

## Research in Brief

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My team of graduate students at Virginia Tech and collaborators from Purdue University collected data from engineering students in their fourth year of undergraduate education. Our survey, titled *Student Survey about Career Goals, College Experiences, and Sustainability*, was completed by a national representative sample of engineering students in the United States in the Spring and Fall semester of 2018. The purpose of this research brief is to summarize our peer-reviewed findings from our national survey. I have organized our results based on the themes of inquiry about climate change, sustainability, design thinking, ethics, and career expectations. I also provide details about how our data was collected and conclude with opportunities for future research and new questions that have emerged from our findings.

### Summary of Findings

#### *Climate change*

Engineering students believe that global warming is happening but do not understand climate science, the causes or methods for climate change mitigation. For example, about half of the engineering students believed that nuclear power generation is a cause of global warming. They also incorrectly believed or were unsure that the ozone hole in the upper atmosphere is a cause of global warming. A possible explanation for these misconceptions is that the engineering students recognized general problems, such as nuclear waste and the ozone hole, but they did not link particular causes with particular consequences.

We specifically looked at civil engineering students understanding of global warming because the systems they design and construct both contribute significantly global warming and they must be built to withstand climatic changes. Civil engineering students understood global warming is an immediate issue for the environment, engineering, health, and science, but less than half recognized global warming presents social justice, poverty, and national security issues. Civil engineering students held an inverse relationship between spatial distance and the timing of the effects of global warming. Civil engineering students predominantly believed 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, this 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

The strongest factors that predicted engineering students' desire to address climate change in their career were related to a feeling of personal responsibility to deal with environmental problems, recognizing climate change as a technical (not social) issue, believing climate change is caused by burning fossil fuels and livestock production, and their engineering discipline. Students majoring in environmental and architectural engineering were more likely to want to address climate change in their careers than other engineering disciplines. Previous known factors to increase motivation for climate action like course topics, political affiliation, student

organization participation, undergraduate research experience, and environmental volunteering were not strong predictors among engineering undergraduate students.

### *Sustainability*

Undergraduate studies tend to reinforce students' engineering agency beliefs to improve quality of life and preserve the environment. Significantly more senior engineering students compared to first year students selected career goals to address environmental issues. In general, students undervalue their roles as engineers in addressing issues related to social inequities. These are topics identified as rarely addressed in engineering courses. Findings from this work suggest discussing sustainability in courses positively impact setting career goals to address such challenges.

We also found that higher perceived design thinking ability increases senior engineering students' interests in designing solutions related to energy sustainability. Active learning experiences positively influence senior engineering students' interests in designing solutions related to energy sustainability. Teaching design thinking in engineering courses is important to empower future engineers to address sustainable challenges through design and innovation.

### *Design thinking*

First-year students who intended to declare an engineering major score significantly higher on the design thinking scale than senior engineering students. The senior engineering students performed significantly worse on the feedback seeking and experimentalism instrument items, but significantly better on the integrative thinking and collaboration items. We found no significant differences in perceived design thinking ability among engineering disciplines among senior students. Feedback seeking and experimentalism are traits that engineering educators should develop in their students to improve perceived design thinking ability. Incorporation of user-centered design and divergent thinking in the engineering classroom are recommended as avenues to foster feedback seeking and experimentalism.

In addition to exploring differences between first year and senior engineering students we also explored the differences between civil engineers and architects. We found a significant difference in perceived design thinking ability between civil engineering and architecture students. Architecture students scored higher than civil engineering students on all design thinking traits. Based on our results, the civil engineering curriculum may benefit from the incorporation of pedagogy that emphasizes design thinking, like studio-based learning.

### *Ethics*

The engineering students who participated in international service learning through capstone and volunteer/work experience held a higher degree of understanding about ethics. International service learning through capstone or volunteer/work experience seems to have a greater effect of males than females. Engineering students who identified as male and participated in international service learning through capstone and volunteer/work experience showed a significantly greater level of understanding about ethics than males without these experiences compared to female engineering students with and without these experiences. The integration of international service learning into engineering education should be more seriously considered to aid in more

effectively teaching ethics. Male engineering students, who make up nearly 80% of engineering programs, can benefit the most in their ethics education from international service learning.

### *Career Expectations*

Underrepresented groups of students in civil engineering held significantly different career satisfaction expectations and co-curricular activities from those of non-underrepresented groups of students. Underrepresented groups of students reported more interest in helping others and in volunteering with charity groups in their careers than non-underrepresented groups of students. Underrepresented groups of students in civil engineering reported higher participation in co-curricular activities such as contributing as a member of an organization for women and/or minorities in engineering, acting as a member of an outreach club, and working a work-study or other type of job to pay for college. These findings highlight the need for the civil engineering profession to move beyond monolithic traditions, which can perpetuate exclusion.

### **Methods**

A national sample of senior engineering students completed a survey in Spring and Fall of 2018. Our sample included four-year institutions chosen from the National Center for Education Statistics institutional database. A 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). This approach was used to avoid oversampling from a few large institutions or the numerous small institutions in the United States.

Capstone instructors were contacted and asked to distribute the survey. A total of 90 capstone instructors returned surveys from students in their class. No incentives were given to the capstone instructors or students for completing the survey. Capstone instructors received paper surveys by mail, along with instructions to distribute the surveys to their class. Instructors returned completed surveys from their students for a total sample of 4,364 senior engineering undergraduate students. The representation by geographic region is representative of the current U.S. population. Figure 1 illustrates all of the participants' home zip codes by state. The larger the dot the more students are represented from that zip code.

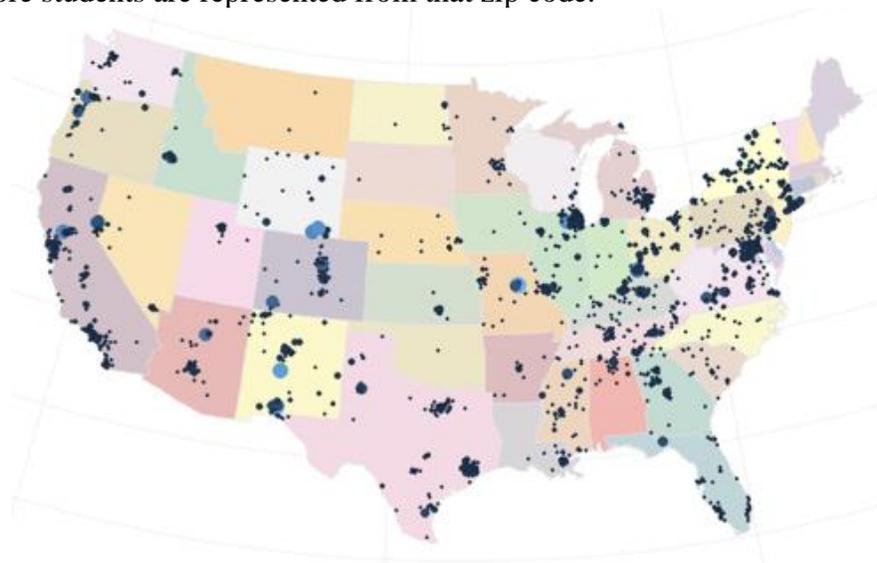


Figure 1: Participants' home locations based on zip code.

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## References

### *Climate change*

- Katz, A., Shealy, T., Godwin, A. (2020) "Civil engineering students' beliefs about the technical and social implications of global warming and when global warming will impact them personally and others" American Society of Engineering Education Annual Conference and Exposition, Virtual, June 21-24.
- Shealy, T., Katz, A., and Godwin, A. (2021). "Predicting engineering students' desire to address climate change in their careers: an exploratory study using responses from a U.S. National survey." *Environmental Education Research*, Routledge, 0(0), 1–26.
- Shealy, T., Katz, A., Godwin, A., and Bell, M. (2021). "Civil Engineering Students' Beliefs about Global Warming and Misconceptions about Climate Science." *Journal of Civil Engineering Education*, American Society of Civil Engineers, 147(4), 04021011.

### *Sustainability*

- France, J., Milovanovic, J., Shealy, T., Godwin, A. (Submitted April 20, 2021) "Engineering students' agency and career goals to engage in sustainable development: Differences between first-year students and seniors" *International Journal of Sustainability in Higher Education*.
- Milovanovic, J., Shealy, T., and Katz, A. (2021). "Higher Perceived Design Thinking Traits and Active Learning in Design Courses Motivate Engineering Students to Tackle Energy Sustainability in Their Careers." *Sustainability*, Multidisciplinary Digital Publishing Institute, 13(22), 12570.

### *Design thinking*

- Coleman, E., Shealy, T., Grohs, J., Godwin, A. (2019) "Design Thinking Among First-year and Senior Engineering Students: A Cross-Sectional, National Study Measuring Perceived Ability" *Journal of Engineering Education*, Published online. doi: 10.1002/jee.20298
- Coleman, E., Shealy, T., Milovanovic, J., Godwin, A., Paige, F. (2020) "Comparing Design Thinking Between National Samples of Civil Engineering and Architecture Students" *Journal of Civil Engineering Education*. doi: 10.1061/(ASCE)EI.2643-9115.0000037

### *Ethics*

- Baughner, B., Shealy, T., Iorrio, J., Knight, D. (2019) "Impact of International Service Learning on Ethics: A National Study of Senior Engineering Students" *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 14(2). Doi: 10.24908/ijlsle.v14i2.13186

### *Career Expectations*

- Keku, D., Paige, F., Shealy, T., Godwin, A. (2020) "Appreciating Differences in Civil Engineering Students' Career Satisfaction Expectations and College Experiences." *Journal of Management in Engineering*.