Developing T-Shaped Civil Engineers Through Involvement in Out-of-Class Activities

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Abstract. The National Academy of Engineering, American Society of Civil Engineering, ABET, Inc. and other entities have described the global vision for the future of engineering and civil engineering specifically. Included in this global vision are the competencies necessary to equip civil engineers to contribute to solving industry-spanning technical, social, financial, political, and cultural challenges. While curricular activities have long been the focus of engineering education research and practice, engineering educators have recently begun to recognize the value of what engineering students do outside of the classroom. The goal of this paper is to introduce and engage the AHFE HSSE community on the workforce challenges specific to the construction industry, and to explore out-of-class activities as pathways for developing the 21st century competencies necessary to solve these challenges.

Keywords: Civil engineers · Construction industry · Rapid rebuilding · Competency

1 Introduction

The National Academy of Engineering (NAE) is a key stakeholder in identifying engineering competencies. The book, *The Engineer of 2020: Visions of Engineering in the New Century,* is a part of the NAE Committee on Engineering Education (CEE) initiative on engineering in the future and educating engineers to meet the needs of the new era. *The Engineer of 2020* presents facts, forecasts future conditions, and develops future scenarios of the possible world conditions for the 2020 engineer and the attributes these engineers must have to prepare them to help the public meet these world conditions [1]. The Engineer of 2020 identifies 10 attributes necessary for graduating engineers to possess in the next three years [1]:

1. strong analytical skills;
2. practical ingenuity (skill in planning, combining, and adapting. Manner in which one identifies problems and finds solutions);
3. creativity (invention, innovation, thinking outside the box, art);
4. good communication skills;

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5. principles of business and management;
6. principles of leadership;
7. high ethical standards;
8. strong sense of professionalism;
9. dynamism, agility, resilience, flexibility (the ability to learn new things quickly and the ability to apply knowledge to new problems and new contexts) and
10. lifelong learning.

Reviewing the calendar and category of each attribute support the timeliness of this discussion. The engineers of 2020 entered college in the fall of 2016 if a four year time to degree completion is assumed. If a longer time to degree completion is assumed, the engineers of 2020 arrived on campus before fall 2016. Are the institutions that received these future engineers ready to develop their whole person in a way that fulfills the vision of engineering in the new century? Further, take note of the 10 attributes and which can be categorized as deep, discipline based versus broad discipline spanning attributes. Surprisingly, nine of the 10 attributes are broad in nature – the very attributes that have been persistently less developed in graduating engineers.

2 Rating the Quality of US Infrastructure

Civil engineers are charged with solving complex technology, infrastructure and labor challenges. Infrastructure spending in the US represents 3.3% of the Gross National Product (GNP) [2]. Personal consumption is the largest sector contributing to the GNP, approximately 70% of GNP, and it relies heavily on infrastructure to transport goods across the US [2]. Businesses depend on a network of infrastructure for all aspects of daily operations. However, the condition of our infrastructure is in such disrepair in the US that it has received a D+ grade by the American Society of Civil Engineers (ASCE) Infrastructure Score Card for many years including the current year [3]. The score card provides one of the most comprehensive snapshots of where the US is, and is not, spending money, and where the needs are likely to be the greatest in the coming years. Infrastructure spans a wide range of public and private assets, including highways and bridges, airports, ports and inland waterways, electricity plants and transmission lines, information and telecommunication networks and water and sewage facilities.

3 Rapidly Rebuilding from Scratch

Civil engineers have an important role in repairing and replacing infrastructure – an enormous US challenge given the number of infrastructure systems rated below a C grade on the ASCE Infrastructure Score Card. The current US government administration promises to devote over $200 billion to infrastructure spending [3]. While consistent investment in infrastructure and planning are essential solutions to raising and sustaining the quality of our infrastructure, competency of civil engineers and other constructors must also be considered. One competency widely discussed as vital to these professionals is the ability to rapidly rebuild infrastructure from scratch.

Rapidly rebuilding from scratch is a measure of resilience of systems. Too often civil engineers think about building something that will last forever, but in the age of accelerating technologies it is like trying to build a stone bridge when steel is coming. Eiffel built one of the first steel bridge in Porto, Portugal at a fraction of the time and cost of building a larger stone bridge.

In the age of accelerations, or the ever-widening range of innovations that simultaneously impact business, society, and the built environment, the nature of what gets built, how it gets built, as well as how it is recycled and rebuilt are changing more rapidly with broad impacts on costs, business models, safety, and environmental factors [4–7]. In an age of rapid change, people may have to rapidly rebuild careers in new areas too. Can we as a civilization create T-shaped engineers who can rapidly rebuild everything from scratch?

4 Competency Development from Out-of-Class Activities

The engineering education community has dedicated attention and research to curricular changes [8] and more recently to out-of-class support for engineering students [9–11]. Involvement in out-of-class activities has long been assumed to be complementary to educational and developmental processes and specifically undergraduate STEM learning [12, 13] and persistence. In this paper, out-of-class activities are defined as activities that occur outside of the formal classroom and curriculum. These activities are connected to the academic curriculum and educational institution and can include "community service groups, student government, fraternities, athletics, honor societies and religious clubs" [12, p. 4].

Solving rapid rebuilding challenges requires civil engineers to have broad and deep competencies. Spohrer and Kwan (2009) [14], through work at the IBM Corporation, articulate these competencies through a model dubbed "The T". They explain that far too many of today's students come out of college with deep competencies in a single discipline, referred to as "I-shaped" professionals, but very little boundary crossing competencies with which to engage in complex interactions. Therefore, they advocate for the development of "T-shaped" students who are deeply skilled in their own area, broadly versed in boundary spanning skills and adept in these skills when they graduate and enter professional practice.

Recent studies have begun to examine the influence of what engineers do outside the college classroom to develop technical and professional competencies [11, 15]. In a recent study of undergraduate civil engineering students, the three most prevalent out-of- class activities in which civil engineering students participate include off- or on-campus employment (53.4%), sports (37.8%), and student clubs and organizations (32.7%) [16]. The most reported positive outcomes of civil engineering students' out-of- class involvement are personal development, social development, and social engagement [16]. These findings complement conclusions from research studies conducted with a broad engineering student sample. For example, Flowers (2004) [17] found that student involvement directly affects gains in personal and social development. Similarly, Burt et al. [18] reported that engineering students involved in co-curricular activities exhibit greater leadership skills and practice more ethical decision-making processes—both significant facets of personal and social development. More specifically, Zydney et al. (2002) [19] found that participation in undergraduate research led to greater enhancement of important personal skills, while other researchers likened positive outcomes such as social engagement to learning community participation [20].

The engineer of 2020 attributes can serve as a proxy for the T-shaped skills and expertise. Initial results from an on-going study of civil engineering students (n = 185) to examine their involvement in and outcomes from out-of-class activities indicate that when the 10 engineer of 2020 attributes are grouped as a single outcome, these students point to involvement in an off- or on-campus job (16.7%), design competition teams (10.8%), research (9.2%) and equally to professional experiences and sports (8.7%) as the activities from which the attributes were developed. These results offer insight into the ability of out-of-class activities to help students development technical and professional competencies.

5 Conclusion and Future Research

This paper introduces the call for rapid rebuilding as a job competency for civil engineers and constructors and explores competencies that may help civil engineers answer this call. Finally, the paper recommends the role that involvement in out-of-class activities by civil engineering students can play in helping them develop broad and deep attributes while in college. Future research includes answering four questions: (1) what specific competencies indicate and, when developed, enable a civil engineer to rapidly rebuild infrastructure from scratch; (2) what out-of-class activities and specific components within out-of-class activities produce positive academic outcomes leading to a civil engineer's ability to rapidly rebuild infrastructure from scratch; (3) What influences civil engineering students' decision to become involved in these out-of-class activities; and (4) What, if any, are the technological and policy barriers to rapidly rebuilding infrastructure from scratch?

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