Engineers are Needed Now More Than Ever: How Can Design Competitions Help?

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

A 2021 infrastructure report card prepared by the American Society of Civil Engineers (ASCE) shows that U.S. infrastructure is operating at a C- level (2021). An investment gap of 2.6 trillion dollars exists for the facilities we rely on every day. While it is up to policymakers to dedicate funds to the issue, they rely on engineers to carry out the actual work.

Infrastructure systems are complicated; there is a need for experts that can design, construct, and manage it all to maintain quality of life for the public. A large stream of well-prepared future engineers is needed to meet the needs of US infrastructure, specifically 400,000 each year, according to experts at Boston Consulting Group (Kodey et al., 2023). Furthermore, these engineers must be motivated to innovate upon current practices to meet the ever changing needs of the world. Currently, there is a gap of 133,000 engineers between new job openings and new engineers entering the market. This number is large, especially since engineering is one of the most lucrative industries today. Headlines like *'New data shows engineering is the highest paying industry for new graduates'* (ES Magazine, n.d.) or *'Best-paying college majors are mostly in engineering'* (Vanderbilt, n.d.) should influence college prospects to choose the field, yet the nation still finds itself battling a shortage. It is not clear why this is the case.

Regardless of the reason, the United States finds itself in a dire situation. National infrastructure that is given a barely passing grade is unacceptable. The issue must be addressed soon, but that cannot happen unless the issue of the shortage of well-prepared engineers is addressed first.

I claim that engineering design competitions can make a significant change in the number of students who pursue engineering and prepare them for this career path. Examples of these competitions are the ASCE Concrete Canoe, American Institute of Steel Construction Steel Bridge, and the American Society of Naval Engineers Promoting Electrical Propulsion Challenge. Through these competitions, students build technical competencies that are sought out by the industry. They also improve upon professional skills like teamwork, communication and leadership - all which are necessary to be an effective engineer.

By drawing on personal experience, other students' experiences, and a literature review, I discovered the direct effects that engineering design competitions have on the perception of the field and how students leverage the skills they learn from participating in the experience. Using Star's theory of infrastructure (1999), I analyze engineering design competitions from a sociotechnical perspective. Star defines infrastructure as an embedded technological system that supports the needs of several social groups. The uses of an infrastructure system are different between social groups; some may see it as a tool, while others may see it as a barrier. It is appropriate to analyze engineering design competitions as infrastructure because of the unique ways they serve different social groups, like students, professors, and engineering firms. Star uses several different properties to further define infrastructure, the one most applicable to design competitions being "reach or scope". This property describes how an infrastructure system can have a hand beyond a single use. Engineering design competitions can be analyzed as a form of infrastructure to delineate what features are the reason behind their impact on the engineers that enter the field.

Creating Interest in Engineering, Genuinely

To ensure that students actually pursue the field of engineering, the benefits of getting on the career path must be clear. Exposure to the field should begin early to ensure that all students know it is an option available to them. Engineering design competitions serve as an engaging method to introduce both K-12 and college students to the field and create interest.

Introducing elementary and middle school students to engineering topics is important as it can chart the course of their interests once they reach high school and beyond. Studies support that students form aspirations in STEM "by the time they are 10-14 years old and vary little after this age" (Daugherty et al., 2014). This evidence highlights how important it is to make students aware of STEM subjects early on. Through elementary and middle school focused engineering activities like the For Inspiration and Recognition of Science and Technology (FIRST) Lego League Junior and RoboCupJunior, these impressionable students can explore the field and may choose to explore engineering further if they find themselves interested.

At the high school level, the added exposure to STEM principles through years of education allow design competitions to introduce intricate details about the engineering field. Professors from the University of Tulsa decided to organize a 'Chem-E-Car' competition for high school students based on the competition hosted by the American Institute of Chemical Engineers (AIChE) for college students (Luks & Ford, 2005). In this competition, students propel a 'shoebox-sized' car with a chemical reaction (p. 1). It is a great example of one of the various engineering design competitions for students to participate in. Luks and Ford collected data throughout two years of hosting the challenge to discover what affects the activity had on the desires of students to pursue engineering (2005). According to the data, 86% of the

participants reported that the experience helped them better understand what engineers do. Additionally, 80% of those considering an engineering career reported that they felt the competition experience made it more likely for them to consider pursuing engineering. The data provided by this source has limitations; only 72 students responded over two years, even though more had participated. However, this source serves as a great example of how engineering design competitions can affect the interest and image of engineering in a positive manner. The experience likely exposed these students to the fundamentals of engineering, like the engineering design process and teamwork. Performing iterative design while working in a team is a large part of what the field offers. Through opportunities like these, students who have never interacted with engineering are provided with a unique introduction to the field that they are sure to remember.

In the college environment, engineering design competitions hosted by professional societies like ASCE provide experiences that parallel project tasks and requirements seen in the industry. Historian Amy Bix described the ASCE concrete canoe competition as a design competition that benefited distinct social groups in different ways (2019). College professors enjoyed the hands-on aspect, concrete companies appreciated the positive perception of the industry, and most importantly, students got to apply their learning in an exciting manner. Most engineering design competitions achieve these different applications, and for that reason they can be perceived as a sort of 'infrastructure' themselves; they serve these different social groups simultaneously and without interruption (Star, 1999).

The concrete canoe competition's popularity created spin-off competitions, such as the Society of Automotive Engineers' (SAE) Formula SAE, and the American Institute of

Aeronautics and Astronautics' (AIAA) Design/Build/Fly challenge (Bix, 2019). Other competitions in other engineering disciplines kept sprouting. Bix notes that over time, engineering design challenges became intertwined with a *competition culture*, where students suddenly became invested in how the application of their skills performed amongst others. This culture reflects what is seen in the industry. The engineering environment that I have been involved in leads me to agree with Bix's observation. I think the integration of competitive tasks has made engineering a more interesting topic to continually learn about.

Participating in an engineering design competition can involve research, experimentation, preparation, team management, and other difficult tasks. This challenging process can be rewarding as it provides an opportunity for growth in the field, which can be a source of 'intrinsic motivation' (Neubert, 2016). Bix describes an example of a Massachusetts Institute of Technology (MIT) class where an engineering design competition took center stage: "Winners earned bragging rights but no extra-credit; even so, MIT had to discourage students from obsessing over the heated contest, which drew cheering audiences of five hundred or more" (p. 122). This example illustrates how invested students can become in the design competitions regardless of the stakes. The culture of competition promotes interest among students to improve upon their engineering skills.

Since this competition culture comes naturally with engineering design competitions, it is logical to assume it permeates through the K-12 competitions previously discussed. Some concerns may exist that this competitive culture may discourage instead of motivate, or cause unneeded stress. However, these problems can be avoided if the intention of the competition is

delineated among everyone involved. Instead of focusing on winning the competition, it should be made clear to students at this age that involvement fosters personal growth in these subjects, and that putting effort into a challenge warrants celebration and applause as well (American Heritage Schools, n.d.). With this clarification, engineering design competitions can engage students better and be more effective at teaching them new skills.

Fostering Technical & Professional Skills, Uniquely

Testimonies from engineering 'industry experts' support that activities outside of the classroom and practical experiences are what set college graduates apart as job candidates (SolidProfessor, n.d.). A National Institute of Health survey for engineering and business students at Gangwon State University yielded results supporting that extracurricular activities like competitions were highly beneficial for job preparedness (Kang, 2023). This dynamic illustrates the importance of garnering real-world experiences alongside the education received in class. Engineering design competitions are vehicles for cultivating the technical and professional skills needed to work on complicated infrastructure problems in real-world engineering. They differ from typical classroom learning because of the interactivity they provide.

Classroom learning should not be the only medium used to prepare engineering students for the workforce. I define classroom learning as any lecture-based method where a student listens to course content from a professor and does not interact with the professor. According to the Ebbinghaus Forgetting Curve, students may retain only 25% of what they learned in a lecture two days later (Wittman, n.d.). This number is low and highlights the ineffectiveness of lectures.

While the course curriculum is inevitably subject to classroom learning, other topics important for workforce preparation should try to be separated. I argue that engineering codes and professional skills are better learned in situations where interaction is involved, or practice occurs.

Engineering codes are typically learned in class, but every chance to apply the work in a non-academic context is valuable. Reinforced Concrete Design is a common course offered by universities in their civil engineering programs. The class discusses *ACI Code-318: the Building Codes Requirement for Structural Concrete***,** the primary concrete design guide used in the United States. Students learn how to use this code for design via problems sets, quizzes, and tests. Imagine how much more effective the learning would be if students used the equations in the book to solve a physical design challenge. The ASCE Concrete Canoe Competition offers this situation by requiring punching shear calculations to be made on the concrete canoe (ASCE, 2023). Punching shear is a localized failure mode that can occur in concrete. Competitors get practice using these equations that are required for real world design on their own project, providing great practice with important code provisions.

The concrete canoe competition goes further than just punching shear when it comes to developing technical skills. I interviewed a second-year and fourth-year student on the University of Virginia's (UVA) Concrete Canoe Team to gain insight on what students believe they get out of these activities. The second-year student mentioned how experimental testing and data collection for concrete compressive testing were new tasks to her as a student transferring from the College of Arts & Sciences. The team was performing compressive strength testing under the American Society for Testing and Materials (ASTM) C39 specification, a concept that is not covered in coursework until the third year of the UVA Civil Engineering curriculum. As a

second year student, this student has developed advantageous skills for internship or research opportunities through an experience her peers may not share.

The fourth-year student, a captain on the mix design team, described how the experience taught him industry practice surrounding concrete. He spent many hours creating concrete mix designs and researching different materials. Although he plans on being a stormwater engineer following graduation, I suspect that his new skills will be useful when he collaborates with other civil engineering disciplines.

Given my personal experience as a member of the UVA Concrete Canoe Team, I can further attest to how useful an engineering design competition can be for learning technical skills. Over the course of nearly two years on this team, I have been involved in drafting construction documents, creating concrete mix designs, and performing structural analysis. As an aspiring structural engineer, all of these tasks are applicable to my future career path. Concrete mix design is a topic that I have not learned through my traditional classes. However, understanding the composition of concrete and how changes to different components affect its material properties is a critical skill to have as a structural engineer. My involvement has given me new skills to use once I enter the profession.

To further confirm the effectiveness of design competitions on fostering technical skills, I interviewed a student in another engineering discipline. I talked to a fourth-year student in UVA's Mechatronics and Robotics Society (MARS). Students in this club work all year to compete in the NASA Robotic Mining Competition (MARS @ UVA, n.d.). The student credited his experience on the design team with greatly improving his skills in computer aided design, mechanical system design, and electrical engineering. He closed by saying he "could get way more specific" about his learning experiences, but we would have been there "all day."

Across the board, all interviewees spoke to the development of their professional skills more strongly than the technical ones. Communication, leadership, public speaking, and confidence were mentioned often. They all described how the skills could be transferred to other tasks, engineering or not. It is not immediately obvious that an academically-related activity can teach you more than just technical skills. However, in the case of engineering design competitions, the team-oriented environment develops professional skills as well. This speaks to the 'reach or scope' property of infrastructure as defined by Star (1999), as design competitions do more than just prepare students technically.

The cultivation of skills due to engineering design competitions has also been documented by other researchers. In 2004, the National Academy of Engineering created a list of traits that engineers must have to address the issues of a world that is rapidly advancing. They described an engineer with these attributes as the *Engineer of 2020.* Some of the traits include analytical skills, communication, and management (Vest, 2005). A survey of 320 civil engineering undergraduates studied how students believed they best attained the attributes of the *Engineer of 2020* (Polmear et al., 2021). Results were separated by race, gender, sexual orientation, disability status, and first-generation student status. Research found that some social groups strongly believed that out-of-class activities, like engineering design competitions, are more effective than what is learned in class to attain the traits of the *Engineer of 2020*. The groups that felt this way were mainly underrepresented populations like African Americans, American Indians, Hispanics, and the LGBTQ+ community.

In addition, students across all social groups agreed that non-class activities had the biggest effect on building their skillset. The survey strongly supports that learning options other than classroom lectures need to be available to students for their professional development. The

“lack of formal leadership development in engineering curricula” the authors describe likely contributed to the results of this survey (Polmear et al., 2021, p. 6). Engineering students that want to develop into future leaders of their discipline will have a harder time attaining that solely by attending classes. The study pointed out interesting differences in opinion between social groups. Overrepresented students in the study, which were male, white, Asian, and continuing generation students, indicated that their development of skills mainly came from jobs or sports. One trend this mirrors is the easier time that these overrepresented students have at getting paid engineering-relevant positions compared to their counterparts. I think this discrepancy in opinion between over and underrepresented groups could be related to privileges and opportunities available to some but not all.

Several factors indicate that this is a reliable source to support my argument. A clear and detailed data set with conclusive evidence is provided. This paper is published in ASCE’s Journal of Management in Engineering, and the research was sponsored by the National Science Foundation (Polmear et al., 2021). The perspectives of the professors who wrote the paper can be identified by the way they decided to frame this study. They looked at the results through the lens of diversity. They were likely aware of the lack of diversity that preexists in civil engineering and wanted to bring forth research that would contribute to fixing the problem.

My personal experience, the experience of other UVA students, and students at other institutions all serve as evidence that engineering design competitions prepare students for the demands of an engineering career. They also may especially benefit students from marginalized groups. The way they supplement classroom learning positively affects the knowledge of students and broadens the ideas they bring to the workforce. Students who participate in these competitions differentiate themselves and become unique candidates for employers to consider.

Building Projects & Resumes, Simultaneously

Although United States infrastructure needs engineers to continue joining the workforce, securing an opportunity to break into the field can be challenging. Having internship experience is advantageous for this endeavor; those with internship experience are more than twice as likely to receive a job offer compared to those without (Kaplan, 2023). These internships are great ways to become familiar with the nature of a field of interest before fully committing to the industry.

However, internships have been extremely competitive in recent years. 49% of Gen Z candidates are submitting more than fifty internship and job applications throughout their searches (Lucas, 2023). This is likely because of the lack of interviews received in return, let alone offers. For example, Google receives 40,000 applications and offers internships to less than 4% of them (Statler, 2023). Acceptance rates that rival those of Ivy League institutions in the engineering internship market can be attributed to market saturation and frequent media coverage of the financial opportunity in the field (Osman, 2024).

I argue that in the face of this selective process, engineering design competition teams are an open and effective alternative for everybody. Being a school-sponsored activity, all are typically welcome to join regardless of year or level of experience. At UVA, the concrete canoe team and Virginia Motorsports follow this structure. By joining the teams earlier in college, students can be prepared to stand out as candidates even when competing against those with internship experience. Returning to Bix, she notes how students benefit from design competitions professionally: “Joining school teams thus offered career-minded undergraduates not just coveted

resume credit, but also chances to impress faculty, mentors, and potential employers by spinning team involvement as initiative, dedication, and leadership experience" (2019, p. 123).

These benefits were evident in the experiences of the 4th-year concrete canoe team member that I interviewed. He described his internship experience as 'weak' and had concerns when comparing his resume to others. When asked how his participation in an engineering design competition affected his internship or work related endeavors, he described his exact experience:

> When I brought my resume to the recruiters, I think concrete canoe and these engineering competitions [were] one of the key eye-catcher moments that they had, and it felt like … 9 out of 10 of these recruiters, and or interviewers, would ask about said competition, about why I joined, about my experience, what I do. I think because [of] their experience within my major, they have a general understanding of what's happening … We formed a connection where we had a mutual topic we could talk about. They were more interested because it was unique and it stood out and made me stand out among other students.

The student continued to describe how he got several job offers. Although the other components of his profile may have contributed to his success, the frequency of times his design competition was brought up in his interviews is noteworthy. This student's answer highlights the value of engineering design competitions among students. When students run into interviewers that have shared similar experiences, the connection can create valuable talking points that elevate the interview and get them to the next stage.

Conclusion

Engineering design competitions can address the shortage of well-prepared engineers the U.S. faces. By creating interest in the field, developing technical and professional skills, and being an accessible resume-builder, they serve as an infrastructure system with defined properties of scope and universality that can be introduced to students at any level of their education (Star, 1999). As seen in my analysis of students at the K-12 and college level, the benefits that a student receives from their experience may vary. No matter what level of understanding that a student may have about engineering, the evidence supports that engineering design competitions are a positive contributor to inclining students to pursue a career path in this field. Engineering design competitions should be promoted to students more often by educators, and students should consider joining them. By addressing the shortage of engineers, we get closer to fully staffing the engineering workforce needed to close that 2.6 trillion dollar infrastructure investment. Skilled engineers with their unique design competition experiences will be confident in joining a field that they are genuinely interested in and contribute to strengthening the framework of our country.

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