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Teaching Climate Change in an Introductory Civil Engineering Course

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Abstract

Climate change is bringing significant impacts that will affect the way the built environment is designed and constructed. Unfortunately, studies have pointed out climate science is not well understood among college students pursuing a civil engineering degree. In addition, civil engineering programs in colleges and universities provide limited to no training toward climate science and climate competency. In an introductory civil engineering course at Western Michigan University, a climate change learning module was incorporated into the course for the first time following the authors' participation and facilitation, respectively, in a faculty learning community on climate change pedagogy. Main topics of the module include climate literacy, ASCE policies on climate change, and mitigation of and adaptation to climate change. Assignments, including a case study essay, a quiz, and exam problems, were given to assess student learning. Pre-module and post-module voluntary climate literacy surveys were conducted. The surveys had a good participation rate, and the preliminary results are presented in this paper. The surveys provided a general picture of civil engineering students' perception/engagement with climate change and identified areas needing to be strengthened in teaching and learning of climate change. Survey data, learning assessments, and teaching reflections will guide future improvements to integrating the topic of climate change into the university's civil engineering program, including other courses, such as Capstone senior design, in the curriculum.

Introduction

Anthropogenic climate change is affecting the planet in an irreversible way. It is one of the most urgent issues our global community is facing. According to the UNEP 2022 Global Status Report for Buildings and Construction [1], the buildings and construction sector consumes about 34 percent of global energy use and accounts for 37 percent of global energy and process-related carbon emissions in 2021. Civil engineers who are responsible for the design and construction of these physical systems play an essential role in reducing carbon emissions, thereby mitigating climate change. In terms of resilience, the infrastructure systems civil engineers design and construct typically have long service lives. That said, the increasing severity of hazards attributable to climate change places these systems at significant risk, where consequences for human health and safety may be profound. The future of the field will require civil engineering professionals who can understand and meet both of these adaptation and mitigation challenges.

Unfortunately, studies have indicated that climate science is not well understood among the public. For example, the EdWeek Research Center surveyed (n = 1055) U.S. high school teenagers in October 2022, on their climate change beliefs and knowledge, discovering that while 79% acknowledged that anthropogenic climate change is what is driving our global climate emergency, nearly half (46%) thought the ozone layer hole was a key driver of warming [2]. This perception that natural systems and inputs are driving warming is unfortunately common. A nationally representative survey of adults (n=1,037) in 2021 revealed that an average of only 57% of Americans believe "global warming is mostly human-caused" [3], despite the fact that more than 97% of climate scientists agree on the anthropogenic nature of climate change [4]. Not only are the public lacking in understanding of the anthropogenic nature of climate change and the crisis it causes for our ecosystems and livelihoods, the importance of climate change is also not sufficiently recognized among civil engineers. In 2020, the United Kingdom National Infrastructure Commission surveyed 900 civil engineering professionals across a variety of civil engineering disciplines and found that 66% of the respondents thought that within their profession, greenhouse gas emissions reductions were not adequately prioritized, with a slightly smaller majority (59%) expressing the same view on climate change adaptation efforts [5]. Furthermore, several studies have pointed out climate science is not well understood among college students pursuing an engineering degree. A large-scale (n = 2658) study conducted in 2018 [6] indicated that engineering students did not have a good understanding of climate science. Interestingly, analysis of another survey (n = 4364) of U.S. engineering students [7] produced results showing that civil engineering students had statistically significant worse understandings of core climate science concepts compared with the students from other engineering fields. A 2017 study [8] showed 53% of first year college students interested in civil engineering were neutral or disagreed that climate change is caused by humans.

To change civil engineering students' engagement with climate change and correct their common misconceptions, education intervention is necessary and has been proven to be effective [9]. Fortunately, in recent years civil engineering programs in universities across the world are increasingly recognizing the importance of preparing students to actively contribute to the mitigation of and adaptation to climate change. However, the current civil engineering undergraduate programs in many colleges and universities still provide limited to no training toward climate science and climate competency. A study reviewed accredited civil engineering programs in Canada and found that "Although various environmental courses are offered … climate-specific courses are not part of the curriculum at any of the reviewed institutions," and concluded that those "undergraduates are lacking the necessary skills to partake in engineering solutions to the largest problem that humanity has ever faced" [10]. The status quo underscores the importance of introducing climate change learning opportunities into civil engineering curricula so students can better recognize its relevance to their careers and be better equipped to address the climate emergency.

In the light of preparing and equipping civil engineering students to tackle the climate emergency, the instructor of CCE 1100: Introduction to Engineering Practice, participated in an exploratory professional development program launched at Western Michigan Unviersity to bring the topic of climate change into diverse disciplines. CCE 1100 is two-credit introductory course that is required for the civil and construction engineering programs. The students taking the course range from freshmen to juniors. Like many introductory courses in typical civil engineering or similar curricula, the course is aimed at introducing the fundamental civil engineering analysis and design process. In Fall 2022, the instructor integrated a climate change module into the course that included new assignments, which were given to the students to assess their learning of fundamental climate science concepts and ability to craft climate adaptation recommendations. Pre-module and post-module anonymous surveys were administered through Qualtrics to determine prior student climate literacy and engagement with the topic, measure the student learning and engagement due to the climate module, and seek their feedback on how the teaching methods and content in the module promoted their understanding of and ability to take action to address climate change. This paper reports the details of the development of the learning module, the assessment of student learning, and the results of the pre- and post- module surveys. The purpose of this paper is to measure how the learning module influences student beliefs, knowledge, and self-efficacy with respect to understanding of climate science and ability to apply that knowledge to their chosen field or in communicating with others about it. The outcome of this study can be used to improve the module and serve as a still-developing model for how this university and others might incorporate the topic of climate change into courses in their civil engineering curriculum.

Climate Change Learning Module Development

Before the climate change module was added, CCE 1100 already had a module on sustainability which focused on environment preservation, green building design and LEED certification. However, in that module, climate change was not directly addressed. In Spring 2022, the instructor of CCE 1100 had an opportunity to participate in a faculty learning community, "Climate Change Across the Curriculum Learning Community" (CCAC-LC). The ten participants of the CCAC-LC were from five different colleges across the university, with the following diverse range of fields represented: biology, environmental sciences, philosophy, English, business communication, health and human performance education, and civil and construction engineering. They met in weekly, 1.5-hour sessions for six consecutive weeks. A mini grant of $500 for research and teaching materials was offered to each participant as an incentive. Textbooks, reading assignments, videos, and other resources were provided to the participants and assignments were given before each class meeting. During the meeting time, participants discussed the prescribed topics under the guidance of the two facilitators. The topics of CCAC-LC included climate science/mitigation, climate adaptation, climate justice, interdisciplinary collaboration in teaching climate change, narrative approaches to teaching, and student climate anxiety and engagement/action. One of the objectives of the learning community, and its primary deliverable, was for the participants to produce a climate change module or course revision that engages in a significant way with climate change and constitutes at least 10% of the material covered in the course.

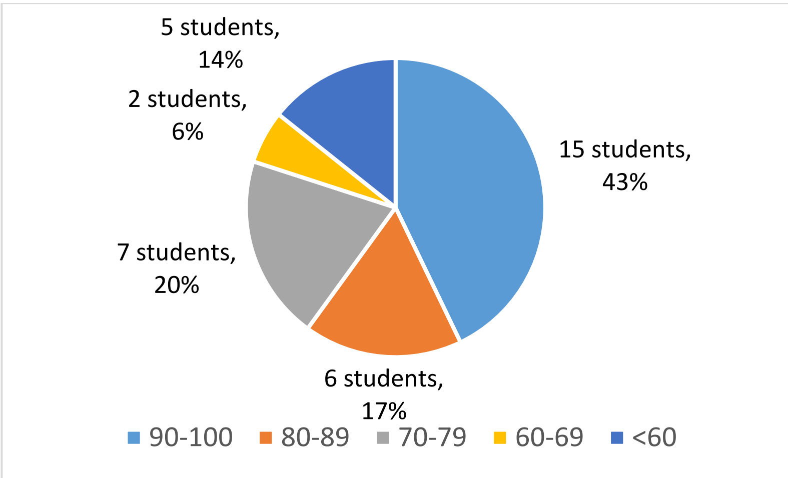
It is not easy to bring changes to a curriculum, be it developing a new course or adding a new module into a course. Faculty must often artfully juggle a heavy workload that involves some combination of teaching, research and/or service. Often, there are no financial or course release incentives provided by their institutions for them to make substantial revisions to a course, which is an effort that requires significant time and resources. In a study on interdisciplinary integration of Education for Sustainability (EfS), the author noted the importance of providing grant funding and professional recognition through awards to demonstrate institutional commitment to faculty development in this vital topic, which would encourage participation [11]. CCAC-LC provided the framework and financial and structural supports for faculty to initiate their own course revisions, participate in dynamic collegial dialogue on climate pedagogy readings, share resources, and report out/gain feedback on their individual course redesign efforts. It also functioned as a platform for the participants to share their findings, outcomes, and recommendations with their peers, with the goal of improving the teaching and learning experience across the institution in a variety of ways. This learning community was instrumental in leading to the development of the climate change learning module in CCE 1100.

In Fall 2022, the instructor of CCE 1100 added the climate change module into the course. The module includes two lectures and the associated readings and homework assignments. The first lecture mainly covers climate science and literacy, and the second lecture covers the related ASCE policy statements on climate change, and civil engineers' role in climate mitigation and adaptation. The resources the instructor learned from CCAC-LC played an important role in developing the lecture materials and assignments. In collaboration between a facilitator of the CCAC-LC and the instructor of CCE 1100, the pre-module and post-module surveys designed by the facilitator were given to the students. The students took the survey voluntarily, but a small incentive of extra credit was offered to them to encourage their participation in the survey.

Assessment

In Fall 2022, there were a total of 36 students enrolled in the course. To assess student learning in the climate change module, homework assignments, quizzes, and exam questions were given to the students. The homework assignment was to write an essay about a case study. Students were asked to read the article "Relocating Kivalina" from the U.S. Climate Resilience Toolkit [12] and research the case study by reading other related resources. Based on their research, the students penned an essay to describe the threats resulting from climate change to this coastal indigenous community in Alaska, then gave recommendations from a civil engineer's perspective on adaptation approaches, including but not limited to establishing local environmental surveillance program, monitoring river erosion caused by thawing permafrost, developing an evacuation route and shelter above the flood zone, and so on. The student grades were evaluated based on the completeness and the depth of the discussion, and the organization and writing. Figure 1 shows the distribution of the student grades in the assignment.

Figure 1. Distribution of Student Grade in the Case Study Assignment

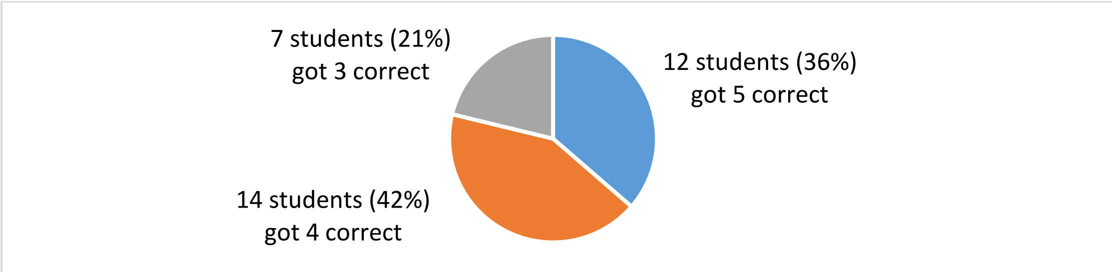


The quiz was given one week after the module. It consisted of 5 multiple-choice questions, all of which are about fundamental climate science. A total of 33 students took the quiz. Table 1 shows the quiz questions. Figure 2 shows distribution of student grades in the assignment.

Table 1. Climate Change Quiz Questions

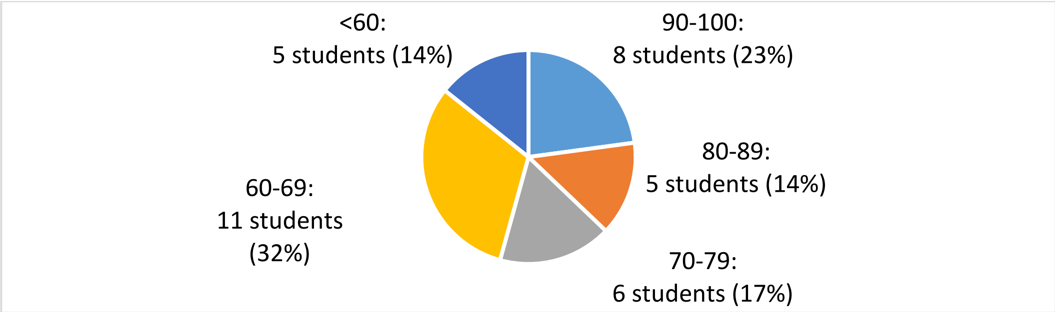
Question 1	What is the greenhouse effect?
Question 2	We know that variations in Earth's orbit, solar output, and other factors cause changes in the climate. If we removed the human impacts of greenhouse gas emissions, what might the climate be doing today, on its own?
Question 3	What proportion of climate scientists has concluded that humans are the primary driver of today's climate warming?
Question 4	What is the primary cause of the overall rising trend in CO_2 in the atmosphere?
Question 5	What are the major causes of sea level rise?

Figure 2. Distribution of Student Grades in the Quiz



The content of the climate change module was covered in the midterm exam, which was given three weeks after the module. The exam items related to climate change were a mix of true or false, multiple-choice, and short answer questions, which were related to climate science and climate mitigation and adaptation. The total point value of the climate change questions in the midterm exam were 32 points out of 100. Figure 3 shows the distribution of student grades in these exam questions. The average points students earned were 23.9 points (74.7%), which reflected that students have achieved satisfactory learning through the climate change module. It is worth mentioning that the average grade of the midterm was 75.1%, which was very close to the average of the student grades in the climate change-related questions. In addition, there were 17 students (about half of the class), who attained a higher percentage in climate change problems compared to the percentage they received for the entire midterm exam. All of the above metrics suggest student learning in the climate change module was similar to other topics in the course.

Figure 3. Distribution of Student Grades in Climate Change Questions in the Exam



Climate Literacy Survey Analysis

The students in CCE 1100 were administered a "Climate Literacy and Engagement" pre-module survey with sections on climate science and mitigation, climate adaptation, and climate change engagement/attitudes designed by the learning community facilitator with a combination of originally written, imported, and adapted questions from publicly available climate change surveys. Imported questions came primarily from the following well-researched sources: The Climate Literacy and Energy Awareness Network (CLEAN) [13], Agroecologist Dr. Alana Siegner's "Climate Literacy Assessment" [14] and the Science Education Resource Center at Carleton College (SERC/Carleton) "InTeGrate" program [15], designed to promote interdisciplinary teaching about sustainability. An additional section of questions soliciting student feedback on the pedagogy employed in teaching the climate module were added into the post-survey, which was disseminated after the module concluded. The surveys were administered via email through Qualtrics, and responses were recorded without reference to the email addresses to which the individualized links each student received were sent. This allowed for extra credit to be awarded to each student without compromising their anonymity in the response data. The incentivization led to a class completion rate of 69.4% (25/36) for the pre-survey and 63.9% (23/36) for the post-survey, excluding those who opened, but did not complete the survey. This was noteworthy when considering the substantial length of the survey (see Appendix).

The results below, which detail the percent correct for each question and section (rather than each student's overall score), may seem low compared to the student performance in the CCE 1100 course assessments; however, given that (a) some of the questions contained more nuanced, and sometimes, more recent conclusions regarding the most effective forms of climate change adaptation and (b) the instructor did not attempt to "teach to the test" (or survey, in this case), the numbers still suggest that baseline climate literacy exceeds the average American's knowledge. A comparison of the pre-module and post-module surveys reveals improvement in both areas of climate literacy, though the score increase was most pronounced in climate science. This comparatively higher score improvement was expected, due to the CCE 1100 climate module's deeper exploration and emphasis on core climate science principles in the lecture, video, and quiz and exam questions. Climate adaptation is also a topic with a less established curriculum, making it more difficult to define what constitutes a core knowledge of the area and thus more challenging for students to achieve the higher scores found in climate science quizzes.

Across the 14 climate science questions (31 total items), the average percentage correct in the pre-module survey reached just 60.8%. The first six basic science/mitigation questions (15 items, or roughly half of the section) covered warming and greenhouse gasses – focusing on their sources and properties – and notably notched the much higher value of 72.7% average correct. Students were less likely to possess knowledge about the more challenging questions, such as the current concentration of carbon dioxide in the Earth's atmosphere (420 ppm); the difference between "positive" and "negative" feedbacks that increase and decrease (respectively) the impacts of human-caused climate change; and which climate mitigation strategies would have the largest impacts. Upon comparison of these results to the post-module survey, it was clear that the implementation of the climate module generally resulted in an increased climate literacy among the students. The average percentage correct across all items showed a uniform improvement, increasing to 66.7% (5.9% improvement). An identical rise of 5.9% was found when the average percent correct for the first six questions was isolated from the overall question average, revealing a percent correct of 78.6% that more closely resembles the midterm exam performance (Table 2). Due to the small sample size (n = 23), the statistical analysis in this study is restricted to basic descriptive statistics.

Table 2. Climate Literacy Survey Pre-/Post-Test Performance

Test Section	Pre-Survey	Post-Survey	Difference (+/-)
Mitigation Section (Questions #1-6)	72.7%	78.6%	(+) 5.9%
Mitigation Section (Total)	60.8%	66.7%	(+) 5.9%
Adaptation Section	50.6%	54.7%	(+) 4.1%

The climate adaptation section scores in the pre-module survey produced a question average of 50.6%. The first question on the definition of climate adaptation only had about half of students select the correct answer, though it is worth observing that 84% of respondents picked the definition of climate adaptation *or* resilience (another answer choice with a very similar definition) over the 12% that chose a mitigation-leaning definition of adaptation. On the post-module survey, students averaged 54.7% correct (Table 2) across the 9 questions/31 items (a 4.1% improvement). Notably, 95.6% of students selected the definition of climate adaptation or resilience (though only 47.8% chose the former) over the 4.4% who picked a definition that referred to mitigation, showing that they more easily distinguished mitigation from adaptation than in the pre-module survey. With respect to other questions in this section, there was increased clarity in being able to explain the mechanism behind urban heat island effect (47.6% correct, up from 26%) and knowledge of some climate adaptation approaches. Significant blending of the climate mitigation and adaptation solutions, though, remained – likely tied to the inclusion of a particularly challenging grid-style question, where 10 different potential climate solutions were identified as “mitigation,” “adaptation,” “both,” or “neither,” with the latter two options introducing a unique level of complexity. Students were more likely to correctly identify that airplane flights to cooler locations are “neither” adaptation nor mitigation strategies (13.6% more students selected it), but slightly more than half of the class missed that “clearing rainforests for better airflow” should have been a “neither,” despite all survey respondents believing (in the science/mitigation section) that planting trees is a major climate mitigation measure. This suggests that students might benefit from additional time in the module (or perhaps in other sections of the course) discussing established and emerging nature-based solutions for climate adaptation in the built environment. There also remained confusion on what constituted climate mitigation vs. climate adaptation approaches (and when they overlapped), so, depending on course priorities, incorporating content and assessments that clarify these distinctions could be valuable.

The climate engagement section of the survey in both the pre- and post- module survey results demonstrated that the students taking this course, and quite likely students enrolled at the university, are more likely to find climate change an important issue and be worried about it. In the pre-survey, 72% ranked climate change either "extremely" (32%) or "very" (40%) important to them (Table 3). This is much higher than the 39% in the April 2022 Yale Climate Change in the American Mind (CCAM) survey [16]. Likely the same 72% rated themselves as "very worried" (32%) or "somewhat worried" (40%) about climate change. This is higher than the 64% in the Yale CCAM survey [16]. For these two questions in the post-survey, importance rose slightly to 73.9% in those highest categories, and worry increased to 82.6% of student respondents. This along with the increased recognition from the pre-survey to the post-survey (+12.2%) that climate change will affect them personally, rising to a total of 68.2%, suggests that with greater knowledge through the climate module, came improved scores on the climate literacy survey sections and increased engagement with the subject.

Table 3. Climate Literacy Survey – Climate Engagement Shift

Survey Data Used	**CC* Rated "Extremely" or "Very" Important to Respondent**	**Respondent "Very" or "Somewhat" Worried about CC**	**CC will Harm Respondent a "Moderate Amount" or "Great Deal"**
Yale CCAM Survey (2022)	39.0%	64.0%	47.0%
Pre-module Survey	72.0%	72.0%	56.0%
Post-module Survey	73.9%	82.6%	68.2%
Difference from Pre- to Post-module Survey	(+) 1.9%	(+) 10.6%	(+) 12.2%

** CC = Climate Change*

With respect to the pedagogical approaches to the teaching of climate change, about one-third of the 23 students who responded (35%) rated the lecture and the structuring of information so that they could ask questions during checks for understanding as one of the most impactful methods. They were inclined to slightly prefer, though, the use of video (61%), due to a preference for visual learning, while also appreciating the Kivalina case study (48%) for a closer examination of climate change's human impacts. This student response supports the positive impact of the learning community on integrating the topic of climate change, as these were materials shared (video) or read about (case study) through the instructor's participation in the faculty learning community. Some students mentioned that it was the blend of all three methods together that helped to convey the basic information on anthropogenic (human-caused) climate change as well as its impacts. When it came to the questions of how well-prepared students felt to take individual or collective action – including in their chosen field – 87% felt "moderately prepared" and 13% felt "comprehensively prepared," with no one selecting "minimally prepared" or "not at all prepared." The open-ended follow-up question on why they felt that way, yielded some recommendations from students for future iterations of the course in terms of how to build on its pedagogical strengths. For example, one student offered, "I believe in working in groups and having discussions and going out into the field to speak with professionals. Additionally, reading more case studies and learning more from the videos and lectures." This sentiment was echoed in the open-ended questions on what teaching methods not already in the course would improve student understanding and preparation to address climate change, with the most common responses including: (1) group work/discussion and class discussion (four mentions); (2) guest lecture from or fieldwork with: someone personally harmed by climate change, in the field of climate change, and/or a civil engineer who deals with this issue (four mentions); and (3) more examples or engagement with how professionals in the field of civil engineering are handling climate change challenges (three mentions). Despite the sense among students that more time would have allowed for greater student self-efficacy with respect to climate change, a NASA-supported study focused on grades 6-12, in the 2011-2012 academic year, that had a similar framework of pre-implementation instructor training and pre- and post- climate module literacy surveys, found that students of teachers employing multiple modules did not show as much climate literacy improvement as students where fewer climate modules were offered in a more in-depth manner [17]. These results suggest that instead of additional modules, it might be more effective to extend the module's length slightly to permit time for the suggested engagement with the applied dimensions of addressing climate change in the field of civil engineering.

Conclusion

Civil engineers are in a special position for addressing climate change issues due to the fact that they design and build the infrastructure that shapes the way that people live their lives. The "wicked problem" of climate change, as it has frequently been characterized, presents the civil engineering profession with the biggest challenge it has faced. In the meantime, climate change also provides the civil engineering profession with an opportunity to be more innovative and adaptive. The current civil engineering education curriculum is not providing students with the needed exposure to the nature and scope of anthropogenic climate change and the professional challenges it presents, which is critical to equipping students to address the global climate emergency. To be broader, even the civil engineering profession is not where it needs to be in relation to climate change. Civil engineers are interacting so much with the built environment, which significantly affects people's daily lives, but the profession has not integrated some of the human dimensions and implications of climate change enough. Therefore, it is critical that in educating the next generation of civil engineers, climate science and climate change impacts be incorporated in teaching about the built environment.

As an initial effort, a climate change module was added into an introductory civil engineering course. The required assessments, which included a writing assignment that involved applied learning, a module quiz, and a midterm exam, indicated, when combined with the voluntary pre- and post- module survey, the measurable improvements in student understanding of and engagement with this important topic. They also provide insights on where the pedagogical approach to weaving the topic of climate change into this introductory course (as well as the entire civil engineering program) both worked well and might be improved to enhance student learning of this vital issue. The blend of lecture, video, and a case study was successful in engaging and communicating the concepts to students. To better promote a higher sense of self-efficacy among students with respect to addressing climate change in their careers, though, it might be valuable to incorporate an opportunity for students to interact with civil engineers directly working on projects with a strong climate mitigation and adaptation dimension.

In addition to the changes to CCE 1100, there is great potential for incorporating climate change into other civil engineering offerings at Western Michigan University, such as the capstone senior design course. Other universities may also find it useful to adopt, and adapt as needed, this model of institutionally supported interdisciplinary professional development programming to promote faculty interest and confidence in integrating climate change into their teaching. With the inclusion of climate change into engineering courses, more engineering students will be able to apply their climate literacy and evaluation skills to the growing climate mitigation and adaptation challenges they will encounter in their professional life.

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Appendix: Full Survey

Title: Climate Literacy and Engagement Survey

[*Note: Correct answers are indicated by an asterisk, unless otherwise indicated.*]

I. Climate Science/Mitigation Section:

1) What is the greenhouse effect? [Q. 1 of Climate Literacy Quiz, Cleanet.org]

a. Certain gases in the atmosphere trap heat and warm the Earth *
b. Life on Earth 'exhales' gas that warms up the atmosphere
c. The tilt of the Earth changes the amount of solar energy the Earth receives
d. The Sun is putting out more radiant energy over time

2) The difference between weather and climate is: [Source: https://www.laneysiegner.com/climate-literacy-assessment]

a. Weather is what we expect based on years of data while climate is what is happening now
b. Weather is predictable but climate is not
c. Weather is a day-to-day event while climate is a consistent pattern over many years *

3) Which of these changes can make Earth's temperature increase, generally speaking? **Mark all that apply**. [*Source: Global Climate Change: Understanding the Science / Understanding the Impacts]

a. Increased emission of radiation from the Sun.*
b. Increased ice in polar regions.
c. Increased greenhouse gases in the atmosphere. *

d. Increased reflectivity (albedo) of Earth's surface.

4) What can we do to avoid the worst impacts of climate change over the next century? [*Source [question adapted]: Global Climate Change: Understanding the Science / Understanding the Impacts]

a. Reduce greenhouse gas emissions gradually over a long period of time.
b. Very little; natural processes will correct the system over the next century without human intervention.
c. Reduce greenhouse gas emissions substantially beginning right away. *
d. Nothing, the mistakes have already been made, and nothing can change the outcome.

5) In addition to CO2, which of the following could also be considered a greenhouse gas? [Check all that apply.]

a. Methane (CH4) *
b. Water Vapor *
c. Nitrous Oxide (N_20) *
d. Sulfur Hexafluoride (SF_6) *

6) What causes CO2 emissions to rise? [Check all that apply.] [Source (slightly adapted to make more challenging)]: https://www.laneysiegner.com/climate-literacy-assessment]

a. Burning fossil fuels *
b. Cutting down trees *
c. Tilling the soil (common agricultural practice) *
d. Landfills *

7) We know that variations in Earth's orbit, solar output, and other factors cause changes in the climate. If we removed the ***anthropogenic*** (human-driven) impacts of greenhouse gas emissions, what might the climate be doing today, on its own? [Q. 7 of Climate Literacy Quiz on Cleanet.org]

a. Slight warming
b. Strong warming
c. No change
d. Slight cooling *
e. Strong cooling

8) In 1750 (just before the Industrial Revolution), the atmosphere contained 278 ppm CO_2 (carbon dioxide), ***only a 1% rise over the average of the previous 10,000 years***. As of 2022, that number has climbed to ______, a/an _____ increase.

a. 320 ppm; 15%
b. 370 ppm; 33%
c. 420 ppm; 51% *
d. 470 ppm; 69%

9) What proportion of climate scientists has concluded that humans are the primary driver of today's climate warming? [Q. 10 of Climate Literacy Quiz on Cleanet.org]

a. 34%
b. 59%
c. 76%
d. 97% or more *

10) Scientists and policy-makers have agreed at the Paris Conference in 2015 (COP 21) to try and limit global average temperature rise to less than ___ degrees Celsius by the end of the century. [Source: https://www.laneysiegner.com/climate-literacy-assessment]

a. 1C (1.8F)
b. 2C (3.6F) *
c. 4C (7.2F)
d. 10C (18F)

11) Discuss in a brief paragraph (minimum of 4 sentences) two ways that climate change will likely affect cities, regions, or nations in the next 30 to 50 years. [*Source: Global Climate Change: Understanding the Science / Understanding the Impacts]

12) If we use more air conditioning to cope with climate change, and thus create more greenhouse gas emissions that worsen climate change due to that coping mechanism, that will be an example of ___________.

a. negative feedback
b. “a wicked problem”
c. positive feedback *
d. mitigation

13) Many of us are already familiar with solutions to climate change. While there are many actions we can take every day, it's important to focus on the solutions with the biggest result. Most of the actions shown below will reduce emissions, but which will have the biggest effect? There are several correct answers. [Q. 19 of Climate Literacy Quiz on Cleanet.org]

a. Household and industrial recycling
b. Adopting a plant-based diet *
c. Cleaning up ocean pollution
d. Planting trees
e. Wasting less food *
f. Large-scale solar farms *
g. Carpooling
h. Restoring degraded tropical forests *
i. Onshore wind turbines *

14) Name one thing your community could realistically do to mitigate (lessen) climate changes. How and why would your plan work? (Open response) [Source: https://www.laneysiegner.com/climate-literacy-assessment] [*Rubric: Answers could include discussion of electric charging infrastructure, improved energy efficiency building standards, solar gardens, reforestation, etc.]

II. Climate Change Adaptation Section:

1) Which of the following descriptions ***most completely*** fits the definition of "climate change adaptation"? [Sources Note: For (c), it is the definition of "climate resilience" provided by the Center for Climate and Energy Solutions; For (d), it is the complete UNFCC definition.]

a. the measurement and assessment process of climate change-induced environmental hazards
b. reducing or stabilizing the level of greenhouse gases in the atmosphere
c. the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate
d. adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts *

2) Which of the following is the ***first*** step in selecting appropriate climate change adaptation strategies and timelines for a region or city?

a. Design a nature based solutions plan
b. Perform a climate risk assessment *
c. Set goals and targets for hazard reduction
d. Complete a climate action plan

3) With respect to climate adaptation, flooding and erosion in and around cities from increasingly extreme precipitation events is a major concern. Which of these are ***nature-based solutions*** to ***this*** urban concern? [Check all that apply.]

a. shift to permeable pavement systems *
b. maintain/restore nearby wetlands *
c. build dams or seawalls
d. use Trombe walls in buildings
e. transition to green roofs and walls *
f. install retention basins
g. integrate rain gardens and bioswales *

4) Which of the following are reasons that indigenous and local knowledge [ILK] offer a much-needed critical perspective to climate change adaptation? [Check all that apply.]

a. familiarity with local weather patterns and ecosystems *
b. proven sustainable land management practices across centuries *
c. their avoidance of fossil fuel usage in daily life
d. commitment to intergenerational knowledge transfer/preservation *

5) Living in a residence adapted to climate change-induced weather extremes will be essential even if the Paris Agreement goals are met. Which of the following is a/are known approach(es) to creating buildings that are climate change ***resilient***? [Check all that apply.]

a. use reflective cool/white roofs *
b. require raised floor level and ban of basements in flood zones *
c. install solar panels on roofs

d. invest in heat/fire resistant building materials *
e. shift from natural gas to electric heating/cooking

6) First, define in your own words what an "urban heat island" is and briefly explain what causes it. [Answer: Urban heat island effect refers to the extreme heat conditions experienced in cities due to a largely asphalt/concrete environment that heats up to hotter temperatures and holds that heat.]

7) Label the following as a sustainable strategy for adapting to climate change (A), for mitigating climate change (M), both (B) or neither (N): [Adapted Source: James Dontje – "Exercise in a Changing Climate" https://serc.carleton.edu/integrate/programs/implementation/program2/activities/170681.html]

___ rescheduling athletic competitions and practices [A]
___ increasing fuel economy standards for vehicles [M]
___ clearing rainforests to allow better air flow [N]
___ switching to renewable energy sources [M]
___ building air conditioned stadiums [N]
___ walking, carpooling and taking public transportation [M]
___ designing buildings that stay cool without air conditioning [B]
___ flying to cooler locations for vacation [N]
___ moving water-intensive crops from dry to wetter/temperate climate regions [A]
___ restoring mangrove forests along tropical coastlines [B]

8) Which of the following is an urgent ecological impact of climate change ***already*** forcing ***entire*** populations to permanently leave their homes as climate refugees?

a. urban heat island effect
b. sea level rise *
c. extreme weather events
d. ocean acidification

9) Name one thing your community could realistically do to adapt to climate changes. How and why would your plan work? (Open response) [Source: https://www.laneysiegner.com/climate-literacy-assessment] [*Rubric: Students should list at least one recognized climate adaptation strategy, and it should be grounded in/make sense for the city, town, or locale selected.]

III. Climate Change Engagement Section:

[Source: https://www.laneysiegner.com/climate-literacy-assessment]:

"The first 4 questions are from the Yale Project on Climate Change Communications (YPCCC) new shortened 4-question survey for the American public to determine their level of concern and engagement with the issue of climate change. You can take the survey online here for an analysis of your results and where you fit in the "Six Americas" spectrum: http://climatecommunication.yale.edu/visualizations-data/sassy/.

**Note about clarifying the difference between global warming and climate change: While the two terms are often used interchangeably by the public, Paul Hawken distinguishes between the two in his recent book Drawdown as follows: “Global warming refers to the surface temperature on the earth. Climate change refers to the many changes that will occur with increases in temperature and greenhouse gases.”]

1) How important is the issue of global warming to you personally?

  e. Extremely important
  f. Very important
  g. Somewhat important
  h. Not too important
  i. Not at all important
  j. How worried are you about global warming?
  k. Very worried
  l. Somewhat worried
  m. Not very worried
  n. Not at all worried

2) How much do you think global warming will harm you personally?

  a. A great deal
  b. A moderate amount
  c. Only a little
  d. Not at all
  e. Don't know

3) How much do you think global warming will harm future generations of people?

  a. A great deal
  b. A moderate amount
  c. Only a little
  d. Not at all
  e. Don't know

4) Do you think climate change will be solved by humans living today?

  a. Yes
  b. Maybe
  c. No
  d. Not sure

5) How many times in the past year have you looked up additional information on climate change that you did not learn in school?

  a. Never
  b. Once or twice
  c. Monthly
  d. Weekly
  e. Every day

6) How often in the past year have you talked to friends/family members about climate change?

  a. Never

b. Once or twice
c. Monthly
d. Weekly
e. Every day

IV. Pedagogy Section (Post-survey only):

1) Check all that apply from the following list of teaching methods that your instructor employed to address the topic of climate change. Please write in any additional methods used to cover the topic not already listed below in the "Other" text box at the end of the list.

- Lecture
- Mini-lectures (usually lasting 10-15 minutes)
- Guest lectures
- Videos (excluding videos of lectures by the instructor)
- Full class discussions
- Small group/paired discussions
- Team/group short-term (1-2 classes) activities and exercises
- Team/group long-term (multi-week) projects
- Case study evaluations/analyses
- Field site studies/trips
- Laboratory work
- Service learning experiences
- Other (write in)

2) Describe in detail which, or which combination, of the teaching approaches used in this course (see list above in Question 1 of this section) most impacted your ***understanding of*** climate change and its impacts. Why were these most impactful for you?

3) Now, describe which teaching methods and learning content in this course were most useful for your understanding of ***how best to act*** upon your knowledge individually and with larger collectives toward addressing climate change. Why do you think these methods and content were more helpful?

4) How well do you feel this course's coverage of climate change prepared you to take some meaningful action toward addressing climate change (e.g., having conversations with others about it, adopting climate-friendly solutions in your field, engaging with ongoing policy efforts to address it, etc.)? Select only one option from the list below:

- Comprehensively prepared
- Moderately prepared
- Minimally prepared
- Not at all prepared

5) Explain your rationale for how you responded to question 4 of this section in the box below.

6) What teaching methods and content not already in the course would have improved your engagement with and/or understanding of the complexities of climate change?

[End of Survey]