responses of “25 years” or “50 years” were grouped as one variable (treated as "later"). Finally, responses of “never” formed the third group.

Next, with these three response options for each of the nine survey items, we performed a two-step process of (1) dimension reduction followed by (2) clustering. We used a uniform manifold approximation and projection (UMAP) algorithm [50] to reduce the data to a two-dimensional

embedding space. This step enabled more meaningful results for the clustering calculations. After projecting the data to the lower-dimensional embedding space, we then used hierarchical density-based spatial clustering for applications with noise (HDBSCAN) [51] to cluster the student responses. We set the group size parameter as a minimum of 25 points for groups. This parameter was optimized for maximizing the internal consistency of the members of each cluster while also minimizing the number of data points treated as outliers.

Results

The results indicate that civil engineering students believe global warming is more of a technical issue (*Mean* = 3.25, *SD* = 0.84; where 0 is strongly disagree, and 4 is strongly agree) than a social issue (*Mean* = 2.04, *SD* = 1.05). Figure 1 shows the distribution of scores. The social issue scores appear normally distributed with floor and ceiling effects. In contrast, the technical issue score sample distribution has a negative skew.

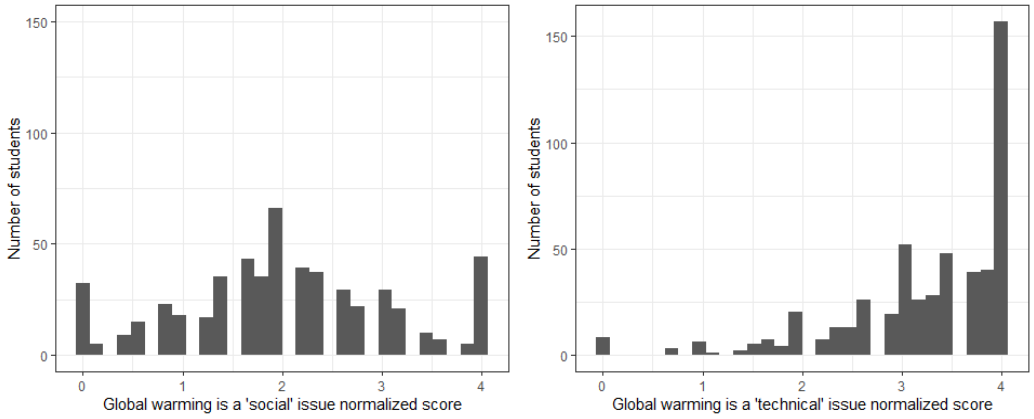

Figure 1: Histograms of students who strongly disagree (0) to strongly agree (4) global warming is a social issue (left) and technical issue (right).

The majority of students strongly agree that global warming is an environmental, scientific engineering, health, economic, and agricultural issue, but less than a quarter believe global warming is an issue related to social justice, national security, or poverty. The percent frequency for each item is provided in Table 2.

Table 2: Percent frequency of responses for each item

	Item	0-Strongly disagree (%)	1	2	3	4-Strongly agree (%)
Technical	Environmental	1.9	1.0	5.5	19.8	71.8
	Scientific	3.4	2.1	7.6	24.0	62.8
	Engineering	2.7	2.7	9.9	24.8	59.9
	Health	5.2	5.5	12.8	26.7	49.8
	Economic	5.9	9.7	16.8	26.1	41.4
	Agricultural	4.0	3.2	14.3	28.8	49.6

Social	Religious	51.3	17.6	14.3	6.3	10.5
	Social justice	25.2	11.5	21.8	19.5	22.1
	Political	10.7	7.1	14.5	25.8	42.0
	National security	16.2	15.8	28.4	15.5	24.0
	Poverty	18.3	14.5	25.0	18.3	23.9

Civil engineering students believe the effects of global warming as having an immediate impact on the natural environment and plant and animal species while potential effects on themselves and their more proximate communities later, if ever. The general trend is an inverse relationship between spatial effects and the timing of those effects (i.e., the further away the target group is from the student, the closer in time global warming will affect that group). The percent frequency for each item and time is provided in Table 3.

Table 3: Percent frequency civil engineering students believe global warming will have an effect on themselves, others, and the planet

Item	**Now (%)**	**10 yrs**	**25 yrs**	**50 yrs**	**Never (%)**
me personally	21.9	23.1	26.1	17.2	11.6
my family	19.3	23.5	27.7	19.8	9.7
people in my community	21.0	25.0	27.7	17.9	8.4
people in the United States	24.4	26.1	23.7	18.9	6.9
people in other modern industrialized countries	28.2	25.8	22.7	17.0	6.3
people in developing countries	36.6	24.0	17.2	15.8	6.3
plant and animal species	53.6	18.7	12.6	9.9	5.2
the world's poor	40.6	25.4	14.1	12.4	7.4
the natural environment	58.0	15.3	11.5	10.7	4.6

The percent frequency does not explain patterns of beliefs between items. So, to better understand how students view multiple items, we used the two-step clustering technique described in the methods section. There are six distinct clusters with six different kinds of belief patterns about global warming. Table 4 summarizes these clusters with short descriptions and the number of students in each group.

The largest group of students consistently believes that global warming is affecting each of the target groups now or within the next 10 years. We call this the "here and now" group. The second-largest group of students is the "down the road" cluster. These students consistently said that global warming would affect each of the listed categories but not within the next 25 years. The smallest cluster of students is the "humans exceptionalist" cluster. This group of students believed plants, animals, and the environment are currently being affected by global warming, and eventually, human communities will be affected, regardless of socioeconomic or geographical status. The "industrialized bubble" cluster included more than double the number

of students in the "humans exceptionalism" cluster. The "industrialized bubble" cluster believes global warming is affecting everything except people in industrialized countries. Students expressing this belief pattern do think that global warming will *eventually* affect people in industrialized countries as well. Cluster four is the "personal bubble" cluster. This group believes global warming is affecting everything except the small bubble of people and communities around them, but eventually (in 50 years) it will affect them, too. Cluster five is the denial group. These students do not believe global warming will affect most or all of the categories listed, ever. They stand in stark contrast to the "here and now" group, which is on the other end of the spectrum, as mentioned above.

Table 4: Student clustered by their patterns of beliefs about global warming

Belief pattern name	Description	No. of students
Down the road	Global warming will affect all categories listed later	109
Humans exceptionalism	Global warming is affecting plants, animals, and the environment now and will affect all human groups later	30
Industrialized bubble	Global warming is affecting the poor, developing countries, and non-human groups now, and will affect people in industrialized countries, including themselves, later	67
Personal bubble	Global warming is affecting everything outside their egocentric networks (e.g., family and community) now and will eventually affect those networks as well	48
Denialists	Global warming is not and never will affect most or all of the listed categories	46
Here and now	Global warming will affect all of the groups within the next ten years	217
Unclassified	These were outliers who did not exhibit one of the six distinct belief patterns	7
Total		524

Discussion

Given engineering education requires a strong foundation in technical problem solving, the finding that civil engineering students see global warming more of a technical than social issue is not surprising. However, engineering students who recognize that engineering addresses societal challenges are more likely to represent minority groups within engineering [52]. These students are also more likely to want to address broad issues related to sustainability in their careers [18]. Helping civil engineering students recognize the social implications for global warming may help attract a more diverse group of students to tackle these challenges in the future. Also, framing global warming about the societal impact rather than just as an environmental or engineering problem may help change beliefs and motivation [37], [38].

The largest cohort of students (217 students) recognize that global warming is affecting everything–themselves, others, and the planet. Although, the cohort students in the "down the road," "humans exceptionalism," "industrialized bubble," and "personal bubble" make up the majority of the students in the sample population (254 students) and believe that global warming will not affect themselves or people like them for decades. This belief is similar to the general

public's view of global warming in the United States [46], [53]. This belief is also similar to ideas among middle school students who see themselves removed from the natural environment and the effects of global warming [54]. Civil engineers should play a more active role in addressing climate change as a result of global warming, and this requires recognizing the temporal scale of the effects of global warming concerning the infrastructure they design and construct [22]

Civil engineering design decisions today and in the near future will lock in energy consumption and carbon emissions for generations to come because of the long life span of infrastructure and development around infrastructure once it is built [55], [56]. Students entering the workforce, therefore, must make forward-looking decisions about future conditions. Recognizing that global warming will have both immediate and future effects is necessary for design [57], [58]. Beliefs about global warming do not translate to a willingness to act among students [59]. Less than half believe global warming will affect them personally, their family, or their community in the next 10 years. Also, greater psychological distance from global warming is associated with less concern about its effects [19]. Recognizing the impacts of climate change are already causing challenges on infrastructure is especially critical for civil engineering students. Their future design decisions can make our built environment and citizens more or less vulnerable to climate change. Students that view the effects of climate change as either too far in the future or not related to them may be more likely to discount the benefits for addressing the issue [48]. These students may associate less value to design options that address climate change [49].

Conclusion

The research presented in this paper measured how civil engineering students perceive the effects of global warming as either a technical or social issue and how civil engineering students perceive the temporal and spatial implications of global warming on themselves, others, and the planet. We sampled a national sample of senior engineering students from Spring and Fall of 2019. A total of 524 civil engineering students completed the survey. The results indicate civil engineering students are significantly more likely to recognize the technical issues associated with global warming compared the social issues. In particular, students understand global warming is an issue for the environment, engineering, health, and science, but less than half recognize global warming presents social justice, poverty, and national security issues. The majority of civil engineering students believe global warming is currently having a serious impact on plant and animal species, the environment, people in developing countries, and the world’s poor but do not recognize themselves, their family, or their community in this group. Instead, civil engineering students predominantly believe the effects of global warming will start to have a serious impact on themselves, their family, and people in their community in 25 to 50 years. Waiting to address the effects of global warming for another two to five decades locks in more emissions and increases the chance of future and more severe global humanitarian crises. Teaching about the social implications of global warming and the temporal and spatial effects of global warming can help prepare students to address global warming in their careers.

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