Building Leadership Capacity in Rising Engineering Professionals through Engagement as Career Mentors: Influencing a Self-Directed Learning Mindset

Dr. J. Eliseo De León, New Mexico State University

Eliseo De León serves as a Professor of Practice in the Chemical and Materials Engineering department and provides support to the Engineering Education Enrichment Initiative, e3, at New Mexico State University. Previously, he served at Iowa State University (ISU) and is a lifetime member of the Society of Hispanic Professional Engineers (SHPE). Since 2009, De León has delivered STEM programming throughout Iowa and nationally through SHPE during the Covid-19 pandemic, to underrepresented students and their families to raise awareness of the possibilities available in STEM higher education fields. De León served the ISU Office of the Vice President for Diversity, Equity, and Inclusion for seven years, leading the Lazos retention and graduation program for Hispanic men on the ISU campus. De León is committed to increasing the success of STEM students through extracurricular learning experiences and industry job placement. De León received his bachelor's degree in Chemistry from the University of California at Davis and his PhD in Materials Science and Engineering from Iowa State University.

Dr. Patricia A. Sullivan, New Mexico State University

Patricia Sullivan currently serves as associate dean in the College of Engineering at New Mexico State University with a joint appointment as Director for Workforce and Strategic Engagement in the Office of the Vice President of Research, Creativity, and Economic Development. Dr. Sullivan received her PhD in industrial engineering, and a master's degree in economics from New Mexico State University. She is a recognized leader in STEM-based workforce development and outreach programming where she leads efforts to align academic programs with employer needs to foster economic benefits at the community level. She serves as lead for a National Science Foundation grant to advance engineering student career-readiness through augmented self-directed micro-credential learning.

Sara Patricolo, New Mexico State University

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Engineers navigate an interconnected yet dynamic ecosystem throughout their formative, academic years and as they advance along their professional careers. Mentoring is widely recognized as a means of cultivating leadership skills for current and future leaders.[1] The integration of industry-led mentoring has been identified as an important asset that enriches career development of undergraduate engineering students. However, while the benefits of the mentoring process are well documented in the literature, a gap exists regarding the potential to build *leadership capacity* among rising engineering professionals (REPs) who serve in the role of *mentor*. Preliminary feedback from industry mentors involved in NSF investigation, "Combining Andragogy and Pedagogy to Help First-Generation, Low-Income Students Succeed in Engineering" (award # 1953466), suggests an interest in the creation of leadership pathways for REPs serving as mentors to undergraduate engineering students (UES). That feedback provided the impetus for creating a professional development, micro-credential, mentoring curriculum comprised of a sequence of online courses, whose completion provides the REPs with mastery digital badges. The curriculum guides REPs on utilizing mentoring as a leadership development tool that helps navigate career advancement in their respective engineering fields. Integrated into each of the three courses are best-practices designed to positively influence the development of a self-directed learning mindset and building leadership capacity among REPs as future engineering leaders.

Mentors often cite the ability to increase their professional skills as personal benefits gained through the mentoring process, stating that serving as mentors caused them to reflect on and sharpen their own skills, including coaching, communicating, and introspection.[2] We report on our ongoing efforts to scale a novel leadership development model for REPs through engagement as mentors. We further share progress to date on the development of the series of professional development digital courses, culminating in "digital badges" upon completion, which can be stacked toward a leadership micro-credential.

Introduction

Preparing and promoting engineering college-graduates into the engineering job market is a continuous challenge for academia, exacerbated by the nonstop evolving requirements of the engineering fields driven by rapid technology advancements.[3] A seamless transition from academia to the profession can best ensue when UES are exposed to extracurricular activities that keep pace with evolving technology. UES paired with mentors have the opportunity to learn from those at the front lines about specific demands and expectations on new engineering professionals, based on the developing technology.[4] The complement to the student experience, is the story of acquired competencies by the mentors who take the UES under their counsel and develop leaderships skills that advance their own careers as a consequence of the mentoring relationship.

The current state of the job market for engineering graduates

The employment outlook for engineering graduates has been historically robust. However, in order to keep pace with advancements in technology and infrastructure, as well as the needs in engineering for innovative ways to look at manufacturing, energy and technology, graduating UES

must gain insight to their professional fields through all available means. A well-trained, graduating engineer values the wisdom gained through first-hand collaborations with experienced engineers via internships, co-operative experiential learning, and one-on-one conversations with industry professionals.[5] The concomitant value to the mentor is the opportunity to sharpen the communication skills that will serve the REP as they advance in their professional responsibilities and aspirations. The engagement of the mentor with the student offers the opportunity to not only enlighten the student with the expectations of the profession, but simultaneously creates the situation for the REP to be introspective about the current and foreseeable needs of the engineering field. As the mentor communicates with the engineering student, the mentor performs the mental assessments necessary for planning the success of then next generation of engineers entering the field. Therefore, as employers demand candidates with proficiency of technical, interpersonal, and adaptation skills, the mentor prepares the students for those expectation while becoming fluent in communicating as management does. As an outcome of the experience, the mentor is consequently qualified to assume the responsibilities and challenges associated with accepting management roles.[6]

Importance of bridging the gap between academia and industry

The evolution of the traditional brick-and-mortar engineering curriculum of theoretical knowledge and fundamental properties has been externally accelerated by the ease of access to traditional pedagogical learning using the internet and artificial intelligence. Today, post-secondary education students, in industrialized countries, have access to a compendium of information at light-speed.[7,8] Therefore, engineering programs *must* partner with industry professionals to keep pace with the engineering fields' evolving needs. While industry partners continue to express the need that engineering students entering the profession possess a strong foundation of theory and exercise, there is a loud and clear expectation for practical skills, problem-solving abilities, and team-based collaborative success.[6] Without the loud voices from industry, effectively driving the direction of colleges to incorporate programs to address such needs and informing students of industry expectations, students risk the possibility of failing to meet employer expectations upon entry to the profession and potentially change professional aspirations, or leaving the engineering profession altogether. The imperative to bridge the gap between academia and industry is essential, not only in the preparation of the next generation of engineering professionals entering the field, but as a development tool inextricably embedded in the hands of REP leaders.

The development of mentoring curricula offers mentors the opportunity to get up-to-date with current best practices in collaborative learning. Mentors build on the experiences they have gained after graduation and during their early-career in a way that is conducive to their own growth and that of the UES. Engineering programs encouraging collaborative research projects, internships, co-operative experiential learning, and mentoring expose UES to timely, real-world challenges where students are able to flex their engineering muscles, fostering a sense of their own engineering identity.[9,10] The role of the mentor in these programs is to serve, direct, and validate the success of engineering students by fostering a culture of innovation and adaptability to engineering challenges. The leadership development promoted by the mentoring curriculum serves to increase the personal knowledge of mentors while preparing them to better serve in management, professional roles.

Mentoring at the university level

The mentoring curriculum addresses the needs of workforce development from the perspective of the REP already in the field. As REPs develop their professional acumen, the natural progression of their careers is to become the leaders and decision makers within their fields. The concept of a mentoring relationship is often viewed as providing paths to success for the student being mentored. However, by flipping the lens, we have developed a curriculum that not only serve the engineering student, but the self-directed learner that is the rising engineering professional.

The altruistic motivations that lead mentors to serve the next generation of UES are also the motivations for self-fulfillment and professional advancement. As the mentors gain confidence in their personal ability to communicate and learn about the values, abilities and aspirations of their team members (UES), they are gaining the personal and technical skills that elevate them to leadership. As mentors communicate with students, they discover their own ability to recognize the needs involved in addressing engineering tasks.[11] As a consequence of forging and growing from mentoring relationships, the mentor sharpens their technical expertise, critical thinking skills, and becomes more confident and comfortable with their ability to communicate and collaborate effectively across teams of diverse constituents.[12,13] The mentor, with each conversation, practices introspection about how to serve and create opportunities that help their students reach rising levels of success. The mentor's ability to narrow the gap between the pedagogical learning in the classroom and the knowledge gained by solving a "real-world" problem lends to the growth of the student's engineering identity and ensures that they are well prepared and confident in their contributions to the engineering field.

As mentors engage in "learning how others learn" and the "motivations for being a life-long learner", their professional prowess flourishes.[14] The mentor's leadership identity emerges as the continuous-learning and problem-solving mindset becomes integral to their communications with the UES, and reflects in the manner with which they make decisions, learn from their peers, and guide others to success. The command the mentor gains over the breath of their own technical and interpersonal skills is essential to their leadership abilities in the dynamic engineering ecosystem.

The present state of engineering education is in flux, and must adapt quickly to keep pace with the ever-changing demands of the engineering fields. We propose an innovative multi-faceted curriculum that addresses the leadership preparation of REPs while simultaneously leveraging their role as mentors to authentically connect with and retain UES. The mentoring curriculum intentionally serves participating mentors and provides a scaffold-model to indirectly foster a self-directed learning mindset among UES. Adopting the curriculum, concomitantly serves the mentor, by instilling the confidence in them to use the tools and best-practices that help students adopt the mindset of becoming self-directed learners. Subsequently, comfort and familiarity with the tools and best-practices by the mentor results in their increased capacity to make decision and take actions that lead the mentor to become a leader of their community.

Mentoring and Leadership curriculum

Mentoring

Throughout human evolution there have been individuals whose teachings and advise direct the decisions that guide the progress of civilization. Why then, is it that mentorship is not formalized

into the academic rigor of engineering curricula? One consideration is recognizing the limitation of classroom education in the past 100 years. Engineering students range in classroom sizes from 15 to 150. These larger venues at best provide direct contact with one professor and one or two teaching assistants. The development of this mentoring model introduces additional expertise to engineering education in the form of extracurricular individuals, who have intentionally acquired training to serve the engineering students and help them adopt a self-directed learning mindset. The extracurricular relationships create opportunities for the UES to discover the importance of hands-on experiences and real-world applications with context to the engineering profession, allowing them to embrace the sense of the engineering identity.

The mentoring courses begin by introducing the mentors to the learning environment. The distinction between natural vs. planned mentorship is described as the basis for becoming a mentor to engineering students. The mentor's experiences are explored and validated, as the pool of knowledge necessary to pass along understanding and motivate UES. Throughout the first course, mentors perform self-reflection exercises, whereby they learn to analyze and assess the value of their own experiences in the classroom and the professional environment. These exercises culminate in recognition of the deep repertoire of personal and professional experiences from which they can draw and pass on their knowledge to benefit UES.

Effective communication follows immediately as the second key-concept to creating a successful mentoring relationship. Mentors are motivated by the "good" they can do in service to UES, but often are not pedagogically equipped with the tools to communicate their good intentions. Establishing good communication is emphasized, and techniques are offered to the mentors, so that as they begin to practice said communication techniques, they experience the growth and satisfaction gained as a consequence of the mentoring relationship. Rubrics are commonplace in engineering processes. Mentors are reminded that creating "road maps" with students, outlining existing knowledge, interests, goals, and aspirations establishes the foundation for future conversations. The trust that arises as a result of building an effective mentoring relationship, founded on respect and the contributions offered by both parties, leads to open communication. As the depth of communications grows and trust follows, the mentor and student more willingly share and learn from one another. Throughout the course, mentors are reminded that mentoring is a power free, two-way, mutually beneficial relationship, and that as the veteran member of the relationship, it is their responsibility to maintain to the extent possible a balanced power dynamic.

As mentors proceed through the first course, exercises guide them through activities that can be performed in preparation to interactions with UES. Worksheets guide the mentors in self-reflection exercises about their personal and professional values, goals, and aspirations. Whether written or simply contemplated, the knowledge gained from each exercise provides the basis of a conversation with the students about how to recognize and develop their own set of values, goals, and aspirations, both personally and as engineering professionals. As part of the communication concepts, mentors are reminded that conversations about the above ideas should be revisited periodically for the benefit of creating higher levels of success for both the mentor and the student. An emphasis is placed on the mentor's responsibility to be a strong, empathetic, and engaged listener. These qualities benefit the growth of the UES, while sharpening the skills for the mentor to lead as these techniques are applied in their own professional career.

The idea of trust is revisited, as the mentor performs introspective exercises around the concept of leading from behind. The notion of allowing the UES to make decisions based on their own skillset, rather than simply following the mentor's solution, is key to the growth of the mentor. As REP managers develop, the ability to understand and trust the skills demonstrated by their subordinates is crucial to collaborative, team success. When the mentor practices sharing responsibility with their subordinates, the mentor is demonstrating an ability to select the right people with the right set of skills to get the job done. To that end, in the mentoring relationship, the mentor is encouraged to anecdotally share experiences with the UES to motivate the students to use their acquired skills and pursue new skills to engage and persevere over challenges.

At the conclusion of the first course the mentor is equipped to enter into a mentoring relationship, confident that their own experiences can be communicated meaningfully and effectively to engineering students. Mentors have been equipped with the tools to form a mentoring relationship founded on respect for the contributions made by both parties, and an understanding of the values, goals, and aspirations expressed by both mentor and student. Course expectations are that with the newfound training, the mentor is able to confidently help the engineering student create a "road map" of their own goals and aspirations, and more importantly be able to communicate those goals in a way that allows the mentoring relationship to flourish. As the mentor meets these goals, on behalf of the student, what is simultaneously taking place is the leadership development of the mentor. By serving the next generation of engineers, the mentor also serves the engineering community by becoming a leader and practicing the skills that prepare them to be among the next group of decision makers.

Andragogy: Self-directed learning

The second mentoring course introduces the concept of self-directed learning. Mentors are informed about the distinction between pedagogic and andragogic learning approaches.[15] The mentor is asked to reflect on everyday engineering practices, which emphasize the REP's ability to identifying and understanding engineering challenges, whose identity and solutions are not often found in textbooks. Introspective exercises, compel the mentor to recall the importance of the engineer's ability to synthesize solutions from the knowledge they have amassed over the length of their cumulative educational and professional experiences. These engineering character traits are visited and revisited from the perspective of self-directed learning. As the mentor progresses through the exercises, their ability to communicate the benefits of engaging said challenges benefits the rising engineers, while simultaneously serving as a thought-experiment in the mentor's leadership development. Mentors are provided with a rubric and encouraged to apply the andragogy learning process with UES. The andragogy iterative-learning model is used with a variety of students (and peers) as they develop their own skills via self-directed learning. The benefits to the mentor are the gains in analytical and problem-solving skills, from the purview of how the andragogy rubric affects the growth of others.

The emphatic message conveyed, is that the mentor "manages" the learning of others (andragogy) rather than prescribing what and how their learning should take place (pedagogy). Exercises are designed to help the mentor practice how to help others identify their values, abilities, short-comings, etc. en route to determining their short- and long-term goals. Developing the mentor's ability to help others recognize their own values and skills, helps the mentor understand the potential contributions possible by individuals.

As the mentor proceed through exercises that compel them to identify resources for their students, the mentor is tracking those resources for future, similar situations. The resulting library of resources the mentor accumulates, not only during the mentoring courses but beyond, serves as a repository of knowledge that serves future UES and the myriad of REPs under the leadership of this individual.

The mentor participating in the second course emerges as a leader with a strong sense of the activities they can undertake in fulfilling the success of others. The REP possesses a solid foundation upon which their professional career will grow, while manage the rise and success of others in the field. Table 1 describes three key concepts contemplated in course one that promote mentor learning on their path to becoming the leader and decision maker in their engineering field.

Table 1. A leader's consideration in promoting the success of others

Mentor role expectations

- Maintain **conditions** that allow **free** and informal **choices** by student
- **Help** student achieve **internal commitment** to **new learning**
    - Intrinsic vs. extrinsic motivation
- Build effective **support system**
    - Identify people, resources, professional and social cultural support

At the conclusion of the second course, the mentor has gained the tools to communicate to UES the benefits of self-directed learning. The mentor is fit to share their understanding of why engineers are life-long learners, as a consequence of the challenges that engineers face every day. The mentor has acquired the self-confidence to know that they can help others identify their strengths, and in so doing bring teams of people together to overcome engineering challenges. Once serving as engineering community leaders, mentors are able to lead others to embrace a mindset of discovery, innovation, and learning that promotes community success.

Leadership development

The final mentoring course takes the newly-discovered leader on a journey of introspection. This course is by far the least prescriptive and most onerous of the leader. The first reflection welcomes the REP to their new role, and warns about the limitations of leadership. The leader is confronted with the reality that leadership is a two-way, fragile relationship between those leading and those following. Once again, the leader is asked to reflect on their personal and professional values, to determine which leadership characteristics they will exercise in guiding others to success. Several leadership styles are explored to distinguish among popular styles in practice today: transactional, transformative, servant, autocratic, etc. Additional exercises compel the mentors to reflect on their personal characteristics, abilities and aspirations, to gain an understanding about their leadership role in the engineering field. The leader is guided through exercises about communicating with differing personalities on a team. The importance of shared values among teammates are discussed at length, to equip the leader with the language, cultural, and professional sensitivities necessary to create cohesive, productive teams. Other concepts shared with the leader touch on the topics of navigating restrictive "can't do" attitudes, how to challenge the status quo, the advantages of taking calculated risk, and encouraging a team attitude of "what could be". These exercises empower the

leader to welcome each team member's personality as a positive contribution to the overall team success, while leveraging the attributes of each member to build on those of others.

The culmination of course three is the REP's transformation and confirmation as a leader and decision maker in the engineering field. Each of the exercises, compels the leader to reflect on the myriad of decision they make every day, as human beings and practicing engineers. Reflection on the congruencies between these everyday decisions and the decisions conducted in engineering leadership roles demonstrate that the REP did not experience a quantum jump in skills from night to day, but that the skills were acquired slowly through the relationships forged as early as first making contact with a UES.

Discussion

The mentoring courses described deliver a stackable set of digital badges that build on one another to serve REPs who wish to mentor UES. To best serve those mentors, each module provides a "road map" based on accepted best-practices, that mentors can follow to develop a mentoring relationship with UES. The courses serve a secondary goal of preparing the mentors to become the leaders of the engineering field, by incorporating the leadership skills necessary in the workforce into how they carry out their mentoring efforts.

Because the mentor strives to meet the goals of the engineering students, it is imperative that they understand where the students are coming from and where they want to go. This information is easily gathered once a mentoring relationship, formed on the basis of trust, has developed and open communication ensues. This is the same level of communication that engineering leadership has to have with team members in order to have successful engineering projects. As the mentor gains confidence in their communication skills and their ability to learn from students about their values, goals, and aspirations, the mentor is able to transfer these valuable skills from the mentoring relationship to the professional environment. Course one covers an array of best-practices for mentors that equip new and veteran mentors with skills not only culminating in successful mentoring outcomes for engineering students, but can be transferred to the professional space in promoting the success of REPs at all levels.

Development of a more formal understanding of how and why adults learn, provides an additional set of skills that the mentor can implement in promoting the success of others. Since the engineering field is often unclear when it comes to the details of a new engineering problem and what the right approach to solving it may be, it is imperative to articulate an attitude of *creating* solutions over one of finding solutions. This attitude implies that where no solution previously exists the engineer must bear the task of self-directed learning to first understand the complexity of the engineering challenge then create solutions that might help address the challenges before them. The andragogy model provides the mentor with a seven-step rubric to walk through the paces with a student, so that they iteratively learn and test their knowledge to edge closer to a solution. The same iterative process is that applied in a professional setting to motivate the personal and professional growth of team members as they contribute to successfully meeting the challenges of an engineering problem. One can observe that by providing the mentor with the andragogy model the mentor gains the knowledge of how to help adult students and professional collaborators learn the skills to rise to a higher level of success.

The culmination of developing the REP through the stacked courses is capped with recognition via a micro-credential awarded the mentor. With the perspective of the first two courses completed, the third course focuses on communicating the transformation of the mentor from an altruist to a leader and decision maker in the engineering field. As the mentor reflects on their personal and professional character and values, they are able to recognize that their professional contribution is founded on the success they facilitate in others. The mentor's ability to create situations for success is based on the decisions they practice every day. The confidence instilled in the mentor, turned leader, offers them the ability to step up and be recognized as an individual with whom decisions can be trusted. The progression from building relationships founded on trust with UES proves transformative for both parties, whether in the academic or professional setting.

Conclusions

Industry partners expect that graduating engineers be ready to enter the workforce ready to keep up with the dynamic demands of the engineering field. The proposed extracurricular adoption of mentors to engineering education serves the needs of industry partners, because the mentors offer first-hand, front-line exposure to the quickly evolving demands of engineering challenges. However, industry feedback informs us that mentors are not always provided with formal training, so we developed a curriculum that provides a road map that mentors can follow when engaging with engineering students. The road maps provided in each of three mentoring courses advocate the idea of relationship building, founded on trust, to promote the success of UES into the engineering profession. We recognize that the skills shared with the mentors reflect the leaderships skills the mentor will use as they become the leaders and decision makers of the engineering field. By offering the micro-credential, recognizing the leadership readiness of mentors who undertake the prescribed curriculum, the engineering fields benefit twofold in preparing graduating engineers for the demands and expectations as they enter the profession, and by meeting the workforce demands of preparing the next generation of leadership and decision makers from within the rising engineering professionals.

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