Fostering Engineering Leadership Identity in the Classroom

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CONTEXT

Today's engineers are expected to lead and work with interdisciplinary teams, and engineering programs should better prepare graduates to lead. Yet engineering students themselves are often reluctant to do so. Research indicates that one method to assist the leadership development of engineering students is the cultivation of engineering leadership identity and that curricular interventions may hold the most promise for this development.

PURPOSE OR GOAL

The purpose of this paper is to summarize the findings of a US-based national study of engineering leadership identity development and present preliminary findings from a pilot classroom intervention designed to foster this process. The research question guiding the overall project asks, how do engineering students develop a sense of engineering leadership identity? Most research on leadership development has shown that a focus on acquiring skills or traits tends to be ineffective in terms of key outcomes, especially long-term retention. Our project posits that seeing oneself as an engineering leader, rather than being trained to perform leadership skills, will lead to more substantial leadership outcomes as engineering students transition into the workforce.

APPROACH OR METHODOLOGY/METHODS

The research project employed a mixed-methods study to understand engineering leadership, and then utilised the results of this research in the formulation of the pilot classroom intervention. First, two national datasets of US college students were analysed to examine engineering students' leadership experiences. Then, a grounded theory study was employed to explore how engineering leadership identity is developed among engineering students at three different US-based universities. Informed by these findings, a pilot intervention was implemented in Spring 2020 in one introductory engineering course with 41 students.

ACTUAL OR ANTICIPATED OUTCOMES

Engineering students actually enjoy more leadership experiences than their peers in other fields, but they perceive gaining less in professional outcomes from these leadership experiences. Experiences that tend to promote leadership development for engineering students include working with groups, applied learning, and interacting with faculty. Development of engineering leadership identity involves mastering the technical knowledge required to practice engineering while cultivating a vision for a project in a manner that can best harness the diverse talents across a team. The intervention showed promise for cultivating engineering leadership identity.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The research presented here aligns with recent research demonstrating that the classroom is likely the setting with the most potential for leadership development with engineering students. as the classroom already has high legitimacy in terms of its place in the engineering formation process. Yet leadership cannot only be taught as added content in the engineering curriculum.

Rather, reflectively engaging students in the process of leading seems to be the best method for shifting their view of what leadership is and that they can be leaders.

KEYWORDS

Engineering leadership, identity, mixed methods research, classroom intervention, leadership development

Introduction

The world faces problems that require interdisciplinary solutions, and thus today's engineers are expected to lead and work with teams that transcend not only discipline, but also national borders. To meet these challenges, engineers need to be prepared with solid leadership skills that allow them to help coordinate these complex efforts. However, programs that ready engineers to engage in practice do not seem to be adequately preparing graduates to lead in the ways expected of them in the field. Faculty are resistant to give up curricular time to incorporate content around leadership and other professional skills, and engineering students themselves tend to be reluctant to consider themselves leaders, usually equating leadership with "management".

We set out to understand how engineering educators might motivate students toward pursuing their development as leaders. Utilizing an identity-based framework to understand engineering leadership development (Schell & Hughes, 2016), over the course of three years we have studied engineering students' experiences with leadership via large, national surveys and focus group interviews to understand how engineering students might develop an engineering leadership identity. The purpose of this paper is two-fold. First, we summarize the results from our research to highlight key findings regarding how engineering students may form an engineering leadership identity. Second, we present preliminary findings from a pilot classroom intervention intended to foster engineering leadership identity. Overall, we find that engineering and leadership are quite compatible when students understand leadership as relevant, even essential, to engineering practice.

Literature Review

Among engineering education scholars, practitioners, and administrators, there is increasing focus on professional skills (e.g. communication, empathy, leadership) as a necessary component of preparation for the engineering profession. Leadership has enjoyed a central position in these professional skills, leading to increasing adoption of engineering leadership programs and initiatives. In fact, there is a broad array of literature exploring different approaches to develop leadership skills in undergraduate engineering students. Unfortunately, research indicates that the efficacy of these efforts to develop leadership skills is weak, at best. This may be due to the complexity of growing as a leader, as well as the diverse pathways students take to develop.

Identity

We are interested in addressing this challenge by implementing an identity framework to influence and measure leadership development amongst engineering students. An identity framework views student development in terms of their self-schema, especially as negotiated with others. Of particular importance to this research, complex developmental processes (e.g. emotional, interpersonal, and professional) may be interpreted in terms of identity growth (Chickering & Reisser, 1993). From this perspective, the very process of learning might be seen as "a process of forging identities" (Lave & Wenger, 1991, p. 3). For this reason, engineering educators have recently focused on engineering identity as a process for understanding students' motivation and commitment to the engineering field, which we have also incorporated into our model for understanding engineering leadership as an identity.

Engineering Identity

The strength of an identity approach to engineering education is reflected by the growing literature on exploring engineering identity (e.g., Morelock, 2017; Patrick & Borrego, 2016). Consensus in the field indicate that identity development improves persistence and a perceived belonging to the profession (Patrick, Borrego, & Prybutok, 2018). One model of engineering identity distils engineering identity into three dimensions (Godwin, Potvin, Hazari, & Lock, 2016), which inform our understanding of engineering identity:

1. Performance / Competence beliefs
2. Interest in content; and
3. Recognition by others (PCIR).

These three dimensions reflect separate axes along which students' engineering identities vary. This perspective is gaining traction in the field but does not represent a consensus among researchers as to how to best conceptualize engineering identity. Other researchers operating under different epistemological assumptions operationalize engineering identity through a myriad of approaches (see Morelock, 2017; Patrick & Borrego, 2016).

Leadership Identity

In the modern era, understanding of leadership has shifted from the traits-based "Great Man" theory through the behaviors of leaders to the process of leadership in organizations (Antonakis, Cianciolo, & Sternberg, 2004). Rather than focusing on particular skills, behaviors, or attitudes, identity-based research explores the possibility of leadership as an aspect of self-concept (Lord & Hall, 2005). Much of this work focuses on leadership identity amongst professionals, especially early-stage managers. However, among college students, the Leadership Identity Development (LID) model has emerged as a widely used, stage-based explanatory model (Komives, Owen, Longerbeam, Mainella, & Osteen, 2005). The LID model is grounded in a relational approach to leadership that defines leadership as a process of influence rather than a static position. This model suggests that students' understanding of what constitutes leadership expands and deepens during their development, resulting in a stronger leadership identity. A core developmental step (often experienced during the college years) includes a differentiation process (between stages 3 and 4), whereby an individual's definition of leadership shifts from a positional view to a relational view—that leadership is not inherently tied to position, but it can be exercised by individuals based on the situation. The LID model provides a framework for understanding student perception of leadership, as well as how their perception might be changing.

Engineering Leadership Identity

With the increased interest in professional skills for engineering graduates, leadership has been identified as a core competency, reflected in ABET accreditation requirements. Moreover, identity frameworks have proven insightful in the development of engineering and leadership. Hence, there is limited, but growing, literature that is exploring engineering leadership identity. One model that has emerged prominently describes three orientations of leadership within industry (Rottmann, Sacks, & Reeve, 2015):

1. Technical Mastery –solving problems;
2. Collaborative Optimization – influencing teams; and
3. Organizational Innovation—creating novel, market-driven solutions.

Our research thus contributes to this conversation by focusing directly on the experiences of students as they progress through their undergraduate engineering professional preparation programs. By integrating engineering identity and leadership identity as understood in college students, we aim to develop an explanatory framework to aid engineering educators in incorporating leadership into the engineering curriculum.

Theoretical Framework

The framework guiding our study integrates the Komives et al. (2005) LID model with Lave and Wenger's (1991) communities of practice model. Lave and Wenger argued that identity is central to learning, especially in the process of learning a profession. Novice practitioners participate in professional practice as legitimate peripheral participants, meaning they are offered authentic experiences to engage with practice and learn the norms, values, and cultures of their desired profession. One outcome of learning then is a sense of identity relevant to the community's field. This model is widely used in engineering education research to conceptualize how engineering formation leads to engineering identity (Johri, Olds, & O'Connor, 2014). What we posit is that experiences which offer opportunities for legitimate peripheral participation in engineering practice are the same types of experiences that can foster leadership identity development as well (e.g., engaging in groups). The opportunity then is to intentionally integrate these two outcomes (engineering and leadership identities) to show students they are exercising leadership as they prepare for engineering practice.

Summary of Past Work

Our research has been a three-year, mixed-methods project to explore engineering leadership identity. The core of the project is a grounded theory study exploring how undergraduate engineering students develop engineering leadership identity. The project started with a quantitative phase using large datasets of U.S.-based college students to better understand the leadership experiences of engineering students. This first stage used datasets collected by the National Survey of Student Engagement (NSSE) at Indiana University and the Higher Education Research Institute (HERI) at UCLA (University of California, Los Angeles). The second stage then involved focus group interviews with 64 engineering students in 20 focus groups across three U.S.-based universities. The results across these two phases informed development of a classroom intervention aimed at fostering engineering leadership identity.

In the first phase, multilevel multiple regression analyses of the NSSE and HERI datasets identified several important predictors of leadership in engineering students. First, leadership experiences that aligned with classroom content promoted technical leadership capabilities (e.g. critical thinking, content mastery) amongst engineering students (Schell, Hughes, & Tallman, 2018). Second, interaction with diverse others promoted leadership capabilities related to professional skills (e.g. understanding others, speaking effectively). Moreover, engineering students seemed especially impacted by these experiences. Third, interaction with faculty was important to leadership self-efficacy growth (Schell, Hughes, Tallman, Annand, et al., 2019). Finally, working with peers, both inside and outside of class, helped leadership self-efficacy.

Further qualitative research supported and expanded upon these findings; moreover, the research provided rich insight into the environments and values that are important to engineering leadership identity development. For example, analysis explored the relationship between participant views of leadership in engineering and other contexts (Schell, Hughes, Tallman, Kwapisz, et al., 2019). This analysis found engineering students characterize engineering leadership differently from the concept of leadership when not contextualized within engineering. Development of engineering identity and leadership identity were supported by common factors, however, notably authentic experiences and recognition by others (Schell et al., under review). In addition, students pointed to specific skills that were necessary for either engineering or leadership identity development, but they identified different skills as necessary for each. Finally, engineering identity development tended to be experienced as a straightforward, linear process, but leadership identity was experienced as non-linear in nature, consistent with much of the literature on leadership identity development. Changes in students' sense of engineering identity are concomitant with changes in their perceptions of the field of engineering (Hughes et al., under review). Authentic experiences were again instrumental in influencing students' engineering identity development as well as changes in their perceptions of the field of engineering. Moreover, confidence and group skills were essential to developing an engineering leadership identity.

The culmination of these project findings begins to paint a rich picture of engineering leadership identity. Quantitative methods revealed the positive impact of aligning leadership experience with coursework, working with diverse peers, and faculty interaction. Qualitative analysis revealed important themes surrounding engineering leadership identity development, such as relevant skills, complex development, confidence, and authentic group experiences. These findings, along with other literature that supports them, provide a solid foundation for exploring engineering leadership identity.

Intervention approach

Recent project efforts developed a classroom-based intervention aimed at fostering engineering leadership identity development. To identify the design elements for preparing this intervention, we analysed previous findings to determine what would be most impactful for assembling this intervention. The analysis process included a thematic coding of experiences identified as significant in our prior research, identifying the most impactful characteristics resulting in the development of a relevant intervention (Tallman et al., 2020).

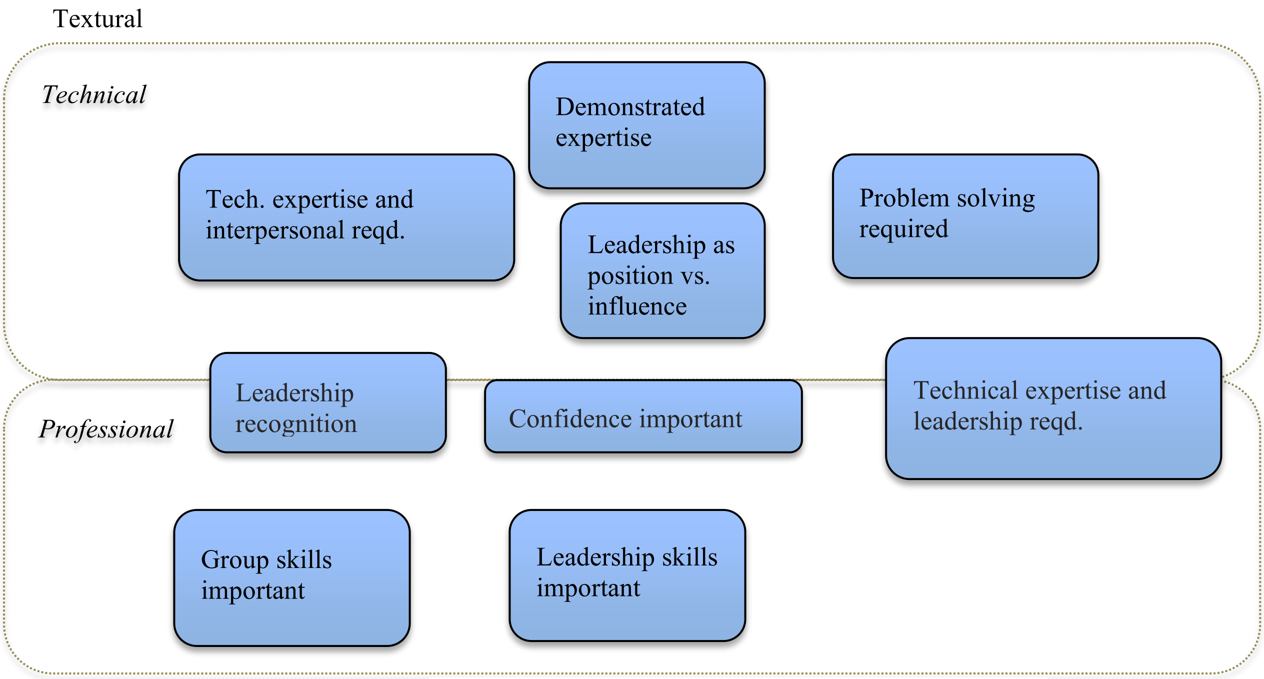

Figure 1. Textural Themes

For the second stage, analysis of the project data provided insight into impactful characteristics of engineering leadership. The analysis followed a transcendental phenomenological methodology (Moustakas, 1994), orienting themes as textural (i.e. "What happened?") and structural themes (i.e. "What was the context?"). The textural themes (e.g. used problem solving, leadership skills important) were further grouped into Technical and Professional categories, which reflect the types of skills, recognition, and self-efficacy that featured most strongly in focus group discussion (Figure 1). As illustrated, proven expertise in technical content and problem-solving were central to the technical category of textural themes. Several other themes spanned both categories: the importance of confidence, recognition, influence, and expertise (both technical and leadership). Finally, participants highlighted the centrality of group and leadership skills in the Professional category.

The structural themes provided insight into what types of contexts (e.g. group projects, applied learning) contributed to identity development (Figure 2). Authentic group projects that included

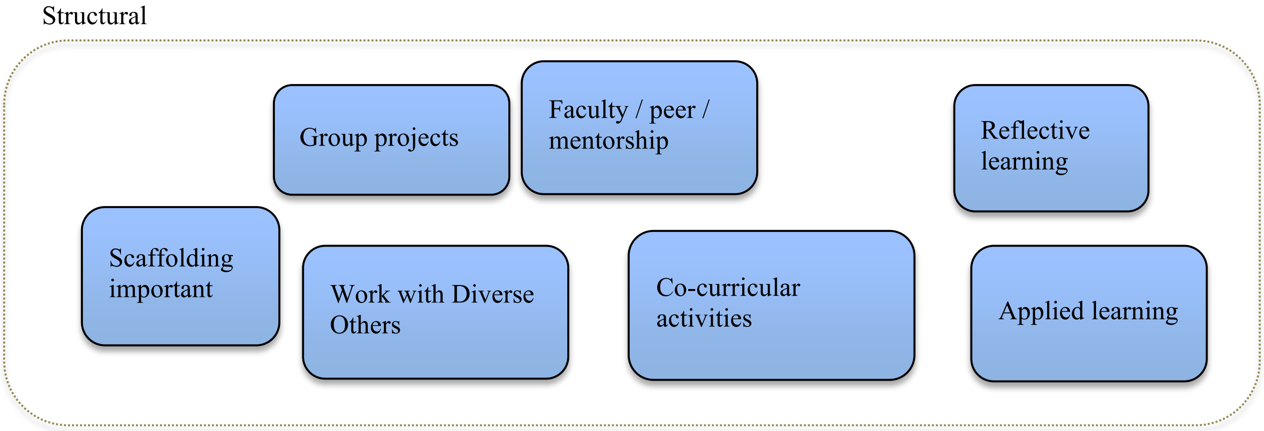

Figure 2, Structural Themes

elements of reflection and scaffolding were especially important, particularly when older faculty or peers were substantially engaged. In addition, working with diverse others was important for developing professional skills; and co-curricular activities often provided a platform for students to further develop their engineering leadership identity.

In summary, this qualitative analysis provided a vision of what was important to engineering students as they developed into leaders.

Overview of Classroom Intervention

With the identification of these themes, we developed a classroom-based intervention that incorporated the "texture" and "structure" of engineering leadership hypothesized to promote engineering leadership identity. Practical considerations were also taken into account, most especially the willingness of engineering instructors to allow us to implement this intervention in their courses. However, implementation was drastically revised after the onset of the COVID-19 pandemic; the intervention was converted to a virtual format as all university activities moved online. Although offering the intervention online was not our initial plan, we found the opportunity useful as the intervention may ultimately receive widest adoption if available to engineering instructors as a virtual module.

A three-pronged activity was developed and implemented to engage engineering students in an authentic experience that prompts them to exercise leadership. First-year students were walked through a virtual activity where they were asked to design a cleanroom. Students first watched a video that explained what a cleanroom is and what activity they would be engaging in as part of the intervention. Next, students worked through a "jigsaw" activity (Persellin & Daniels, 2014) where they each were assigned a different role in contributing to the cleanroom design and expected to work through all of the differing considerations each role brought to the design process. Finally, students engaged in a class discussion of the activity and reflected on the importance of leadership to engineering as experienced in this process. Students were assessed before and after the activity with respect to their sense of engineering leadership identity. Engineering leadership identity was measured using a 10-item instrument at both time points. Items for this instrument were taken or adapted from research by Godwin, Potvin, and Hazari (2013), Komives et al. (2005), and Wielkiewicz (2002).

Results of pilot intervention

The results of the intervention showed promise for promoting engineering leadership identity development. Of the 41 students in the class, only 20 provided consent and full data, but a post-hoc power analysis showed we had adequate power (β=80%) for nonparametric binomial sign tests to detect large effect sizes (g=0.25) for each of the ten items (Cohen, 1969; Faul, Erdfelder, Lang, & Buchner, 2007). The item with the greatest increase was "Others see me as a leader" (g=0.5; p<0.05). This item captures part of the recognition aspect of identity (similar to the PCIR model for engineering identity), reflecting changes in students' perceptions of how others may see them after completing the intervention activity. A second item that significantly increased was "I can be a leader, even if it is not my title" (g=0.27; p<0.05). This item pertained to the concept of relational leadership as well as leadership self-efficacy.

Three items showed large effect sizes (g=0.25) but, at best, marginal significance levels. Students' scores in this sample changed enough to be practically significant, in terms of effect size, but statistical power was not reach to determine whether these changes are generalizable (statistically significant); future work will test these with larger sample sizes. These items included:

- Leadership is important to engineering.
- I am interested in developing leadership.
- I am confident in my leadership.

The first item may reflect one of the most important outcomes of this project, that leadership is essential for engineering practice and thus should be developed in engineering students. The second and third items are relevant to developing engineering leadership identity in terms of students' perceptions of their ability to be leaders and their interest in leadership. Items that did not change significantly, either in terms of practical or statistical significance, included two measures of interest in learning about engineering leadership and three items measuring perceptions of the role of a leader. What stands out is the fact that the items that appeared to change most as a result of this intervention related to students' leadership identities, a primary goal of this research project.

Conclusions and Recommendations

The results from our pilot intervention show promise that could be confirmed by testing with larger samples. In addition to the seven items discussed, the item, "It is important that a single leader emerges in a group" did not change from pre to post-test. Although we hoped to see this particular item significantly decrease over the intervention, it's still encouraging that this item did not increase. Two significant items were of the most concern to our research, that students start to recognize that leadership is not necessarily tied to a specific position or role and that students start to recognize that their peers may view them as leaders. Both of these items directly relate to our theoretical framework in terms of the recognition aspect of both engineering and leadership identities (Godwin et al., 2016; Komives et al., 2005) and the recognition of leadership as a process separate from any particular role or position.

Two other items pertaining to desired outcomes of the intervention did not significantly change which raises questions regarding the efficacy of the intervention. These items were "I am interested in learning more about engineering leadership" and "Learning engineering leadership will improve my career as an engineer." These two items were two of the three that dealt specifically with leadership in engineering, suggesting students were more interested in learning how to be leaders in a broad sense and not specifically within engineering. In comparison to items that almost met the threshold for significance, we observed a higher effect size for the "developing leadership" item than either "learning leadership" items: in further testing, we may be able to discern if these findings reflect a greater interest in doing leadership rather than learning about leadership. This may not appear to be a problem for most educators, but our qualitative data suggest that students do distinguish the engineering context from other contexts in describing leadership. This differentiation suggests that educators need to tap into students' motivations to develop leadership specifically within the engineering context. Otherwise students may compartmentalize leadership from their formation in engineering. That said, the average for these items on the pre-test was already close to the top of the scale (M=4.30 and M=4.60, respectively, out of 5). It appears that students initially recognized, or maybe knew they ought to convey as such, that leadership will be important to practicing engineering.

Lessons Learned

We took away a number of lessons regarding facilitation of such an intervention both for when we scale up the intervention and test it with a larger group of students and for other educators who wish to implement a similar intervention in their setting. First, this intervention was conducted with first-year students, and we found that first-year students need much more structure to scaffold the intervention for them to work through it most effectively. Some of the ways we intended to structure the intervention were not possible due to the pandemic, such as letting students meet other members in the small groups in which they completed the cleanroom activity. We also thought it might be helpful for the facilitator (if not the course instructor) to be present at each stage in the activity for assistance and ask questions about how to proceed.

Directions for Future Research

Given the generally encouraging results from this pilot, our primary focus moving forward is to refine and test this intervention with a larger number of students. Not only will we be able to determine if some of the results we observed in this sample hold with a larger sample, but we will also be able to perform more sophisticated analyses to determine whether we are tapping into engineering leadership identity as a latent construct. We also plan to develop and test a parallel intervention for fourth-year students to see if we observe similar results with students who are on the verge of entering engineering practice and if fourth-year students differ from first-year students with respect to engineering leadership identity.

Our research raises other important questions. Given prior research that demonstrates lacklustre results from stand-alone leadership development programs (Collins & Holton, 2004; Day, Fleenor, Atwater, Sturm, & McKee, 2014), to what extent does this curricular-based approach offer a more promising direction? In other words, might we see differences between students who complete a curricular-based intervention and those who participate in a stand-alone leadership training or program? A second important question is the extent to which these changes in leadership are retained over time. Are students who participate in a curricular-based intervention more likely to retain a stronger sense of engineering leadership identity compared either to those who do not participate in this type of intervention or those who participate in stand-alone opportunities? Finally, to what extent does targeting engineering leadership identity shape students' future engineering practice—how do their outcomes and experiences in the workplace differ from other engineers?

Engineering in the twenty-first century requires professionals to work across disciplines and national boundaries to solve incredibly complex problems. Engineers are called upon to demonstrate a practiced sense of leadership in order to collaborate with people of differing backgrounds, but programs that prepare engineers for practice do not appear to be effectively developing leadership as an important learning outcome. We piloted an intervention intended to be facilitated as part of nearly any engineering course to cultivate in students an engineering leadership identity, and the results of our pilot are encouraging toward this end. Finding opportunities like these to integrate leadership into the existing engineering curriculum may not only be the most efficient way to add this content without adding curricular requirements but also be the most effective way to integrate leadership with students' burgeoning engineering identities.

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