Rethinking Engineering Leadership

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***Abstract*—Engineering educators have a growing interest in supporting the development of a suite of professional and technical skills in engineering graduates, called for by both professional organizations and industry. This suite of professional skills can be viewed as comprising an (implicit) model of engineering leadership. But a number of definitions and models for engineering leadership have emerged, and no consensus has been reached on a definition of engineering leadership that can be effectively translated into educational experiences that are pedagogically and developmentally appropriate for undergraduate students. In this special session, we bring engineering educators together to work towards a shared understanding of engineering leadership, and to develop strategies for learning experiences in this space.**

Keywords—undergraduate engineering education, contextual awareness, teamwork, effectual behavior, emotional intelligence, engineering leadership

I. Introduction

What is a leader? Better yet, what is an engineering leader? These are questions that have been asked by professional bodies and industry. Because of the emphasis that industry has placed on hiring graduates with leadership skills [1], [2], [3], [4], [5], the number of engineering leadership development programs has increased in recent years. While what is meant by 'engineering leadership' is often implicit, a number of definitions and models for engineering leadership have also emerged. One common approach to 'engineering leadership' is to adopt existing theories of leadership that arise from organizational psychology or management studies. Many of these theories of leadership are centered on influence (e.g. [6]). On the other hand, engineering leadership is sometimes taken as purely technical, so that engineering leaders become those with the most technical expertise in the field [7]. Neither of these definitions encompass the values that are inherent in the uptake and use of technologies. Theories of influence describe how leadership happens, while technical brilliance describes what leadership could create. Here we argue that such notions of leadership in engineering fall short because they do not include the upstream (the why) and the downstream (the impact) elements, which all engineering projects encompass. A focus on influence or on technical skills both leaves out the values that drive leadership in engineering, as well as its potential impact. Engineering leadership is of increasing interest to educators, as evidenced by the the rapid growth of the Engineering Leadership Development Division (LEAD) of the American Society of Engineering Education. We believe that now is the time for a deeper discussion about a more inclusive definition of engineering leadership, and how it would be taught and assessed at the undergraduate level.

How might we foster engineering leadership? What scaffolding is needed for engineering majors to develop skills and approaches for working with others that encourage inquiry and ethical decision making and actions? Will these students be able to take initiative when appropriate, while motivating themselves and others to reach a deeper level of responsibility with regards to understanding the impacts of their designs, products, or services on the world? How might we infuse leadership principles into engineering undergraduate educational structures? To begin answering these questions, this Special Session will give participants the opportunity to explore the student-centered engineering leadership education space in four dimensions: technical mastery, teamwork, contextual awareness, and effectual behavior [8].

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These four elements of a student-centered engineering leadership approach were generated by programs that were focused on reconceptualizing the education of individuals that would be practicing engineering in the future. The themes were generated by following a qualitative assessment approach, which used an iterative reflection process focused on four engineering programs that address engineering leadership. A key element of the model, which is embedded into each of the programs studied, was providing students with opportunities to produce meaning from the upstream and downstream elements of the engineering process. This emergent framework of engineering leadership shares similarities with other recent models (e.g. [9], [10])

The four programs, from which these themes of engineering leadership emerged and whose representatives are serving as moderators of this special session, have very different structures. One is a new engineering school which addresses engineering leadership implicitly through innovative teaching and learning practices (Olin College of Engineering, Needham, MA) while another is a new engineering degree program that explicitly focuses on engineering leadership (University of Texas at El Paso, El Paso, TX). A third is a co-curricular program in engineering leadership that selected students can take in addition to their disciplinary engineering program (James Madison University, Harrisonburg, VA). The final program has a teaching framework that includes a series of required practical and skills-based learning experiences which are embedded into existing disciplinary engineering degrees (University College London, London, UK).

This model for the development of engineering leadership in undergraduate students views *technical mastery* as a medium from which the complementary attributes of *effectual behavior*, *teamwork*, and *contextual awareness* can grow. These three attributes are each primarily centered around a different social scale: effectual behavior lends itself to the individual level, teamwork lends itself to the small group level, and contextual awareness weaves itself through the individual, larger group and societal levels.

Technical mastery is one of the distinguishing skills of an engineer and is considered a cornerstone characteristic that separates engineering leadership from leadership. These skills are developed through an iterative process: ideate, design, analysis, diagnosis, and coordinated plan action. Technical mastery joined with cultivating curiosity within others, understanding the motives and values that drive a project, and empathically considering the social context that surround a project increase the ability of engineers to shape the elements of a project and therefore its impacts. In this sense, technical mastery with these leadership concepts provide opportunities for engineers to communicate and demonstrate how the practice of engineering can produce appropriate solutions that are better for the world.

Working towards a common shared vision in the pursuit of creating value for others is a hallmark of teamwork. Working in a team, especially for undergraduates, can be utilized as a mechanism to showcase the strength of diversity, inclusivity and communication, which are important factors of effective leadership. Teaming experiences also provide students with opportunities to collaborate with individuals, both within or outside science, technology, engineering and mathematics disciplines, in a setting that can support the development of personal and interpersonal leadership styles.

For students to grasp the complexity of leadership as professional service, an awareness of context is crucial. Contextual awareness embraces thinking about social constructs and the impacts of the work on multiple stakeholders, as well as discerning the intended and unintended consequences of actions. Contextual awareness also involves assessing and internalizing the merit of engineering work through multiple perspectives, including but not limited to political, social, cultural, environmental, technical, economical, and legal lenses.

Effectual behavior is supported by valuing and employing emotional intelligence. The core of emotional intelligence is understanding what an individual personal acknowledges (i.e., self and social awareness), and what an individual personal does in response to situations (i.e., self-management and relationship management) [11]. Effectual behavior also includes the confidence and skills to advocate for, curate, and prototype ideas in the world, in order to understand and build upon their real-world impact.

II. Special Session Description

This session will incorporate an overview of the growing landscape of engineering leadership and share specific pedagogical approaches and learning experiences implemented at the four host institutions. But our primary intent for the session is to engage participants in a structured discussion around this broader, more inclusive model of engineering leadership, with the goal of surfacing and sharing insights from participants. To this end, we plan to include extensive small group work and activities. In particular, we will ask participants to share learning experiences that they are already creating that fit into this model of engineering leadership (as well as those which do not but perhaps should). This will enable us to map the engineering education community's current understanding and implementation of the model by exploring the learning experiences that are currently offered, and for educators to learn from each other's concrete approaches. The Special Session will also include a debrief reflection on this model of engineering leadership.

We anticipate that the participants will primarily be engineering educators who are committed to the personal and professional development of their students, and in thinking about 'engineering leadership' more broadly. The projected impact from this session is twofold: first, it will contribute to a growing understanding among the engineering education community of the need for a broader, more inclusive, and more pedagogically-appropriate model of engineering leadership at the undergraduate level. Second, the session is a platform to disseminate practical, engaging strategies to

support students in establishing a solid foundation for their development as engineering leaders.

III. Special Session Objectives

- Document how engineering educators conceive of and teach engineering leadership, including pedagogical approaches and frameworks.
- Highlight examples of approaches to undergraduate engineering leadership development.
- Disseminate and obtain feedback on a preliminary framework for the development of engineering leadership at the undergraduate level.
- Collaboratively identify engineering educational pedagogies well suited to teaching engineering leadership.

IV. Special Session Agenda

In this special session, we aim to bring engineering educators together to continue to work towards a shared understanding of engineering leadership. From this framework, we plan to then collaboratively brainstorm possible pedagogical approaches to teach the foundational elements of engineering leadership across the curriculum.

A preliminary agenda includes:

- A 1-2-4-All style discussion comparing the definitions of an engineer, leader, and engineering leader. (30 min)
- Illustrate how a new definition of engineering leadership is emerging, i.e. the Iowa State model and case studies from innovative engineering programs, including those of the facilitators (15 min)
- Critique and revise these emerging frameworks for engineering leadership based on discussion outcomes. (15 min)
- Group brainstorm (or sharing-out) of key theoretical concepts and pedagogical approaches towards elements of engineering leadership development. (20 min)

V. Future Work from the Special Session

The greatest impact that we anticipate from this session is its contribution to a growing understanding among the engineering education community of the need for a broader, more inclusive, and more pedagogically-appropriate model of engineering leadership at the undergraduate level. We anticipate that participants in the session will incorporate their enriched understanding of engineering leadership and specific pedagogical approaches into learning experiences at their home institution. We intend for the results of this session to contribute to the groundwork for future studies which assess and validate approaches for teaching engineering leadership, including the development of a much-needed assessment instrument for educators in this space.

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