

THE EFFECT OF ENGINEERING LEADERSHIP IDENTITY RESEARCH ON THE IDENTITIES OF STUDENT RESEARCHERS

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Abstract

Undergraduate research is a common method for students to gain experience in fields related to their major during their time in college. While involvement in research has many possible outcomes for undergraduates, the study of its effect on engineering, leadership, and engineering leadership identity development is underdeveloped and inconclusive. To contribute to this area of study the experiences of four undergraduate engineering students who were involved in research were examined through combined collective case study and autoethnographic methods. The research the students participated in centered on understanding the development of the identities of interest in engineering students more broadly, giving the four students repeated opportunities to engage with the subject. This combination of involvement in research and exposure to engineering, leadership, and engineering leadership concepts was found to have mixed results. The impact on the student's own identity development was inconsistent, ranging from positive to negligible to negative. It is hypothesized that this discrepancy can be attributed to diversity of individual experience both before and during involvement in research.

Key Words

undergraduate research, engineering identity, leadership identity, engineering leadership identity, case study

Introduction

The need for engineers with leadership skills has been acknowledged since the early 1930s and has increased in prominence in the past decades (Waddell, 2002). Repeated calls from industry, publication of seminal reports, and recognition of the dearth of professional skills in engineering graduates have all highlighted this need (Duderstadt, 2008; National Academy of Engineering, 2013). In response researchers and educators have increased focus on engineering leadership development within engineering education by developing engineering leadership models and increasing the number of engineering leadership development programs (Klassen et al., 2016).

This paper and the multiphase research project encompassing it also respond to the recognized need for engineering leaders. The literature on the subject lacks clarity on how undergraduate students develop a professional identity as an engineer, how students make meaning of their exercise of leadership, and how these two phenomena occur within each other's context (Schell & Hughes, 2016). These ideas have been conceptualized using the theoretically based concepts of engineering identity (EI), leadership identity (LI), and engineering leadership identity (ELI) development (e.g., Knight & Novoselich, 2017; Komives, Owen, Longerbeam, Mainella, & Osteen, 2005; Morelock, 2017). While various models are used to explain EI, LI, and ELI development, none of the identities have a single, agreed upon definition (Schell & Hughes, 2016). A description of common models and their impact on our research can be found in our previous work (Schell & Hughes, 2016). Our larger project seeks to make headway into filling the literature gap on ELI as well as further understanding of EI and LI. To do so the project examines student experiences using both quantitative and qualitative data to develop an empirically supported understanding of the definition of, development of, and effective interventions on ELI as well as EI and LI.

The purpose of this paper in the context of the larger project is to develop a detailed picture of the impact of involvement in undergraduate research (UR) on the identity constructs of interest by examining the identity development of the four students who have participated in this research project. The students were funded by the NSF Research Experiences for Undergraduates (REU) program and were engaged in the project for between four and nine months at the time of this writing. While involved, the students (henceforth REUs) conducted and observed focus groups, learned qualitative research methods, reviewed literature on engineering and leadership identity, and dialogued with team members. They also acted as lead authors for this and other conference papers. Because of the REUs' repeated exposure to EI, LI, and ELI through the research project, this paper is able to go beyond studying the impact of UR or exposure to identity concepts individually. Instead it examines the impact of participating in identity focused research on students' EI, LI, and ELI development. While this makes the study unique, it also limits the generalizability of the findings. Despite this potential limitation, the information gathered here can inform future research and provide insight for educators curious about effectively fostering EI, LI, and ELI development through an undergraduate research program.

Literature Review

Existing research on the impact of participation in undergraduate research on EI, LI, and ELI is limited and contradictory. Participation in UR has been found to improve leadership self-construct scores (Hughes, Schell, & Tallman, 2018a). It also positively contributes to engineering identity (Hughes & Hurtado, 2013; Hughes, Schell, & Tallman, 2018b). Other sources have shown UR increases interest in graduate work and careers in STEM fields (Boylan, 2006; Fitzsimmons, 1990). It has also been shown that both students and mentoring professors involved with UR perceive improved leadership skills as a student benefit (Lei & Chuang, 2009; Sabatini, 1997). In contrast, UR has been shown to have no significant relationship to leadership (Carter, Ro, Alcott, & Lattuca, 2016; Zydney, Bennett, Shahid, & Bauer, 2002), to self-identifying as an engineer (Meyers, Ohland, Pawley, Silliman, & Smith, 2012), or to retention in engineering education (Hughes, Schell, & Tallman, 2019). While these sources relate to the core subject here, there exists little literature specific to the impact of UR on the identities of interest. This paper will help bridge this gap in the literature by presenting the impact of participation in UR as experienced by the REU students.

Methods

The approach taken for this study was a collective case study to allow a close investigation of the impact of researching EI, LI, and ELI on those very identities in the REU students. Not only does a case study allow effective portrayal of the information surrounding the students' identity development despite the small sample, it also allows the experiences of the four students to be compared (Creswell & Poth, 2017). There are many precedents for the use of a case study in the subject of identity development: they have been employed frequently in the encompassing fields of education, psychology, and sociology (Creswell & Poth, 2017; Patrick & Borrego, 2016), and have been used to examine leadership and professional identity development (Pierrakos, Beam, Constantz, Johri, & Anderson, 2009; Poole, 2017). The approach is also informed by autoethnographic methods, or the study of oneself as part of one's own culture (Hayano, 1979). Specifically, the REU students employed collaborative autoethnography to reflect on their own experiences and bring these reflections into dialogue to understand, in their own words, their development of EI, LI, and ELI through the REU experience (Chang, Ngunjiri, & Hernandez, 2012).

Data for the case study was collected over a six-month time span in the form of two focus groups and self-reported personal statements. This timeline allowed the students' EI, LI, and ELI to develop between data points, thereby offering an objective view of their identity development over their involvement in the research project. The first focus group (FG1) was conducted in November 2018. The three REUs involved at the time participated and three other team members, two co-PIs and a graduate student, acted as interviewers. Three months later another focus group (FG2) was conducted. The same three students participated as interviewees, but a new REU led the discussion as a training experience. Both interviews used the protocol of the larger project, which explores each of the identity constructs. The personal statements were gathered in May 2019 as the final stage of data collection. The statements were responses to questions targeting identity development before and during the REU program.

The information collected was reviewed, synthesized, and compared to develop an understanding of the changes in the students' identities and the impact of UR participation on those changes. First, the opinions captured in the two focus groups were compared for each of the three students who were interviewed in both focus groups. The focus groups offer snapshots in time; therefore, their comparison allowed differences and similarities in the REUs'

accounts of their identities over time to be identified. Next, the focus group results were summarized alongside the key concepts present in the personal statements. Due to the reflective nature of the personal statements the students' entire experience as an REU was captured, making the changes seen in the personal statements comparable to the information gathered from the focus groups. Two REUs were missing a personal statement or a focus group due to the dates of their participation; they are included to offer further insight despite their incomplete data. Exhibit 1 summarizes the involvement and information available for each REU student.

The REUs' individual biographies are included at the beginning of each case study, but there are a handful of shared characteristics. The students were all undergraduates in the industrial and management systems engineering major (IMSE) at MSU during their participation in UR. They had all taken the Engineering Management and Ethics class taught by one of the PIs. They all have held student leadership positions while at MSU.

Exhibit 1. REU Involvement and Information Available

<i>Student</i>	<i>Dates as REU</i>	<i>FG1</i>	<i>FG2</i>	<i>Personal Statement</i>	<i>Authorship of this paper</i>
<i>Emma</i>	Aug. 2018 - May 2019	X	X	X	Supporting
<i>Monika</i>	Nov. 2018 - Current	X	X	X	Lead
<i>Romy</i>	Aug. 2018 - Jan. 2019	X	X		Supporting
<i>Tessa</i>	Jan. 2019 - Current		Lead	X	Lead

Emma

Emma became an REU student at the beginning of the academic year in August of 2018. Emma identifies as a woman and uses she/her/hers pronouns. She began studying at MSU three years ago as a general engineer. Emma served as the fundraising team lead for MSU's chapter of Engineers Without Borders (EWB) for the 2018-19 academic year. This role included leading 8+ students to collectively organize fundraisers for the club, delegating to and following up with team members, and securing donations from local businesses. Over the summers of 2018 and 2019 Emma traveled to western Kenya with EWB. The first time she was part of a team overseeing the implementation of a borehole well at a primary school, and the second time she was team lead of the structural assessment team. Overall, she has identified as a leader for most of her adolescence and limited adulthood.

Personal Statement

As an REU participant in the project I worked with the PIs and other REU students to build an effective protocol, conduct focus groups, and collect qualitative data to formulate an understanding of engineering leadership identity development in undergraduate students. I found the experience as part of the project meaningful; it shed insight on ideas that I have grappled with in life and in academia, while also validating my personal identity growth. As an REU student, I was introduced to different identity development theories and models. Using this information, I was able to compare my own experience with the models to pinpoint my progress within my identity development. Gaining a deeper understanding of identity development, especially engineering and leadership identity development, has helped me reflect on my experiences in the engineering program at MSU. My experience as fundraising lead with EWB also contributed to my identity as an engineering leader because this role provided an opportunity to grow my professional skills as a leader, communicator, and project manager. Overall, the synthesis of my work as a researcher and as a voluntary leader sculpted my engineering leadership identity to its current form.

Before taking the course Engineering Management and Ethics, I perceived engineers as masters of technical knowledge and skills. After the first year and a half of studying engineering I thought of engineering as a mindset and engineering school as an entity similar to the army. All engineers are taught how to problem solve. Engineering schools force students to think in the exact same way, almost as if brainwashing an entire industry, demanding a structured procedure in place of a student's natural thought process. The basis of this problem-solving stems from the following steps – define, state given facts, state assumptions, state tools that will be used to solve the problem, state the solution, state a reflection of this solution, and reiterate if necessary. Although my education has tried to slash the problem-solving approach I have developed over my childhood and adolescence to make me think like an engineer, I catch myself using my personal problem-solving approach still in non-engineering, informal situations. Having both methods available allows me to take a step back and try a new method if the first attempt does not come to a conclusion that is up to expected standards. Even though I often use an engineering mindset to problem solve, I have never

considered myself an engineer. I do not own that title because I do not feel like I have had the opportunity to apply my technical engineering knowledge to real problems. For years my education has encouraged me to work on theoretical textbook problems and the development of my professional skills. Due to the promotion of professional skills in my major and my research at MSU, I now see engineering as a learned mix of technical and professional skills that allows people to have creative yet structured problem-solving approaches and validate solutions.

During the first two years of college, before I was an REU, I defined leadership as a skill that can be grown through practice but that is mainly based on recognition from others. At that point in my life I did see myself as a leader because of my experiences as the fundraising team lead at MSU's chapter of EWB and as the member in group projects who drove the team to start working. During my time as a research assistant, I found leadership to be a collaboration between encouraging and supporting others to do their best, building a shared vision with the team, and leading team members by example. These findings were a product of my Multidisciplinary Engineering course, conversations with mentors, and learning from the project. The idea that community recognition was imperative for leadership identity was heavily endorsed by Lave and Wenger's Communities of Practice model (Lave & Wenger, 1991) and the first few stages of Komives' Leadership Identity Development model (Komives et al., 2005), which I only found out about because of my participation in the research project. Both models are used frequently in our research as frameworks for identity. At this point, I still identify as a leader but a more informed leader. I now know more about effective methods for growing my leadership skills.

Before I became a research assistant for the project, leadership did not seem like a critical aspect of engineering. Instead, I thought of leadership in engineering as a bonus, not a necessity. After taking on a leadership role in EWB and spending my time on the research project, I began to see the clear advantages of leaders within the engineering context. I feel an urgency to develop my engineering leadership identity and talk with my peers about their engineering leadership identity and skills; we are the technical leaders of the future. As young people, our generation must step up to create solutions to the world's problems and unite to build those solutions together. The key to working together is supporting each other and ensuring effective work is happening collaboratively, which is where a technical leader is essential. For example, the President of MSU's student chapter of EWB plays a significant part in what the club is able to accomplish. I have watched three remarkable students step into this presidency each with differing strengths and weaknesses. As their engineering leadership identity grows into the role, they become better at instilling a shared vision between the working groups, communicating where our club is going, and encouraging our working groups to do their best. Although I lead the fundraising team in EWB, I do not identify as an engineering leader because my team's scope does not include technical engineering work. In addition, I still do not identify as an engineer which makes identifying as an engineering leader contradictory. Overall, I am working on building both my engineering and my engineering leadership identities.

Focus Group Comparison

Emma's focus group responses indicated empowerment, validation, and development of a methodical engineering way of thinking as meaningful to the formation of EI. In both focus groups she did not identify as an engineer because she was lacking the "validation of being hired by somebody to help out with engineering problems." When asked about steps to becoming an engineer in FG1 Emma identified several, including "actually feeling like you are smart enough and worthy enough to call yourself an engineer." Similarly, in FG2 she identified encouragement as central to EI development. She also brought up in FG2 that participation in college level engineering education is tied to financial privilege.

The theme of leadership being inseparable from followership persisted in Emma's definition of leadership across both focus groups. According to Emma, a leader "should just be a little bit more influential member of the team." To illustrate in FG1 Emma referenced Derek Sivers' popular YouTube video that describes first followers as underrepresented leaders (Sivers, 2010). Three months later she was firmer in this view and explained that "even people who are working with leaders can also be leaders in a sense." In both focus groups she considered herself a leader, or "somebody who is looked upon to get a certain goal finished...using the power of a team," due to her appointment to lead the money team of EWB. During FG2 Emma described her personal leadership style as emphasizing personal responsibility, intrinsic motivation from all team members, and little distinction between leaders and followers. Emma frequently referenced EWB in her responses, which indicates the experience was instrumental to developing her LI.

To Emma an engineering leader is a person with enough technical knowledge to ask necessary questions, effectively communicate, and check fine details. In FG1 she was hesitant to personally identify as an engineering leader because the team she managed did not solve what she considered to be engineering problems. Later, in FG2, she said she did not have a developed ELI due to her limited EI. She planned on developing those identities with

influence from her strong LI. Emma explained, “before joining this project I didn’t really think about engineering leadership differently than leadership, so being on this project has made me realize that it’s important to have both of those identities developed.” Her REU experience encouraged her to target development of a cohesive ELI.

Monika

Monika is a white, first-generation US citizen who was raised by non-engineering college professors in Bozeman. Monika has a non-binary gender identity and uses they/them/theirs as pronouns. Although they did not know which major specifically, Monika knew they wanted to be an engineer from the second semester of college. Monika joined the project at the beginning of November 2018 when they were a junior in the IMSE program with a minor in mathematics. This coincided with their participation in the Out in Science, Technology, Engineering, and Mathematics (oSTEM) conference in mid-November. Monika was not very involved on campus until returning from the oSTEM conference when they became a member of the oSTEM club and Queer Straight Alliance. In January 2019 they became the president of oSTEM. They had not held leadership roles in college before this but had been a leader in high school.

Personal Statement

As an REU the bulk of my research activities are leading focus groups and writing. Community shapes people, so I have come to identify as a researcher more than an engineer through my time as an REU. I got hired to the project and attended my first oSTEM conference within two weeks of one another. The oSTEM conference helps LGBTQ+ students embrace their gender and sexuality identities within academia. I experienced changes to my personal identity due to being more accepting of myself and beginning a transition in my gender expression.

My engineering identity was not formed by my in-class experiences; instead my work as a researcher feels more relevant. I grew up in a family where academic research was always happening at home. In high school I learned the definition of “engineer” by taking engineering classes based on hands-on building and computer aided design. I would have described engineering as strictly technical. This definition was challenged when I learned about the scope of the work that industrial engineers do. I don’t identify myself as an engineer because I identify as an engineering researcher and advocate for queer STEM communities. I have struggled with feeling out of place among engineers the more I have come out and transitioned. I would define an engineer as a problem solver, but it is hard for me not to imagine the stereotype of a white, wealthy, cisgender man. My REU experience impacted what I think of engineers because I have had the pleasure of meeting a variety of people in various engineering majors. I also understand research is a function of engineering, but my research experience feels outside of that.

In the past I defined “leader” mostly positionally but also as someone with a leadership personality. Before becoming an REU I was in a class titled Engineering Management and Ethics that allowed me to think about leadership a lot. I did not identify as a leader in the past for a variety of personal and philosophical reasons. I do currently identify as a leader. For me that identity is based on my capacities as an advocate and the president of oSTEM at MSU. I received the 2019 Lavender Leader award for my leadership in the queer community. If leadership is socially bestowed upon people, then I feel as though I have been recognized by my community as one.

I would define a leader as someone who other people have designated as such, but my experience as an REU student gave me perspectives on many types of leadership constructs. For example, I interviewed one student who started a company to help minority groups. Not once did he call himself a leader, but in my mind he certainly was. In preparation for working with indigenous students I learned about how social constructs such as leadership can be very different depending on their society of origin. Leadership is a construct with a multitude of definitions. I never thought about the intersection of engineering and leadership before my time as an REU and before taking Engineering Management and Ethics. One of the PIs taught the class, so when I first formally learned about engineering leadership it was from the same lens that I am studying it from now. Engineering leadership identity is a lesser discussed leadership construct in the engineering community. Although I see myself as a leader, I do not see myself as an engineer. Thus, I am reluctant to claim my engineering leadership identity.

Focus Group Comparison

Monika did not identify as an engineer over the timeframe spanned by the two focus groups. In FG1 they explained, “I lean towards applying my engineering skills in contexts that are not necessarily an engineering job.” Later they said their EI reduced with increased awareness of diversity issues in school. They pointed out that engineering is marketed as creative problem solving, but in reality, engineering has “not a lot of diversity of thought.”

Monika had similar concerns to Emma about the way leadership and followership are generally discussed. Seeing the same value in leadership and followership, in contrast to the commonly accepted strict binary between leaders and followers, prohibited Monika from identifying as a leader in FG1. Three months later Monika identified

as a leader due to being elected president of oSTEM at MSU. By FG2 Monika's view of leadership was still positional as indicated by their change in identity due to gaining a leadership position.

Monika identified empowerment as important to the formation of an ELI in FG1, but their understanding of engineering leadership was fragmented. FG1 took place at the very beginning of Monika's time as an REU and contains evidence of a lack of exposure to engineering leadership. In FG2 Monika's ELI was shaped by the clash of lack of gender diversity and abundance of neurodiversity in engineering. Monika's definition of neurodiversity, the social movement of people on the autism spectrum, is based off Singer's work (2017). When explaining the lack of gender diversity, they said, "being a leader feels like you're going to stand up in front of a group of men." In this case the lack of gender diversity in Monika's experience had a negative impact on their ELI. However, Monika believed neurodiversity to be common in engineering and this bolstered their ELI.

Romy

Romy graduated in May 2019 from MSU with a B.S. in IMSE and an honors diploma. She was no longer involved as an REU at the time of FG2. Romy uses the pronouns she/her/hers. She began college in electrical engineering, her father's profession, but soon switched to IMSE. During high school she was involved with multiple clubs and leadership positions including the marketing leadership position for the robotics club. Romy also held many leadership positions during college. She mentored students of various ages, including other IMSE students through the ePals Mentoring Program. She also was a student member of the Women in Engineering board at MSU, a leader in MSU's chapter of Institute of Industrial and Systems Engineers, and a board member of the industrial engineering honors society, Alpha Pi Mu, at MSU.

Focus Group Comparison

Romy's responses in both focus groups indicated she identified as an engineer. She saw accepting an engineering-titled job and doing highly technical work as the primary validation for this identity. In FG1 Romy described engineering as "a way to use math and science to solve problems and... a way to help people." This definition was apparent in Romy's statements in FG2 as well. In FG1 she focused on engineering as a means for financial stability, a theme not present in FG2. During FG2 she mentioned seeing engineering professors as researchers not engineers, which may indicate that her participation in UR had a negative or null impact on her engineering identity.

Romy's definition of leadership was centered around inspiring and influencing a group to achieve a goal. However, in FG1 she explicitly listed out three types of leaders. These types were defined by having a natural leadership personality, a position, and/or trained skill. Romy did not list these three types in FG2, but the idea of differentiation of leaders was present. Overall, Romy's view of leadership appeared to be relational; she acknowledged that leaders can, but don't have to, hold management positions. When asked if she saw herself as a leader, she responded positively in both focus groups. In FG2 she qualified that statement by pointing out that her LI is a situational identity. Romy mentioned her personality traits, positions of leadership, and recognition as a leader as contributors to her LI.

In both focus groups Romy defined engineering leadership broadly as leadership within an engineering context. In FG1 she clarified that she views it as a leadership approach that is systematic or engineering-related. She explained, "people who get engineering degrees and then don't necessarily do engineering — I don't think that makes them any less of engineering leaders if they're still using engineering processes and engineering mindsets in their leadership approach." While Romy identified as an engineering leader in both focus groups, she clarified in FG1 that she saw herself as an engineering leader specifically within the context of her major. She said she identifies within that context because "that's where most of my experience being a leader and being thought of as a leader is." The theme of recognition validating her engineering leadership identity was also common to Romy's statements in both focus groups.

Tessa

Tessa has been studying at MSU as an honors student for three years. She joined the research project in January 2019. She began college in university studies with little knowledge of engineering but transferred to IMSE by the end of her freshman year. Tessa is a woman, and she uses the pronouns she/her/hers. She is a white U.S. citizen who had no close ties to engineers before college. During high school Tessa was involved in various groups but did not hold any leadership positions. While at MSU she has been involved with the campus ministry CRU and the Industrial Engineering honors society, Alpha Pi Mu. She was involved with CRU for two years holding a student leadership

position the second year. She joined Alpha Pi Mu during her junior year and currently holds the position of vice president in the MSU's chapter of that club.

Personal Statement

My experience in UR has influenced me in a variety of ways, though its impact has been limited thus far due the short amount of time I have been on the project. My involvement has taught me about aspects of research, academic work, and leadership and engineering identity theory. It has also increased my belief of my ability to be an effective, self-motivated employee, my identity as a researcher, and my personal understanding of the world. Over the time I have been involved with this research project, my EI, LI, and ELI have also changed due to both my REU experience and factors such as interactions with faculty, classmates, friends, and family; involvement in clubs, classes, and other activities; and exposure to concepts through books and other materials

The first of the identities, engineering identity, has been influenced by factors both within and outside of my participation in research. Before beginning as an REU student I defined an engineer as someone who typically has several years of formal training and who develops technical solutions to primarily physical or tangible problems using known methods of analysis and problem solving. At the time I would have described myself as a developing engineer, as I believed my schooling in IMSE would continue to develop me in ways that fit into my definition of an engineer. My association with engineering faculty and students, identification by others as an engineer, and my highly technical course load up to that point (mechanics, calculus, physics, etc.) all also contributed to my identification as an engineer. After participating as an REU for a semester I would now say that an engineer not only has and uses technical skills but that they do work that uses or supports their own use of those skills a majority of the time. This is in contrast to not using technical skills regularly or simply supporting or leading those who use technical skills. My participation as a REU student has impacted this definition by helping me realize that I do not view leading, research, or supporting engineers as specifically engineering activities. Under my new definition I still view myself as a developing engineer but to a lesser extent. This was caused by the distinct definitions of engineering, leadership, and engineering leadership used in the research project as well as my increased identification as a researcher. Not only does this new definition re-title what I previously identified as part of my engineering identity but has also made my direction of time and focus on these subjects, direction of time and focus away from learning strictly engineering skills.

A leader, as I would have defined one going into my time as an REU, is someone who directs, inspires, and motivates others often by giving them independence and responsibility. At the time I did not identify as a leader but as someone who had some intellectual knowledge of leadership and a desire to become a leader. This desire and knowledge was instilled primarily by an engineering management and ethics course I had taken the semester previous to my start on the research project. At the time I did not believe myself to be a leader because I did not believe I had any practical knowledge or experience with leading and had not been identified as a leader by myself or others. Over my time as an REU my definition of what a leader is, thus also my understanding of myself in the context of leadership, has morphed. Due to interactions with one of the PIs and with interviewees I understand that a leader is often not the technical expert, but rather someone who knows how to tap into and support the technical expertise of others. I have recognized due to various factors that a leader should be able to effectively work with, motivate, support and defend a diverse team, not just people they are similar to. Understanding the LID model (a leadership development model used in our research) has helped me continue to develop an understanding that one's ability to lead does not depend on position or title (Komives et al., 2005). The crossroad of each of these changes and my previous definition of leadership is where my definition currently stands. Under this current definition, I would say that I am or can be a leader but that I still have a lot to learn about how to lead well. This change from not a leader to a leader was brought about primarily by various opportunities to practice leading in scenarios such as conducting interviews for our research, participating in group projects in various courses, and tutoring other students. My increased understanding that my leadership experience does not have to be positional also influenced this change.

Before beginning as a REU student, I had no clear definition of what engineering leadership is, though I would have described it generally as leading within an engineering context. While my perception of engineering leadership has not changed drastically over the past few months, my definition has become clearer. I now would describe it as leadership of engineers by a technically-competent person to develop innovative and scientifically sound solutions to problems. When I first began as an REU, my identity as an engineering leader was nearly non-existent. Similar to my leadership identity, this was largely due to my lack of experience with engineering leadership and leadership in general. Since then that identity has developed to the point that I would say I am an engineering leader, though one that is just budding. This change was brought about by my experience tutoring other engineering students,

my contribution to engineering education through research with this project, and a deliberate shift in my focus to learning leadership or soft skills. It was also influenced by my increased understanding that IMSE curriculum at MSU is largely designed for breadth of knowledge which leads to more effective leadership of technical people rather than for depth which leads to technical expertise.

My identification with each of these identities exists within the recognition that as a student I am not capable of fully being an engineer or an engineering leader due to the fact that I am not yet a part of the professional field of practice. However, I do believe that I am able to begin developing and identifying with these identities while I am still a student.

Conclusions

A handful of themes were notable in the focus groups and personal statements. REU students who felt a certain identity was lacking were often waiting for outside empowerment in the form of employment or another outside validation. Monika and Emma both objected to the current paradigm of dividing the world into leaders and followers. Monika, Romy, and Tessa all identified research as separate from engineering. Finally, a growth mindset and the understanding of being in a time of self-improvement was touched by most REU students and heavily relied on by Tessa. The four students changed (+/-) in identification with the constructs of interest over the course of participation in UR. Exhibit 2 summarizes this and attributes changes to significant experiences, such as REU or clubs.

Exhibit 2. Summary of EI, LI, and ELI changes

<i>Student</i>	<i>EI</i>	<i>LI</i>	<i>ELI</i>
<i>Emma</i>	0	+ (EWB)	+ (REU)
<i>Monika</i>	- (REU, family)	+ (oSTEM)	0
<i>Romy</i>	0	0	0
<i>Tessa</i>	- (REU)	+ (REU)	+ (REU, curriculum)

Emma self-identified REU and EWB as both shaping various aspects of her personal identity. This was consistent throughout her personal statement and focus groups. Emma expanded on the concept of engineering mindset in her personal statement after its importance was originally identified by Romy in FG1. This change of focus indicates growth of a more nuanced outlook on her EI. Although she did not identify as an engineer in the focus groups, she discussed a duality between personal problem-solving approaches and the engineering mindset she was taught in school in her personal statement. Emma's LI developed during her time as an REU mainly due to reviewing relevant literature that allowed her to contextualize her lived experience of leadership in EWB. The REU experience can also be credited with exposing Emma to the concept of engineering leadership and increasing ELI's perceived value.

Monika's REU experience and family were the most relevant forces counteracting EI because they formed a strong identity as a researcher. This was consistent between FG2 and the personal statement and was starting in FG1 when they described wanting to apply engineering skills outside of engineering. Overall, Monika's LI was unchanged by REU but greatly shifted by leading oSTEM at MSU. On the contrary, in their personal statement they highlighted conducting and observing focus groups as being valuable aspects of leadership education in REU. Monika's ELI was slowly developing over the six-month span, but the identity was not claimed until the process of writing this paper. See the Postface for more.

Romy's focus group responses did not show identities in flux like the other three students did. Instead, Romy's identity was formed before she joined the project. She later reported the REU experience negatively challenging her leadership identities. See the Postface for more about how she did not see the experience as constructive.

In Tessa's personal statement she made a strong case for REU being an impactful experience on EI, LI, ELI and other areas. The theme of growth was prevalent throughout her personal statement. Tessa's EI decreased because her definition of an engineer shifted towards a technical expert and her increased identity as a researcher and leader contradicted that definition. She also documented increased self-efficacy attributed to REU. Tessa's LI changed dramatically, partially due to REU. She attributed the change to a variety of factors, one of which was conducting focus groups, which she perceived as leadership experiences. Tessa saw her ELI grow as well, a change that was brought about by various experiences and awareness of engineering leadership.

Participating in UR elicited a variety of identity changes or lack thereof for each REU student. Although the timeframe of data collection (two focus groups and a personal statement) was six months, the REU students were

involved in the project for various lengths of time with various levels of personal commitment. Overall, the REU program and clubs were most often attributed to identity development. The REU program had a notable impact in a handful of situations summarized in Exhibit 2. Emma's LI and ELI were both bolstered by her experience as an REU. Monika's EI decreased was attributed to REU and, to a smaller degree, family. Tessa's EI declined because of participation in UR, but it slightly improved both her LI and ELI. Perhaps a larger sample size and more complete data would show otherwise, but inconsistency is the only constant in the range of REU experiences outlined by this paper.

This inconsistency is congruent with the lack of agreement throughout the literature. One explanation for this may be seen through the work of Meyers et al. (2012) argued that the nonsignificant relationship between activities like undergraduate research and engineering identity may mean these experiences are very individual. So for some students they might enhance engineering identity, for others possibly hinder, and others might experience little measurable outcome. Students entering REU each bear their own unique incoming perception, motivation, previous work experience and a combination of other factors. Likely, these are enough to change the relative impact of the UR experience on the studied identities for each student. It should also be noted that overarchingly the intent of involving undergraduates in research is not to develop the studied identities, so it should not be surprising that positive outcomes in those regards are far from assured. Thus, while UR, even EI, LI and ELI focused UR, may give opportunities for development, may have surprising positive outcomes on EI, LI, and ELI, and may have other, more predictable favorable outcomes, it should not be depended on for the development of the three identities of interest.

Postface

Over the course of writing this paper I claimed my ELI for the first time. Revisiting the half-baked concepts in FG2 of neurodiversity being inseparable from ELI led me to define an engineering leader as someone who harnesses individual's skills that the individual is not marketing, a common trait in people on the autism spectrum. What it took to form my ELI was many hours of introspection while authoring this paper. My experience was the opposite of Romy's. After I sent her a draft of this paper, she bravely shared how the culture and content of the UR caused her to feel as though she "conceptualized leadership incorrectly." She felt an expectation for REU to be her dominant identity, which did not nurture other identities and personal growth. UR is far from being a reliable or efficient way to develop students' EI, LI, and ELI due to the broad spectrum of experiences.

— Monika

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