2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34901

Leadership in Engineering Innovation and Entrepreneurship

Dr. Peter Golding P.E., University of Texas at El Paso

Professor in the Department of Engineering Education and Leadership. Director of the Center for Research in Engineering and Technology Education at the University of Texas at El Paso

Dr. Scott A. Starks P.E., University of Texas at El Paso

Dr. Starks is a Professor of Engineering Leadership at the University of Texas at El Paso. He received the Ph.D. in Electrical Engineering from Rice University in 1978 and is a registered Professional Engineer.

Dr. Roger V. Gonzalez P.E., University of Texas at El Paso

Roger V. Gonzalez, Ph.D., P.E., is the Director of the Leadership Engineering program for the College of Engineering and Professor and Chair of Engineering Education and Leadership. Dr. Gonzalez earned a B.S. in Mechanical Engineering in 1986 from UTEP. He earned his M.S. in Biomedical Engineering and Ph.D. in Mechanical Engineering from The University of Texas at Austin and was a Post-Doctoral Fellow and the premier Rehabilitation Institute of Chicago and Northwestern Medical School. Professor Gonzalez has been recognized for scholarly work, education innovation and socio-entrepreneurial humanitarian efforts. He is known and respected for actively incorporating students into all three of these areas.

Among many highlights of his scholarly work, he was awarded a prestigious National Institutes of Health (NIH) National Research Service Award for his work in neuromuscular control and musculoskeletal biomechanics on children with juvenile rheumatoid arthritis. Dr. Gonzalez's scholarly work includes over 100 publications in journals and conference proceedings many of which are co-authored with his students.

For his efforts and innovation in engineering education Dr. Gonzalez has received the American Society of Engineering Educators (ASEE) Teaching Award, the Minnie Stevens Piper Foundation Award, and LeTourneau University's top research and scholarship award. He was also a Finalist for the IEEE Global Humanitarian Engineer of the Year award in 2013. He serves as an engineering program evaluator for the Accrediting Board for Engineering and Technology (ABET), the sole entity for accrediting engineering programs in the United States.

Dr. Gonzalez is Founder and President of LIMBS International (www.limbs.org), a 501(c)3 non-profit humanitarian organization that designs, creates and deploys prosthetic devices to transform the lives of amputees in the developing world by restoring their ability to walk. Since its founding in 2004, the LIMBS Knee has helped over one thousand amputees in almost 50 countries on four continents.

Dr. Meagan R. Kendall, University of Texas at El Paso

An Assistant Professor at The University of Texas at El Paso, Dr. Meagan R. Kendall is helping develop a new Engineering Leadership Program to enable students to bridge the gap between traditional engineering education and what they will really experience in industry. With a background in both engineering education and design thinking, her research focuses on how Hispanic students develop an identity as an engineer, methods for enhancing student motivation, and methods for involving students in curriculum development and teaching through Peer Designed Instruction.

Dr. David G. Novick, University of Texas at El Paso

David G. Novick, Mike Loya Distinguished Chair in Engineering and Professor of Engineering Education and Leadership, earned his J.D.at Harvard University in 1977 and his Ph.D. in Computer and Information Science at the University of Oregon in 1988. Before coming to UTEP he was on the faculty of the Department of Computer Science and Engineering at the Oregon Graduate Institute and then Director of Research at the European Institute of Cognitive Sciences and Engineering. At UTEP he has served in a number of positions including as Chair of the Department of Computer Science, Associate Provost, Associate Dean of Engineering for Graduate Studies and Research, and co-director of the Mike Loya

Center for Innovation and Commerce. His research focuses on college-level engineering education for entrepreneurship and leadership. He has authored or co-authored over 135 refereed publications and over $16 million in funded grant proposals.

Dr. Cole Hatfield Joslyn, University of Texas at El Paso

Cole Joslyn is an Assistant Professor of Practice in the Department of Engineering Education and Leadership at The University of Texas at El Paso. His research emphasizes humanizing engineering education, particularly 1) increasing Latinx students' sense of belonging in engineering by a) integrating holistic, socio-culturally responsive practices and Latinx cultural assets and values into educational success strategies, and b) understanding how Latinx students experience values conflicts and exploring how to help them reconcile those conflicts; 3) promoting student growth/development in multiple dimensions; and 4) reconciling the social and technical nature of engineering.

Leadership in Engineering Innovation and Entrepreneurship

Abstract

The establishment of an innovation, entrepreneurship, and leadership engineering undergraduate program at a university is shared. The development timeline began at The University of Texas at El Paso (UTEP) in 2007 and culminated in its inception in 2015. Five years of implementation and continuous quality improvement following the inauguration culminated with ABET accreditation in summer 2020.

The degree plan features a four-year spiral curriculum. There is an iterative revisiting of engineering topics, innovation and entrepreneurship subjects, business acumen, and leadership engineering themes throughout the courses. The first year introduces core concepts in design, innovation, and entrepreneurship, the second year brings engineering modeling and simulations, and measurements to incorporate technical engineering practices, the third year focuses on entrepreneurship, people, and products, and the capstone year drives innovation in practice, through culminating team-driven projects.

The concept of "leadership engineering" was first coined in 2011. The development of the plans for a new generation degree program offering proceeded through 2013 when the proposal for establishment passed procedurally through the university and our state public university system. The original proposal of "Leadership Engineering" was requested to be adapted to be titled "Engineering Leadership" on the basis that it aligned with conservative generally accepted norms for "Engineering Management." Now coined the E-LEAD degree program, it is the first of a kind undergraduate degree in the US. The degree offering was ratified and approved by the Texas Higher Education Coordinating Board in October 2014. The first students began undertaking technical engineering courses at the university, taught within conventional engineering disciplinary departments, during 2013. By achieving this head start and completing inaugural groundbreaking special topics classes in leadership engineering subjects in 2014, we celebrated our first cohort of students graduating in May 2017. We have since achieved a further four major milestone graduating cohorts; May 2018, 2019, virtually in May 2020, with the fifth and latest in May 2021. In total, we have graduated 51 students, with the majority (26) being women. The degree program has proceeded through three iterations, updating courses, emphases, and aligning pre-requisites, and refining course outcomes during this period.

During pioneering the student-centric program, several innovations in teaching methods and curriculum proceeded. Teaching methods and pedagogical approaches used at Olin College are adapted to teach engineering innovation, entrepreneurship and leadership. The resulting program has a unique character, emphasizing small cohorts engaged in learning within a hands-on project-based studio environment. Improvements have been made by partnering with businesses and industries, including Boeing Corporation, Halliburton, and Lockheed Martin.

Entrepreneurship Education as an Innovation in Context

The first topic we wrestled with at an innovative teaching preparatory program of the Whitman School of Management at Syracuse University in Fall 2003 was "Is Entrepreneurship a Discipline?" A fiery discussion ensued at the Teaching Experiential Entrepreneurship and Emerging Enterprises Bootcamp, led by renowned entrepreneurship educator Dr. Michael Morris, held at the Whitman School of Management at Syracuse University. Nichols and Armstrong analyzed the subject in the context of engineering education: "Engineering Entrepreneurship: Does Entrepreneurship Have a Role in Engineering Education?" [1]. Croci [2] reframed this question in terms of a research discipline in 2016, and Weilerstein and Byers laid out the engineering education challenges in a guest editorial in Advances in Engineering Education in the Winter of 2016 [3], (quote):

> "The challenge now is to change engineering education to match the changes in the world at large. The innovation economy requires a new approach to preparing engineers, one that builds on and reinforces deep technical knowledge and analytical techniques while also equipping engineering graduates with the skills to be creative, empathetic, adaptable, and to have the ability to recognize and act on opportunities. It is no longer sufficient to be technically qualified; to succeed engineers must be prepared to understand the business context of decisions and contribute to, if not lead, the success of the organizations they join. Key skills now include effectively working on interdisciplinary teams, communicating ideas, thinking critically, understanding business basics, and being comfortable with solving open-ended problems."

At UTEP, we were busy working on this challenge of incorporating entrepreneurship and innovation into engineering education, beginning in 2007 and proposing and then implementing an innovative Bachelor of Science degree program that commenced formerly in 2015. UTEP's goal was to plan, pioneer, and establish a new undergraduate program in Leadership Engineering [4], [5].

The overarching program goal is the graduation of a new pedigree of qualified engineers with professional skills, business acumen, and strategic foresight, in addition to engineering prowess, to meet the needs of industry in the 21st century. Following the recommendation from James Duderstadt's "Engineering for a Changing World" [6], we proposed a new paradigm for the education of the engineering leaders of the 21st century. Duderstadt provided a roadmap to the future of engineering practice, research and education. Dr. James Duderstadt's report, published in 2008, was part of the Millennium Project at The University of Michigan.

The Duderstadt model mirrors the medical school training model credited with propelling advancement in medical practice during the last century [7], where the Bachelor of Science degree includes a broad-based curriculum of engineering design, entrepreneurship, business acumen, project management, technology, ingenuity, and innovation, professional communication, ethics, and social sciences. We anticipated a significant fraction of the proposed Leadership Engineering program graduates to pursue professional graduate degrees in various engineering fields. Through a curriculum that provides a framework for building successful

businesses, we expected students graduating from the program would enter the booming technology services sector or start their own innovative companies. Finally, we proposed graduates of the Leadership Engineering program serve as leading engineering educators in the K-12 sector or for further graduate preparation in the expanding field of engineering education.

Degree Inauguration Process and Timeline

The establishment of the innovative degree program proceeded in three periods. From commencement through to the 2016 catalog, the first period involved the testing and inauguration, including practicing Olin adoptions and adaptations of several courses. The first two tracks established were business and education.

With the introduction of sequences in our 2017 catalog, the second period followed to provide students scaffolding and guidance in technical engineering coursework pathways: in topical areas such as biomedical engineering, computer sciences, mechanics, and materials science and engineering.

The third and latest development period began in earnest in fall 2019; it includes further improvement and specification of options and clarifying pre-requisite and degree program coursework pathways. Progress further includes ABET accreditation, aligned with the university's existing, regular ABET program process. Further initiatives include changes and improvements in the curriculum offerings, including business engineering, ethics, finance, innovation and technology, and entrepreneurship practices.

The program has gained in status and function. All student two-semester senior capstone experiences are industry-partner funded. The professionally prepared student graduates are into US STEM international industries, graduate schools, and government.

Request for Planning Authority – 2009

The request for preliminary planning authority for a Bachelor of Science in Leadership Engineering focused on entrepreneurship, innovation and leadership, was submitted in 2009, following broad consultations with academic and industry leaders. Leading US technology companies were engaged in supporting the UTEP undergraduate degree program, including AT&T, Boeing, Bull Ventures, Dow Chemical, General Electric, Halliburton, IBM, Lockheed Martin, Millennium Management, Peabody Energy, Proctor & Gamble, Raytheon, Rockwell Collins, and Shell. Additionally, insights were provided during 2009 and 2010 by thought leaders in engineering education, notably Dr. Kamyar Haghighi at Purdue University and Dr. Hayden Griffen at Virginia Tech, as well as with entrepreneurship and innovation leaders at the University of Calfornia – Berkeley, Union College, the University of Michigan, the University of North Carolina, and Stanford University. We involved both industry and engineering education thought leaders, as we were planning to transition the new program from our Center for Research in Engineering Technology & Education (CREaTE), where it was incubated, into a unique interdisciplinary department unifying engineering education, innovation, entrepreneurship and leadership engineering studies, teaching, and research.

Engineering Lecture Series to Promoting Proposal Inputs and Aspirations – 2010

We gained much insight through the hosting of an Engineering Lecture Series [8] that brought renowned speakers to UTEP to share their thoughts on the elements critical to 21st-century engineering education. Further, Dr. Duderstadt provided the keynote at a "Today Engineering Tomorrow" workshop for all faculty and staff in the College of Engineering at UTEP and a panel of engineering sector speakers: engineering education, professional engineering practice, business, and society. The faculty and staff present were engaged in active learning activities that provided all the chance to give input and ideas on a new entrepreneurship/leadership program proposal. The framework of the now so-called undergraduate degree plan in Engineering Innovation and Leadership grew out of these beginnings.

The BSLE degree was proposed to offer a rigorous yet flexible major in Engineering with an in-depth study of leadership in entrepreneurship and innovation and its effect upon engineering and society. The degree's primary educational objective was canvassed as developing engineering leaders who possess transdisciplinary knowledge, business acumen, entrepreneurship, and broad leadership knowledge and can provide themselves and others' leadership. Ultimately, the degree was proposed to better prepare UTEP engineering students for 21st-century workplace demands, which require professional engineering skills, business acumen, and strategic foresight. We consider Engineering Innovation and Leadership (EIL, or as we commonly refer to it as E-Lead) as a pioneering sub-field within engineering studies. Much like computer science was about 50-years ago or biomedical engineering was 25-years ago, E-Lead is at the forefront of a new sub-field of engineering. It is emerging as a direct result of the industry's immediate and long-term need for a new kind of engineer: one with excellent communication skills, business acumen, and leadership abilities. We postulated that the need for such engineers is arising for many reasons. Rapid engineering advances in the 21st century have led to scientific, medical, and technological breakthroughs requiring engineers to work on multidisciplinary teams and develop broad, interdisciplinary knowledge. Advances in information technologies have also caused industries to emphasize service systems, which require engineers to understand business management and marketing strategies. Pressing social and global problems needs engineers to better communicate with government officials and others about their work's complex social, economic, and political constraints.

Despite industry needs for engineers with these competencies, few educational institutions foster the 21st-century skills engineers need. As a result, some industries (e.g., AT&T) have resorted to forming leadership training "universities" to fill workplace needs. In contrast, others (e.g., IBM) have advocated that universities create new degree programs to better prepare students for industry positions. However, to develop engineers with 21st-century competencies, engineering programs must radically redesign their curricula since many 21st-century competencies require training in traditionally liberal arts-oriented fields. Developing such competencies is vitally important. For, as Halliburton Energy Services' President and CEO David Lesar asserted, engineers lacking 21st-century competencies will be unable to move into senior leadership positions within organizations [8]. Such assertions have been supported by National Science Foundation data, suggesting that engineers who have master's degrees in fields other than engineering are more likely to become senior managers [9]. Engineers seeking to

advance to management positions within companies will need a much broader, more liberal arts-oriented background than most engineering programs currently offer to students. The E-Lead program at the UTEP provides "liberal and entrepreneurial thinking education" within a highly structured engineering program.

Student Interest -- 2011

Early student interest in an E-Lead degree was canvassed in 2011, through a survey of 465 UTEP engineering students, 43% indicated an interest in entrepreneurship, innovation, and leadership studies, and 71% showed an interest in using entrepreneurship, design, and leadership coursework as documentation for employers and graduate schools. A 2012 survey of 45 high school seniors in each area's three largest school districts, 112 first-year engineering students, and 28 engineering seniors also revealed strong student support for an E-Lead style degree program. 98% of the high school seniors surveyed indicated they would be "likely" or "very likely" to choose the proposed plan as their field of study.

Similarly, 71% of UTEP engineering freshmen surveyed indicated they would be "likely" or "very likely" to choose the proposed E-Lead program, and 36% of graduating engineering seniors indicated that they would be "likely" or "very likely" to select the program. In 2012, we led a Hispanic Engineering Institute (HELI) for engineering students at UTEP, anticipating that about 35 students would apply to the proposed program. After that, it seemed feasible that about 20 new full-time and 5 new part-time students would enter the program each year.

Programmatic Design – 2013

As we advanced our design in 2013, our proposed vision was for the Bachelor of Science in Leadership Engineering (BSLE) degree to differentiate it from management studies at UTEP. We also envisioned the degree as an initial step toward wide-scale engineering educational reform, which organizations such as ABET, the National Academy of Engineering (NAE), the Carnegie Foundation for the Advancement of Teaching, and the National Science Board (NSB) have called for since 1996, summarized by Lattuca et al. [10]. Our primary objective of the proposed E-Lead program was to produce graduates with a strong sense of values, think critically and differently – attributes of entrepreneurs and innovators, and make connections contextually and transdisciplinary. We imagined our graduates becoming critical thinkers and problem solvers with the creativity, entrepreneurship mindset, and ambition to seek challenging appointments and fast-paced self-started companies or corporate environments. The graduates we proposed would become renowned for their contributions to the nation's workforce need for engineering leaders. Samuel Florman, the author of *The Existential Pleasures of Engineering* and *The Introspective Engineer*, stated it pointedly: "We live in a technological age, and if our society is to flourish, many of our leaders should be engineers, and many of our engineers should be leaders" [11].

Programmatic Student Outcomes

The new degree has nine student outcomes, seven of which are the typical outcomes expected in engineering degrees, the eighth and ninth focused on innovation and

entrepreneurship qualities, being: (8) An ability to recognize leadership issues and apply leadership principles, and (9) An ability to recognize the need for and to apply business acumen in an engineering context. The evaluation of these outcomes has now proceeded across five years, culminating in ABET accreditation, awarded in July 2020. Student outcomes are correlated with Program Educational Objectives through a mapping established to provide concrete evaluations.

The program uses a direct course assessment approach for student outcomes. Firstly, the faculty review the curriculum to determine which student outcomes are developed in each of the required engineering innovation and leadership courses. Second, the faculty identify the specific courses needed where individual student outcomes are formally assessed. Then, results of student outcome performance data are aggregated across multiple courses to achieve meaningful results. The assessment processes adopted are driven by data based upon student performance on exam questions/problems, oral presentations, written reports, media, and other means that individual faculty members consider relevant and appropriate for their courses. In short, our instructional team develops and cultivates student outcomes through instructional activities within courses, assessing achievement of student outcomes using rubrics and metrics. Cumulatively, the assessment process results for individual courses are aggregated to provide insight into student learning and success in achieving student outcomes.

Our first version of the curriculum was designed around four programmatic objectives: (a) General education requirements, (b) ABET engineering criteria, (c) substantive leadership in business acumen (entrepreneurship and innovation), and (d) providing 12-semester credit hours in specialized coursework concentrations (that we at first called "tracks"). To meet these objectives, we divided the suggested 125-credit hour degree into the following bin requirements: (1) A general education UTEP core curriculum (42 credit hours), (2) Required math, science, and engineering courses (59 credit hours), (3) Upper-division math and science electives (3 credit hours), (4) Upper engineering electives (9 credit hours), and (5) Concentration (so-called track electives) (12 credit hours). The degree plan included professional practice courses to emphasize experiential learning. We included two 1-semester credit hour summer internships, primarily for students to complete in sophomore and junior years. These internships, requiring 240 hours of practicum, were formed to support practice-based, professional community service beyond the traditional classroom experiences.

Innovation and Entrepreneurship Courses

Fostering entrepreneurship and entrepreneurial thinking in students is integral to the program's culture and is highlighted as an essential part of the curriculum in our UTEP catalog. We are currently considering a curricular revision to provide a more holistic approach to integrating entrepreneurial thinking throughout the curriculum. As a result, we expect to have more opportunities to assess the related competencies critical for developing entrepreneurism in our students.

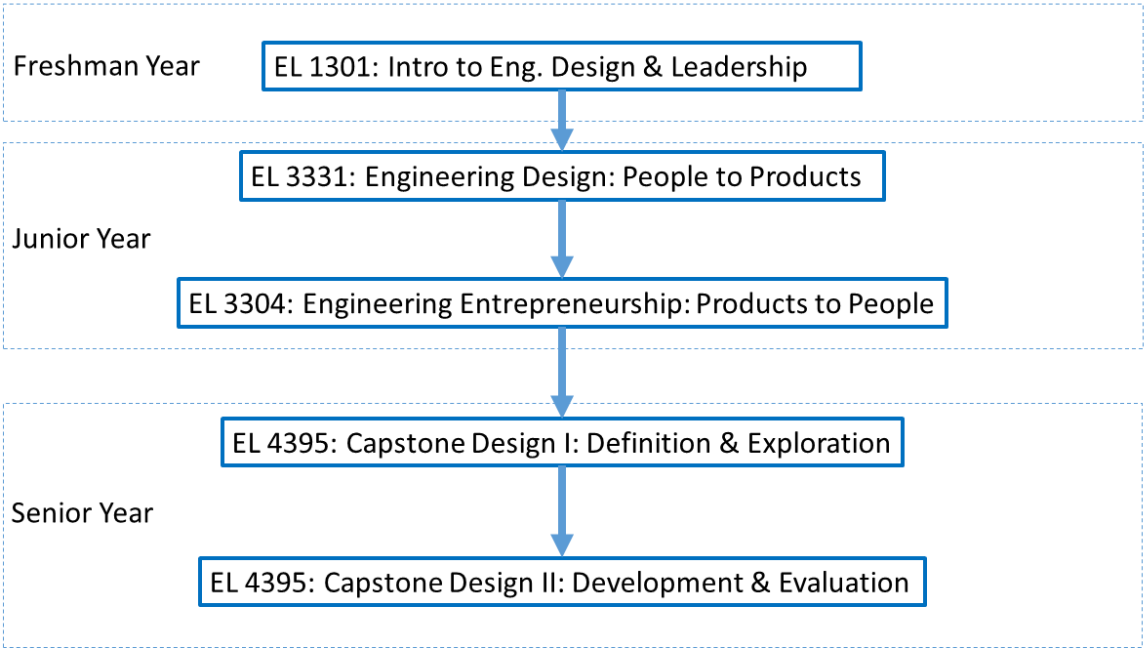

Figure 1. The main engineering design stream courses in the program.

Enrolled students complete the central engineering and entrepreneurship design stream. A summary of each of these courses is provided below.

EL 1302 Introduction to Engineering Design and Leadership: In this course, nature is an important source of inspiration and understanding. Nature is employed as a theme to develop bio-inspired ideas that can be transformed into functional prototypes. Emphasis is placed on the general principles and methods that shape the practice of engineering design. Students complete both individual and team projects in a studio environment to develop a shared approach and understanding of engineering design. They also gain visualization, experimentation, estimation, fabrication, and presentation skills related to the engineering design process.

EL 3331 Engineering Design: People to Products: This course is the first in a two-course sequence in Engineering Design and Entrepreneurship required for all Engineering Leadership majors. It is intended to present students with an opportunity to experience the human-centered design process from start to finish. In this course, students learn a variety of critical tools and techniques of engineering design. These techniques are applied iteratively to deliver a final product. User groups are engaged throughout the process. The course is intended to develop students' ability to function as a leader and as a high-performance team member using Scrum methodologies.

EL 3304 Engineering Entrepreneurship: Products to People: This course is the second in the two-course sequence on Design and Entrepreneurship required in the B.SBS

Engineering Leadership. It is intended to allow students to experience the commercialization process from start to finish in a single semester. Students will go from a functional prototype to an advanced prototype and a business model that prepares them for a go/no-go decision in teams. It requires students to conduct empirical experiments through interviews with people in the start-up's ecosystem, recognize the impacts of the start-up on the ecosystem, (re-)design the product based on their findings, and analyses function effectively on teams.

EL 4395 Design Capstone I: Definition & Exploration: This course is the first of a two-semester Capstone Design sequence in Engineering Leadership. Particular focus is placed on defining (specifying) and exploring (ideation) various project designs in which engineering leadership skills are applied to build a cohesive team. Industrial involvement is critical in this course. All projects emanate from industrial partners who help mentor students through the engineering design process.

EL 4396 Design Capstone II: Development & Evaluation: This course is the second semester of a two-semester Design experience in Engineering Leadership. Preparing and implementing a project design in which leadership engineering skills are applied is of prime importance in this course. Leadership engineering skills are applied to contribute to building a cohesive team. Industrial mentors are utilized to guide teams of students to the successful implementation of a real-world project.

A typical Design Capstone project is conducted by a team of three to six students. It consists of a substantial engineering project for an external industry, government, or community partner to give each student valuable exposure to all of the current engineering marketplace's challenges. The project objective is to produce useful engineering results on an authentic, open-ended project to the sponsor's satisfaction within time and budget constraints. Capstone design projects come from engineering companies and other organizations. They are linked to customer needs, requiring customer segmentation, and budgetary constraints, requiring economic performance analyses.

Special Topics Transitioned to Dedicated Courses - 2015

Given the significant growing awareness of the program, which had been transitioned through the various administrative processes, and the lengthy time required to achieve Texas Higher Education Coordinating Board (THECB) approval for the degree program to be initiated, students were provided the opportunity to undertake courses in the first instance while enrolled as majors in existing (traditional, undergraduate engineering) disciplines, such as Electrical, Industrial, and Mechanical Engineering at UTEP. The faculty taught students under special topics designation until the degree program was formally inaugurated in October 2015. As a consequence of this process, students graduating in the first cohorts required numerous course substitutions to be undertaken to transfer coursework completed into the new degree plan implementation. Programmatic teaching of the new curriculum was introduced, course-by-course, with all active learning- through-doing in the new curriculum and catalog (2015 being the first catalog year for the degree). Course content and methods were experimentally developed in situ while teaching the first cohorts of students.

Update to Degree Plan -- 2017

In 2017, we updated our degree plan to include concentrations at the behest of our Advisory Board. The rationale is that students could readily select a technical emphasis to complement the core E-Lead courses taught in sequence, one per semester, across four years. The catalog was updated to reflect these changes. In 2019, the UTEP catalog was updated to establish common language usage across the College Engineering (terms such as tracks, emphases, specialties, etc.), confusing persons unfamiliar with the program. These changes are expected as the program moves towards a stable profile.

Other US Innovation and Entrepreneurship Offerings

Programs in entrepreneurship, innovation, and leadership are beginning to blossom in the US. The Technology Entrepreneur Center at the University of Illinois offers studies leading to the Bachelor of Science in Innovation, Leadership, and Engineering Entrepreneurship (ILEE) [13]. The BS in ILEE degree is intended and only offered as a dual degree for current Grainger Engineering students. It seeks to understand better the innovative processes involved in identifying problems and creating, developing, and leading efforts to provide their engineering solutions. The curriculum is based on a sound disciplinary engineering technical core with additional aspects of problem identification and innovation and complex multidisciplinary engineering project management and leadership [13]. The first cohort of 16 students in the Illinois program is discussed by Newell and Varshney [14]. The Illinois program is similar to that pioneered at UTEP in terms of curriculum and experiential learning pedagogies. The UTEP program draws upon teaching approaches used at the Franklin W. Olin College of Engineering [15], [16]. In 2016, the University of Michigan established an Entrepreneurs Leadership Program (ELP). The program isn't an undergraduate degree program [17].

Many universities offer certificate courses in engineering management, engineering leadership, engineering entrepreneurship, and increasingly online offerings; Ohio University and The University of Utah are examples [18], [19]. Rowan University offers a B.SBS in Engineering Entrepreneurship, with the first graduates anticipated in 2023 [20]. Purdue University provides an Engineering Leadership Minor, with one track concentrating on innovation and creativity [21].

Current Status -- 2021

As of 2021, there are presently 5 full-time faculty members in the Department of Engineering Education and Leadership and 145 students enrolled. Student numbers have demonstrated a 3-year doubling time, with 51 students graduated, including ten students who graduated in May 2021. Of the graduates, 26 are women, making this the first program in the UTEP College of Engineering to graduate with women as a majority. Women are underrepresented in STEM and entrepreneurship [22]. A gender-sensitive entrepreneurship education program graduating women in engineering is thus notable. The graduates are all employed or have advanced into graduate schools. Our graduates are sought after by top technology companies, who increasingly recruit them before graduation.

References

[1] S.P. Nichols and N. E. Armstrong, "Engineering Entrepreneurship: Does Entrepreneurship Have a Role in Engineering Education?" IEEE Antennas and Propagation Magazine, vol. 45, no. 1, pp. 134-138, Feb. 2003.

[2] C.L. Croci, "Is Entrepreneurship a Discipline?" (2016). Honors Theses and Capstones. 296, [Online] Available: https://scholars.unh.edu/honors/296 [Accessed: Feb. 08, 2021].

[3] P. Weilerstein and T. Byers, Guest Editorial: "Entrepreneurship and Innovation in Engineering Education," Advances in Engineering Education, pp. 1-9, Winter 2016.

[4] R.T. Schoephoerster and P. Golding, "A New Program in Leadership Engineering," *2010 IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments*, Dublin, Ireland, 2010, pp. 1-17, doi: 10.1109/TEE.2010.5508824.

[5] R.V. Gonzalez, E.Q. Villa, P. Golding, and J. Ramos, "Presenting a New Opportunity for Engineering Students: Introduction of an Undergraduate Degree Plan in Leadership Engineering," T566·Programs in Support of Systems Engineering Education, Technical Program-Systems Engineering Division, Proceedings of the 120th American Society for Engineering Education Annual Conference & Exhibition, Atlanta, GA, June 25, 2013. pp. 23.982.1-23.982.14.

[6] J.J. Duderstadt, "Engineering for a Changing World," (2008) Millenium Project, University of Michigan, Ann Arbor, Michigan, [Online] Available: http://milproj.dc.umich.edu [Accessed: Feb. 12, 2021].

[7] A. Flexner, "Medical Education in the United States and Canada," A Report to the Carnegie Foundation for the Advancement of Teaching, Intro. by H. S. Pritchett, 2009.

[8] "Engineering for the Conceptual Age," UTEP College of Engineering Lecture Series [Online] Available: engineering.utep.edu/engineeringlectureseries [Accessed: Nov. 11, 2020].

[9] C.W. Clough, et al., "The Engineer of 2020: Visions of Engineering in the New Century," Washington D.CDCational Academies Press, 2004, pp 28-29.

[10] L.R. Lattuca, P.T. Terenzini, J.F. Volkwein and G. D. Peterson, "The Changing Face of Engineering Education," Reforming Engineering Education, vol. 36, no. 2, 1996.

[11] S.C. Florman, The Introspective Engineer, New York: Thomas Dunne, St. Martin's Press, 1996.

[12] "Engineering for the Conceptual Age," UTEP College of Engineering Lecture Series [Online] Available: engineering.utep.edu/engineeringlectureseries [Accessed: Nov. 11, 2020].

[13] Innovation, Leadership and Engineering Entrepreneurship (ILEE), BS [Online], Available: http://catalog.illinois.edu/undergraduate/engineering/innovation-leadership-engineering-entrepreneurship-bs/ [Accessed: Mar. 4, 2021].

[14] B. S. Newell and L. R. Varshney, "The first cohort in a new innovation, leadership, and engineering entrepreneurship B. S. degree program," 2017 IEEE Frontiers in Education Conference (FIE), Indianapolis, IN, 2017, pp. 1-6.

[15] D.C. Aragon, P. Golding, R.V. Gonzalez, V. Manno, R.K. Miller, R. Martello, G. Moreno, D. Natera, R.F. O'Brien, R.T. Schoephoerster, M. Sommerville, S. Starks, L.A. Stein, J.D. Stolk, J. Townsend, E.Q. Villa, and I.N. Webb, "Model Collaboration for Advancing Student-Centered Engineering Education," Energizing the Future, IEEE Frontiers in Engineering Education (FIE), Oklahoma City, OK. Oct. 23 – 26, 2013.

[16] P. Golding, R.V. Gonzalez, G. Moreno, R.T. Schoephoerster, S.A. Starks, M. Vaughan, and J. Townsend, "The creation and inauguration of engineering leadership: UTEP and Olin College innovation project," 2015 IEEE Frontiers in Education Conference (FIE), El Paso, TX, USA, 2015, pp. 1-8, doi: 10.1109/FIE.2015.7344095.

[17] Kiely, "Introducing the Entrepreneurs Leadership Program: Where Elite Students Will Shape Their Future, [Online], Available: https://cfe.umich.edu/introducing-the-entrepreneurs-leadership-program-where-elite-students-will-shape-their-future-2/ [Accessed: Mar. 5, 2021].

[18] "Russ College of Engineering and Technology Certificates" [Online], Available: https://www.ohio.edu/engineering/academics/certificates [Accessed: Mar. 5, 2021].

[19] Engineering Entrepreneurship, [Online], Available: https://advising.utah.edu/majors/quick-look/engineering-entrepreneurship.php [Accessed: Mar. 5, 2021].

[20] "BS in Engineering Entrepreneurship," [Online], Available: https://engineering.rowan.edu/programs/exeed/ug-programs/index.html [Accessed: Mar. 5, 2021].

[21] "Engineering Leadership Minor," [Online], Available: https://catalog.purdue.edu/preview_program.php?catoid=7&poid=6423 [Accessed: Mar. 5, 2021].

[22] C. Elliott, C. Mavriplis & H. Anis. "An entrepreneurship education and peer mentoring program for women in STEM: mentors' experiences and perceptions of entrepreneurial self-efficacy and intent." *Int Entrep Manag J* **16,** 43–67 (2020). https://doi.org/10.1007/s11365-019-00624-2.