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EARLY CAREER ENGINEERS' PERSPECTIVES ON LEADERSHIP COMPETENCY DEVELOPMENT IN UNDERGRADUATE EDUCATION

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Joining the Penn State engineering faculty a year ago, my professional interests as an instructor of engineering are developing and refining methods of engineering instruction that will allow students to gain confidence and to increase their own success.

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Abstract

This study investigated the perceptions of early career engineers regarding professional development and leadership competency within the undergraduate engineering curricula. Study participants represented the early career engineering population, those five years or less removed from graduating with their engineering degrees. Perspectives on leadership competency and professional skills development within the undergraduate engineering curricula were gathered through semi-structured interviews. Study participants (N=20), through their lived experiences at work, described expectations of professional competency from their employers and their ability to meet these expectations. Their ability related to preparedness results from their undergraduate engineering programs. Findings generated from interview transcripts showed challenges for early career engineers in meeting the professional expectations of their employers. Engineers related these challenges to a lack of effective training encountered within the undergraduate engineering curricula. Early career engineers made recommendations for educators and administrations on how to increase the effectiveness of professional skills development including leadership competency.

Introduction

The integration of leadership and other professional skills into the undergraduate engineering curriculum has been informed by research on student, faculty, and employer perceptions. Despite the response from the university officials to these studies and their findings, employers continue to find newly hired engineers lacking in the capacity to lead

(Armin et al., 2022; Knight & Novoselich, 2017; Kotnour et al., 2014; Rose & Flateby, 2022). In response to graduates' lack of professional skills indicated by employers (Armin et al., 2022; Knight & Novoselich, 2017; Kotnour et al., 2014; Rose & Flateby, 2022), this study provided early career engineers' perspectives on the expectations of leadership their employers placed on them and their readiness and competence to lead along with how important their undergraduate education was in developing these skills. This study's purpose was to develop a framework to which engineering educators could use for successful leadership curricula that align directly with employer expectations as described through newly hired engineers.

Background

Employers' expectations of entry-level engineers' preparation and the level higher education considered its graduates as prepared for work are disconnected according to a study conducted by Hirudayaraj et al. (2021). These authors administered a survey to determine managers' assessment of early career engineers; results indicate more than half of these managers cited a lack of professional skills in newly hired engineers. These skills included the ability to work in a team, make sensible and responsible decisions, communicate with a diverse group, and take initiative and responsibility. Survey results informed engineering educators on the importance employers place on leadership skills and yet, find these skills still lacking in graduates. On the contrary, a study conducted by Miller (2017) found 96% of university officials claimed their institutions effective in leadership competency development in their graduates confirming the disconnect found by Hirudayaraj et al. In Miller's study, only 11% of business and organization leaders found newly hired employees ready to lead in their entry-level roles.

Studies conducted by Knight and Novoselich (2017) found conflicting attitudes among

engineering educators when considering leadership competency development. These researchers found some educators believe their students exclusively develop leadership skills outside of the classroom while participating in extra-curricular activities and internships. These authors utilized a self-reflective survey of faculty members to raise awareness of entrusting leadership development of undergraduate engineering students to extra- and co-curriculum as an inefficient method of developing leadership skills for undergraduate engineers.

Righter et al. (2020) found engineering educators rely solely on teamwork in developing leadership competency in students. These authors investigated the frequency of interaction between faculty and engineering student teams and the nature of these interactions being able to define a relationship between these interactions and the effectiveness of leadership skills development. Results showed the need for educators to be more purposeful in developing the framework of team-based group projects and more interactive by providing guidance and mentorship.

Novoselich and Knight (2018) conducted research on shared leadership within capstone design teams. Their findings indicated that integrating social network analysis into engineering teams demonstrated the lack of the vertical (hierarchical) structure. These authors stated engineering educators should account for shared conceptualizations of leadership when working with undergraduate design teams.

ABET's requirement for developing professional skills and leadership competency in engineering students is generated from feedback from employers, industry representatives, and university administration. Feedback is based on prevailing needs and is intended to inform (engineering) curriculum. Over the past three decades, employers urged ABET to include stringent requirements in the development of more modern technical and professional

skills for undergraduate engineering students. Employers continue to find some of these skills lacking in newly hired engineers while deeming these essential for the success of both the (mission of the) organization and the engineer's career. ABET responded with its third criteria, Criterion 3, a set of eleven outcomes that all engineering graduates should possess (Shuman et al., 2005). These eleven outcomes were grouped into two categories, one known as the "hard" skills category, the other as "soft" skills. These labels inadvertently created a stigma towards the outcomes' importance especially to an engineering educator with regards to the soft skills. Over time, ABET relabeled the groups as technical and professional skills. While this prompted more emphasis on universities to ensure they are meeting the requirements of the criteria, the latter group remains controversial and ambiguous. Nonetheless, industry continues to urge university officials on the criticality of professional skills needed in an engineering graduate. Criterion Three has been the subject of many studies investigating how to effectively teach professional skills within an undergraduate engineering program (Didiano et al., 2022; Gilbuena et al., 2015, Kendall et al., 2018, Liu et al., 2022; Seemiller, 2016; Wankat, 2017).

Team-based learning (TBL), deemed the most conventional method in teaching leadership skills, is prevalent in engineering education (Wolfinbarger, 2022) Methods for professional skills development using TBL include team-based frameworks (Lui et al.), competency-based approaches using a student leadership model (Seemiller), problem-solving techniques using scaffolding within the teamwork structure (Wankat), case studies, narrative exploration, and lessons learned (Didiano et al.), defined engineering leadership programs (Kendall et al.), and communities of practice integrated into engineering design projects (Gilbuena et al.). Findings from these studies show positive outcomes in

engineering students being capable of functioning within a team. These positive outcomes are evidenced by student teams meeting the goals of the project and gaining the intended competencies. Faculty intends leadership competency to be developed through teamwork, a method demonstrated as ineffective in producing leadership indicated through employer feedback. Wolfinbarger (2022) found that "although many studies in engineering education literature discuss both teamwork and leadership, the treatment of these concepts, especially the link between the acquisition of leadership skills and teamwork, is inconsistent and the connection is not clear."

Lui et al. (2022) demonstrated a comprehensive plan and highly structured framework leads to a team-based project that has the propensity to effectively develop intended professional skills. These frameworks are structured so that shared responsibility is emphasized and includes the development of interpersonal, creative, quality-based, and problem-solving skills. Strategies within the framework contain careful planning, objective alignment, engagement, and collaboration. These authors found successful team-based learning occurred when projects are structured with clear, concise, and transparent communication along with accountability among a highly structured, diverse team.

Seemiller (2016b) found leadership competency development as an essential component of higher education due to centrality of leadership in institutional mission statements, desire of employers to hire graduates possessing leadership competencies, and because 100% of programmatic accrediting organizations require leadership-competency development of students. Seemiller developed a student leadership competency model geared towards the specific competencies desired by employers, required for accreditation, and suggested incorporating its use with concentrated effort by university administration. This author found

positive results in universities that mapped (the details of) leadership competencies across curricula, co- and extra- curricular courses, and opportunities. This led to a concentrated effort in the curricula aspect for development of team-based learning where leadership competency development was well- defined, accurately assessed, and most importantly, supported by university administration.

Wankat (2017) studied the alignment of required learning outcomes surrounding teamwork designated by ABET with the structure of teamwork and group projects utilized by many engineering educators. His study found aspects of team structure associated with inferior performance and assessment. Wankat then suggested engineering educators require task cohesiveness where each member acknowledges the goals of the team in writing and code of cooperation where practices in making critical decisions are standardized. Incorporation of these suggestions improved team performance.

Several studies (Chan et al., 2017; Ozgen et al., 2013; Schell et al., 2021) found leadership competency assessment inaccurate in capturing engineering graduates' capacity to lead. Findings in these studies suggest the lack of an evidence-based definition of engineering leadership and understanding engineers' role in a cross-functional team, misguided importance, and other compelling factors contribute to the inability to accurately assess leadership competency in engineering students.

Engineering leadership education remains a nascent field as engineering faculty not necessarily trained in this area are those responsible for delivering and assessing leadership education. Educators struggle to develop meaningful instruction for professional skills as their efforts are much more siloed into technical competencies demanded by both university degree requirements and ABET (Novoselich & Knight, 2022). Participants sensed this struggle

especially once employed.

Method

This qualitative, phenomenological research study examined the perceptions of early career engineers formulated through their lived experiences. Twenty participants were interviewed between July and October 2023. Semi-structured interviews were transcribed; all identifying information was removed. Responses were evaluated and analyzed using inductive approaches to construct the themes and deductive approaches to confirm findings from previous studies.

Summary of Major Findings

Participants described their experiences in meeting the expectations of leadership from their employers. They described details of what was expected and how they met these demands. Participants described instances where they were not capable of meeting the expectations of their employers and contributed this inability to their lack of preparation during their undergraduate engineering programs. Participants described how well they were prepared to meet their employers' expectations mentioning what worked and what did not in terms of undergraduate preparation. All participants claimed their internships were essential in preparing them for the workplace. They did not feel fully prepared in delivering effective communication, problem

solving and critical thinking, all of which were expected and essential in executing their roles as early career engineers.

Recommendations spanned across curricular, and co- and extra-curricular considerations along with recommendations for university officials. Participants described how they would modify team-based project work, assignments and assessments for written

and oral communication, and exercises intending to increase problem-solving and critical thinking skills. These engineers suggested listing professional skills on syllabi for engineering courses. This would indicate importance of leadership and other professional skills to students. Participants indicated universities should be committed to producing leaders and, in turn, should provide effective messaging and opportunities to accomplish this.

Early career engineers are better equipped in connecting their undergraduate preparation to the demands of the job as they may not have been fully indoctrinated into their engineering role within the organization and are still actively transferring their learned skills from school to work. Perspectives of early career engineers provided knowledge expanding the limited research of this population. Early career engineers may be best suited to provide evaluation of leadership education for undergraduate engineering students. National associations such as AAC&U and NACE continue to survey employers relaying the findings to engineering educators and administrators. While this feedback is valuable in identifying industry needs, it does not offer the information on how best to address deficiencies. Early career engineers who have experienced what it takes to meet their employers' demands provide meaningful recommendations on how to deliver leadership competency training.

This study uncovered what employers expect in terms of professional skills and leadership competency. Newly hired graduates are expected to use critical thinking in problem- solving as they lead in some capacity. Participants described challenges while working in a team environment. The teamwork expected of them was different than what they experienced at school. At work, early career engineers are clear as to why they are assigned to a specific team; they understand what their role is and in turn, understand the importance of delegated tasks they are expected to complete. However, this is not the typical structure for

teamwork at school where teams are randomly assigned. Engineering students may not understand why they or a student are assigned to a particular team. Recommendations were made to engineering educators regarding teamwork where assignments to a team should be more purposeful indicating the importance of each student member. Language such as "leading the effort" when utilized by engineering educators guiding a team can create an opportunity for each member to lead in some capacity avoiding the lack of leadership development in members other than the designated leader.

Critical thinking is an essential skill for engineering leaders; there appears to be difficulty in defining and how expectations for this skill are relayed. In some cases, scripted rubrics and learning objectives/outcomes lessen the opportunity to develop critical thinking. Participants describe the rubric as something that guides students towards a solution to the problem. While it may create a sense of frustration for engineering students to complete assignments with unclear directives, engineering educators should explain these will be the same challenges students will face at work and these "messy details" provide practice in improving critical thinking. Along these same lines, students should be assigned projects where the problem has not been fully defined and multiple approaches to solving the problem once defined are feasible. Participants shared at work they were expected to define problems they were asked to solve and to produce efficient, cost-effective, compliant, and ethical solutions. While these solutions may develop from technical knowledge, the ability to communicate with team members, clients, and management are necessary in solving the problem as well.

Effective communication is a vital skill in engineering leaders especially when the information which needs to be disseminated is of a complex, technical nature. Engineering

leaders must be able to communicate with creditability being upheld while transparency is maintained. Leaders must be able to determine information that should and should not be disclosed. Writing and speaking needs to be clear, concise, and on point. Engineering students' writing and public speaking courses are often classified as English and Communications courses; technical writing courses may not include the content employers are seeking. Participants struggled to prepare written technical reports and presentations for their managers and clients and to disseminate essential information. The writing and speaking they practiced as undergraduates was, again, different than what was needed at work. Participants as well as engineering managers cite an inability to construct and defend an argument, story tell, and identify the purpose of a presentation (Rose, et al., 2022).

Participants were unprepared to offer and respond to constructive feedback. The lack of this skill stemmed from limited face-to-face interaction with faculty and administrators. Being prepared to offer and respond to accurate feedback comes from practice and being informed on whether the feedback is effective, accurate, and constructive. Engineering students are not assessed on this practice to the degree necessary. Students should be required to practice this skill; one suggested method required participation in in-person office hour visits.

Perceived positive assessments of leadership competency in graduates of an undergraduate engineering program had participants recalling being ready to lead. Engineering graduates included leadership skills on their resumes. While participants acknowledged the lack of importance placed on leadership development resulting in a lack of pursuing opportunities to develop leadership, most included leadership skills on their resumes necessitating the need to prepare responses to potential interview questions from employers on details for their capacity to lead. Participants were not surprised by their employers'

expectation of leadership; this skill was, in fact, typically included on job requisitions. They were surprised by their lack of preparation once on the job since they perceive themselves to be leaders. This shed light on the difficulty in accurately assessing leadership. Engineering educators must model, relay the importance of developing, and properly teach and assess leadership.

Availability of leadership-specific courses continues to increase within undergraduate engineering programs attesting to the importance of leadership in engineering graduates (Kendall et al., 2018). Engineering students fortunate enough to take these courses experienced learning through interaction with industry representatives. Students received first-hand knowledge of what would eventually be expected of them while still in school providing an opportunity to fine- tune these skills before graduation. Participants recommended these courses to ensure that students are exposed to engineering leadership. Engineering students should be encouraged to maximize their effectiveness in professional skills development through other required electives as well. Registration in courses that contain a significant writing or speaking component should be encouraged to practice professional skills development. Engineering students should be made aware of how certain general elective courses fit into the development of skills needed to fulfill the engineering role.

Engineering educators profess their role in teaching students how to learn (Knight & Novoselich, 2017). Participants agreed to the relevance of this statement. Many participants were called to act upon specific technical skills they did not acquire as undergraduates. They needed to learn on the job, a skill, the ability to learn, acquired in school and one needed for engineering leaders. However, participants felt learning how to learn could be enhanced in engineering education through encouraged inquiry. Here is where they noted the prevalence of

a minimal mindset as undergraduates, a practice that did not serve them well in their engineering roles. Striving for excellence and going beyond the minimum were expected at work; participants encouraged educators to expect going beyond the minimum especially as this pertains to learning beyond the required.

Engineering leadership remains ill-defined (Kendall et al., 2018). Early career engineers, however, through this study, formulated a definition based on experiences at work and previous training at school. With a well-thought-out working definition of engineering leadership, educators and administrators can provide effective leadership competency development in undergraduate programs.

Conclusion

In this study, findings are consistent with research and indicate early career engineers graduate with the belief they developed leadership competencies and professional skills while in school only to find themselves unprepared to meet their employers' demands.

This study found teamwork as the main mechanism for developing leadership skills. Participants realized leadership competency was expected to develop during team-based project work but felt this method was ineffective at doing so. Developing the skills of providing and receiving feedback, setting goals, managing multiple priorities, and problem solving was feasible utilizing teamwork, participants stated, with appropriate modification to the current framework their instructors used. Participants experienced confusion while working on teams as their instructors expected the conventional, vertical structure and, in some cases, frowned upon shared leadership. This study along with Novoselich and Knight's research establishes implications for engineering educators to promote shared leadership within student engineering teams including senior capstones. This study found early career

engineers to have limited exposure to compliance and disclosure even though employers expected them to have this knowledge especially because ABET requires compliance training. This study found participants claiming a lack of cohesiveness and operation within the team structure leading to ineffective leadership development and recommended ways to improve upon the structure of the team that aligned with Wankat's study.

This study's findings indicate a lack of structure in projects frustrated participants resulting in a lack of proper development of professional skills. Shared responsibility among team members was not promoted within the team or by faculty leading to a lack of accountability. Therefore, the recommendations provided by early career engineers as these relate to the structure of teamwork and should be highly considered as these recommendations align with current research. These recommendations allow for leadership development in all members of the team.

Engineering education research continues to be informed by faculty, current students, graduates, and industry. In this study, early career engineers provided information on effectiveness of leadership competency development assessed through their experiences at work as they strived to meet employer expectations of leadership skills. Participants confirmed early career engineers remain expected to display leadership skills even at the onset of their hiring. The study provides details on what tasks requiring leadership skills engineers are expected to perform along with the challenges in completing the tasks. This information better informs engineering educators on how to improve leadership training and goes beyond employer claims of lacking skills in newly hired engineers. The findings better correlate to the instruction and methods used in delivering leadership education that these engineers recently experienced. The conclusions in this study not only support current research but fill a gap of

knowledge generated from a relevant population. One implication that can be derived from this study is that of including early career engineers' feedback in the evaluation of current ABET requirements. Early career engineers stress the importance of leadership competency development that needs to take place within undergraduate engineering programs; in fact, these engineers state this competency is essential in fulfilling the role of a newly hired engineer. Having been recently exposed to the methods and opportunities set forth by engineering educators and university officials, these engineers' claims of not being fully prepared to meet employers' expectations of leadership competencies are founded in lived experiences.

Corporate officers and high-level managers acknowledge the importance of employing engineers with leadership competency. Technical skills can be leveraged by engineering leaders. For these reasons and others, employers seek engineering graduates who can lead upon graduation. Reassurance can be established when it is well-understood the colleges and universities have assumed an integral role in developing leaders. Hutson et al. concluded, "As employers increasingly demand general competencies in professional skills as noted in current job postings, a college education needs to address the skills gap and realize transferable skills that can be applied in a wide array of future careers and situations are as important as field-specific knowledge."

With having experienced employers' demands for leadership competency, early career engineers are better suited to inform engineering educations on effective means for developing these essential skills.

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