



Implementation of an Undergraduate Engineering Curriculum to Prepare 21st Century Leaders

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Abstract

We have created a three-year leadership curriculum for undergraduate students enrolled in the Opus College of Engineering at Marquette University - a medium-sized, private, urban, religiously affiliated university. The objectives of this people-focused, technical leadership program are to: (1) develop engineers who are able to address 21st century global challenges; (2) prepare individuals to lead, not only through innovation and technical expertise, but also through their ability to motivate, engage and guide people and organizations who represent the full range of diversity across the human spectrum; and (3) educate and develop the leadership and character of outstanding engineering students, who are able to lead technical teams in solving problems. In this paper, we present curriculum design, early results and recommendations from first year assessment of the program and plans for future programmatic elements and assessment.

Students are accepted into the leadership program during sophomore year. The curriculum is designed to follow an intentional sequence of experiences that meet students' developmental readiness and needs over the three years in the program. In each year, the student cohorts explore one of three themes of the program (leading oneself, leading with others, or leading technology and innovation) through a combination of three formal leadership courses, a variety of experiential learning opportunities, and the completion of a capstone project. Upon completion of the program, students will have a concentration in engineering leadership noted on their transcript.

Formal coursework is designed specifically for undergraduate engineering students. The courses explore topics including: self-awareness and emotional intelligence, leadership styles and theories, servant leadership, team dynamics, motivating and guiding others, diversity in the workplace (cultural, gender, etc.), communication, conflict management, ethical leadership, leading change, leading technology and innovation, market analysis, product development, entrepreneurship, and strategic and financial planning.

A variety of assessment methods were employed in the first year. A pre- and post-test leadership inventory was administered to students to during the first course. Results of this qualitative assessment were analyzed using a rubric developed to measure growth in perceptions and attitudes. In addition, students wrote reflection papers about practical leadership experiences during their industry internships, using the guiding principles and themes of the program to illustrate what they learned. Students also synthesized their observations of industry leaders after shadowing each of two C-Level leaders.

Early results from assessments conducted after the first year in the program indicate students are developing significant self-awareness, building life-long skills and habits that will serve them well as they assume greater leadership responsibility. Early results also indicate the necessity of creating challenging experiences for students to critically examine their personal leadership capacity, skills, values, and awareness in order to foster growth and development. Observing

and reflecting on others' leadership practice is also a valuable process for building awareness of one's own leadership capacity and efficacy.

Introduction

The need for engineers to possess strong leadership skills is documented in countless articles, conference papers and presentations, and opinion pieces. As Hinkle describes: "Engineers need to be influential. At all levels of an organization, engineers should play a significant role in driving innovations that will benefit customers and increase profits."^[1] In addition, the need for engineering students to develop leadership capacity is evidenced by the fact that many institutions are investing time and resources into creating engineering leadership programs for students. Indeed, leadership is articulated as a desired learning outcome for many institutional mission statements.^[2] In spring 2014, the Opus College of Engineering at Marquette University launched *Engineers in the Lead (E-Lead)*, a three-year curricular leadership program for undergraduate students. The purpose of this paper is to outline the intentional development of this program and the lessons learned in the process.

Program background

The objectives of the E-Lead Program at Marquette University - a people-focused, technical leadership program - are to: (1) develop engineers who are able to address 21st century global challenges; (2) prepare individuals to lead, not only through innovation and technical expertise, but also through their ability to motivate, engage and guide people and organizations who represent the full range of diversity across the human spectrum; and (3) educate and develop the leadership and character of outstanding engineering students, who are able to lead technical teams in solving problems. In addition to these objectives, the program is shaped by three guiding principles: guiding change, solving problems, and serving others, and it intentionally draws together three learning contexts: leadership, engineering, and the *Jesuit* tradition of the institution.

Students are accepted into the leadership program during sophomore year. The curriculum is designed to follow an intentional sequence of experiences that meet students' developmental readiness and needs over the three years in the program. In each year, the student cohorts explore one of three themes of the program (leading oneself, leading with others, or leading technology and innovation) through a combination of three formal leadership courses, a variety of experiential learning opportunities, and the completion of a capstone project. Upon completion of the program, students have a concentration in engineering leadership noted on their transcript.

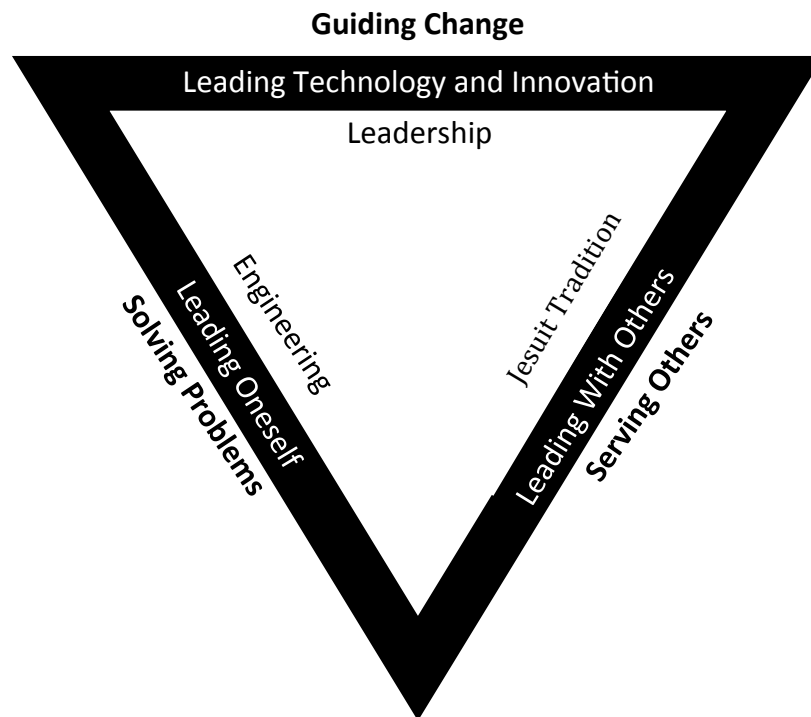
The strategic curricular theme in the first year is *leading oneself*, informed by the notion that leaders must be self-aware, authentic, and have developed a set of professional and leadership skills grounded in emotional intelligence in order to effectively lead *with others*.^[3] In the second year, the curriculum is designed to focus participant learning on *leading with others*, rooted in the understanding that leaders must motivate, empower, listen to, and collaborate with others in order to solve problems and create change. Finally, the theme of the third year, *leading technology and innovation*, articulates that leaders in technical fields create innovative change

because they have technical competence, an entrepreneurial mindset and the skills to strategically lead people to through problem solving.

Formal coursework is designed specifically for undergraduate engineering students and aligns with elements of leadership development concepts offered to professionals in industry. The courses explore topics including: self-awareness and emotional intelligence, leadership styles and theories, leadership and management, leadership and followership, servant leadership, Ignatian leadership, team dynamics, motivating and guiding others, diversity in the workplace (including race, ethnicity, culture, gender, education level, and perspectives), communication, conflict management, ethical leadership, leading change, leading technology and innovation, market analysis, product development, entrepreneurship, and strategic and financial planning.

All courses in the program - theory-based and experiential - draw on the principles, contexts and themes outlined above. Figure 1 illustrates the interconnectedness of these concepts.

Figure 1: Interconnectedness of Guiding Principles, Learning Contexts, and Strategic Themes



Each year of study is designed to build upon the learning outcomes of the previous year. Moreover, as illustrated in Figure 1 above, the overarching leadership paradigm for this program is illustrated using an inverted pyramid in which a group of people shares leadership responsibility in a “more complex, relational, and democratic approach.”^[4] This paradigm is intentionally used as opposed to a “structural, hierarchical, and unidirectional” approach characterized by Rost as the industrial paradigm.^[4]

Figure 2 outlines the curriculum design, including both formal classroom instruction and industry-related experiences required in each year of the program.

Figure 2: Required Curricular Components of Program

Year 1 Leading Oneself	Year 2 Leading With Others	Year 3 Leading Technology and Innovation
<ul style="list-style-type: none"> • Seminar: Leading Oneself • Participate in a national leadership institute 	<ul style="list-style-type: none"> • Seminar: Leading With Others • Professional Engineering Leadership Experience <ul style="list-style-type: none"> • Co-op, internship, research project, or major service project) • Experiential Engineering Leadership Practice <ul style="list-style-type: none"> • Self-guided study of a leadership theory • Shadow two industry leaders for a total of 12 hours 	<ul style="list-style-type: none"> • Seminar: Leading Technology and Innovation • Leadership Capstone Project

Learning outcomes and results

The leadership program is now in its second year of implementation. Twenty students were selected for each of the first cohort and the second cohorts (forty students total). Students apply for the program, and student selection is performed by a group of industry advisors in concert with the program directors. The program is being administered by one faculty director from engineering, one administrative director with education in business and student affairs in higher education, and a graduate teaching assistant in the university's college student personnel degree program. All program administrators team-teach the courses. The student participants originate from all six engineering majors, including biomedical, mechanical, electrical and computer, civil, environmental and construction engineering. Of the forty current participants, nineteen are female and six are non-white.

In the first two years, two of the three formal, one-credit courses have been offered. In these courses, students completed regular reading assignments, reflection papers, large group and small group simulations and discussions, personality profile instruments, and conversations with guest speakers from industry. In the beginning of the first year, students also completed a six-day national leadership program introducing students to visioning, fostering partnerships, integrity, inclusive leadership and achieving results.^[5] The first cohort of students, now in their second year, have participated in required industry internships or cooperative education experiences, and they have shadowed at least two executive leaders in technical industries.

Student learning and leadership development is being assessed through a variety of instruments, including surveys and inventories before and after course completion, reflection papers, observations by program directors, group discussions, one-on-one interviews with course directors, a student-designed portfolio, student presentations, peer evaluations, and student leadership activity in campus organizations.

After the first year, participants are highly engaged, demonstrated by attendance, class participation, completion of assignments, peer review, interviews, and reflection papers. Students have achieved considerable personal growth as evidenced through inventories about perceptions of leadership, expression of personal strengths and attitudes in class discussion and reflection papers, engagement in campus leadership roles, oral presentations in class, and relationships with fellow students in the program.

The first and most robust assessment of student learning, completed in the first year, was in the form of a pre- and post-test leadership inventory administered to students during the first course. Students completed a leadership inventory prior to the first class session and an identical version during the final exam, with a few additional questions added to the instrument gathering feedback about the experiences that had the greatest impact and that challenged them most significantly during the course. During the final exam, they were given a copy of their responses to the original inventory and were asked to discuss how and why their answers changed or stayed the same. Results of this qualitative assessment were analyzed using a rubric developed to measure growth in perceptions and attitudes.

The most notable change was in the complexity of their responses. Seventy-eight percent (n=18) of students in the course demonstrated significant growth or change in the way they define leader and leadership as a result of the first course in the program, *Leading Oneself*. In defining “leader”, student responses shifted from simplistic definitions that viewed leaders as authoritarian figures with the responsibility for command and controlling others to more complex definitions that view leaders as those who have a positive and authentic relationship with and responsibility to those s/he is leading. There is a shift from a focus on the leader to a focus on the relationship the leader has with others. In defining “leadership”, once again the student responses shift from simple to more complex definitions. They started with a focus on the leader him or herself, and moved to an understanding of leadership as a process that must be marked by positive interactions and relationships with others. These are positive findings, given the focus on values-driven, relational and emotionally intelligent leadership in the course.

Students who completed industry internships or co-op experiences were asked to intentionally observe specific leadership values, skills and dispositions in the workplace among individuals, teams and the larger organization. Some of the observations made most frequently by the students after shadowing executives include the ability of the host to think strategically and make quick decisions, the ability of the host to “read” their direct reports and demonstrate emotional intelligence, the ability to listen, and the humility and unassuming character of the hosts. All students commented on the tremendous impact of the shadow visits on their perceptions of leadership. And, the impact was heightened by the initial coursework completed by the students prior to the shadow experience. The coursework intentionally provided the

students with vocabulary, leadership constructs and the framework necessary to observe the leadership traits and habits of another individual.

More robust assessment efforts are currently being developed with the assistance of a team of graduate students in an ongoing effort to capture data about student learning and growth. As we continue to gather this and other data each year from each cohort, we will be able to get a better idea of the particular growth that happens in each year of the program and the growth that students experience over time in their three years of the program. One specific element of our future assessment plan will be to compare perceptions about leadership and leadership practice between the students who have completed this program and students who have been selected randomly from the general engineering student population. Other assessment plans also include tracking the leadership and management roles offered to and assumed by program participants following graduation.

Faculty Support

Fifteen short months after the program launched, faculty in the Opus College of Engineering and in other colleges on campus have provided the program directors with positive and unsolicited feedback. While the feedback to this point is anecdotal, it is significant. For example, one department chair in engineering commented recently that he has noticed radical growth in the leadership capacity and interpersonal skills of the students from his department that are participating in the program. Similarly, the vice provost for undergraduate programs and teaching commented: “I cannot tell you how delighted I am to see this concentration move through the University Board of Undergraduate Studies. I believe you have developed a model that will not only benefit students at Marquette University, but others around the country as other Engineering schools find out, and replicate, what you have created.” Further, deans and faculty in other colleges have inquired about the process used to create this program and to develop the curriculum, with the idea of developing a similar offering in their own colleges directly pertaining to their specific professional context.

Lessons Learned

Although still in the infancy of the implementation of this program, we have learned many lessons to this point in the development of this program and in the process of implementing an engineering leadership curriculum that may be applicable to other institutions and settings. The most important recommendation in designing and implementing this leadership curriculum flows from one overarching theme: it must be intentionally designed for the intended audience. From conceptualization through curriculum design, from the hiring of program staff to the selection of student participants, every step of Marquette University’s E-Lead program development was intentional and that has paid off in literal and figurative terms. This program is funded entirely through the generosity of donors who believe in and embrace the concepts of this program. Industry leaders are supporting this program by giving of their time and talent to share their experiences with participants. Perhaps most importantly, student participants are diving deep into the curriculum and their own lives, committing themselves to personal and collective growth as leaders. The following lessons learned through the intentional development

of this program can be applied at any institution seeking to create a leadership program in an engineering school.

Start with a vision

The desire to develop leadership capacity in engineering students was a vision of the program's current faculty director long before a framework existed for the delivery of the program. This vision was strongly supported by alumni and close industry partners. As the faculty director ascended into a significant leadership role in the college, she was able to inspire others in decision-making positions in the college to share the vision and make the development of this program a priority in the college's strategic plan to invest in people, programs, and places in order to transform engineering education. Support at that level made it a fundraising priority in the college and the first course was offered within one year. That support was essential to the program's development and implementation.

Institutional mission and context

The vision for this program is rooted in the Jesuit mission of the institution, which names "the development of leadership expressed in service to others...for the common benefit of the human community" as one of its four pillars.^[6] In addition, the charisms found in the Jesuit's history value educating the whole person – mind and heart. The call for the type of engineer and leader the university hopes to graduate is clear. As a result, the models of leadership chosen to guide the program and student participants are rooted in this institutional mission. The program's objectives flow from this mission and understanding. Alumni of the college who embrace the institutional mission see these values often absent in industry, particularly in the engineering professions, and are very supportive of the guiding values. All of our industry advisors, many of whom are alumni, strongly emphasize the role of self-awareness and the ability to work with others as central to the program's development of technical leaders. As such, these alumni and advisors are willing to share their time, talent and treasure in supporting this program. Recognizing that not all schools draw on a religious tradition, it is important to note that every institution has a mission and guiding core values. Leadership programs should draw on the values and mission of an institution, organization, and the team implementing the elements of the program. Industry programs are based on the values of a company – undergraduate programs should follow suit and be based in the values of the institution and/or college.

Professional context

Many universities offer leadership minors, concentrations, or co-curricular leadership development programs for students. They may be housed in a college of education, a management program, or the division of student affairs. However, many of these programs do not connect the development of a student's leadership capacity to the professional environment in which s/he will spend most of his/her energy as a leader. Students - especially those in technical fields – are often left to make these connections to their profession on their own, with little or no experience in the industry. In this program, which requires students to complete an engineering internship or co-op and requires students to shadow two different engineering executives, they are intentionally making meaning of their leadership growth over time in an

engineering context. The students in this program have found it to be incredibly relevant and have seen immediate results, including securing internships and co-ops and the ability to be more effective in student organizations and group projects for class.

Engaging industry partners

Industry leaders were critical in supporting the development of this program. In deciding what topics to cover throughout the program, the faculty director met with each of the college departments' industrial advisory boards. At those meetings, industry leaders from over thirty companies shared the values, skills, dispositions and attitudes that they found most important for technical leaders to possess. Common themes and ideas quickly emerged from their recommendations. An advisory board for the program, comprised of engineers, industry leaders and executive coaches that embody the values and leadership practices at the core of the program, assisted the faculty director in sorting through those themes and creating the framework for the program.

This early and intentional engagement of industry leaders resulted in their investment in the program's success. Now, the program is developing young leaders who will enter the workplace with competence in the leadership skills and values sought by the leaders of those companies.

Designing the curriculum

With a framework for the program in place, the faculty director hired a program director with significant experience running college student leadership development programs in the student life area of campus. This blend of the academic and co-curricular aspects of the university environment is a significant asset to this program. The engineering faculty director brings an understanding of the technical environment in which the students will ultimately lead and has significant connections to industry. The student affairs professional brings knowledge of emerging adult psychology and models and theories of leadership development. As a result, the program capitalizes on both an understanding of college student development theory as well as a deep knowledge of the environments in which these students will ultimately be employing the self-awareness, knowledge and leadership skills gained in the program.

The overall program design and the courses themselves reflect this blend of professional and educational leadership development. There are three seminar courses – one in each year of the program – that are centered on the theme for the year: leading oneself, leading with others, and leading technology and innovation. As described earlier, in these courses students read and participate in activities that are building their knowledge, skills and awareness of various theories, models, and practices centered around that theme. In addition, in each year, there are significant experiential elements the students must complete, practicing what they have learned in the classroom. Finally, intentionally built into all elements of the program – classroom and experiential alike – is the practice of regular self-reflection. Not only is this a hallmark of *faith tradition* pedagogy, it is also a critical element of leadership development.^[7]

Scores of books, chapters, articles, essays are written about the framework for curriculum design in a leadership program – both in higher education and corporate settings. Intentionality

matters in designing a curriculum centered on one's program's values, intended outcomes, institutional mission, the intended recipients of the program and ultimate industry context – this makes the curriculum relevant for students.

Measuring impact and effectiveness

As with all things in higher education today, the program's staff understands the need to measure its impact on participants. This is important to not only ensure students are fulfilling intended learning outcomes, but also to provide evidence for current and future program supporters that their investment matters. Assessment efforts will also make it possible to communicate with employers the value that the graduates of this program will bring to their company. Again, intentionality matters in the design of a curricular leadership program when it comes to measurement of outcomes. From the beginning, a program should develop learning outcomes that clearly communicate what the participants will learn through their time and effort in the program. Doing so early on allows for the creation of instruments and measures that will capture student learning during both specific elements of the program and overall.

Participant selection

Is the goal of the program to polish diamonds or press coals? That is the fundamental question guiding the philosophy of selecting students for this program. In other words, are the best and brightest student leaders in the college selected to make them even better, or are students without leadership experience, skills (or confidence in those skills) identified in order to give them a chance to shine? The answer ultimately settled on in this program is that it must be a combination of both.

We have intentionally shaped cohorts that include students from each of the engineering departments in the college. Our selection process has resulted in gender balance and recruiting efforts have been focused on attracting students from diverse backgrounds. We seek to select students who demonstrate a genuine interest in developing their leadership knowledge, values, skills and abilities and not students who simply wish to add a line to their resume.

Every application, which includes a written essay and a resume, is reviewed by at least two members of our industrial advisory board and both program directors. Those reviewers recommend whether or not the applicant should receive an interview. Finalists must then interview with a panel of program staff and current participants. From feedback about these interviews alongside the applicant's written materials, the program staff selects the final twenty participants for that cohort.

Intentional thought behind this philosophy and approach is important to settle prior to the application review process. By doing so, we have been able to shape cohorts that are energetic yet reflective, eager and motivated, diverse in personality, thought and experiences, and above all, genuinely open-minded and interested in growing as a leader.

Student-centered approach

Engineering students face a demanding course load. In the design of this program, the directors were sensitive to academic load, and as a result, created a concentration in engineering leadership rather than a minor. Classes are all offered late Friday afternoons at a time when there no other engineering classes are scheduled, ensuring that accepted students will be able to complete the three-year program by graduation.

In addition, the classroom and indeed, the entire program is treated as a laboratory, where all involved (participants and instructors alike) are seen as teachers and learners. Students are encouraged to try out different leadership styles and approaches, and they even deliver pieces of the curriculum. The students support what they help to create. Their engagement is evidenced by near 100% attendance and participation at events that are all held after 3:00pm on Friday afternoons.

To foster this laboratory environment, the students need to be comfortable with one another. The classroom must be a place where they are able and willing to be vulnerable with one another and open to receiving feedback. As referred to earlier, a weeklong off-campus leadership development retreat, which includes goals related to community building and encourages students to be open with one another, is offered during a university holiday break prior to the start of the first course in the program. This creates the space for students to get to know one another well and fosters a trust-filled and supportive environment in the classroom back on campus.

High-touch mentoring capacity

Mentoring relationships matter in the lives of young adults.^[8] The role of mentors and coaches in leadership development is critical. As a result, the size and structure of a leadership program matters. More specifically, those responsible for teaching and coaching in the program must have the capacity - time, ability and passion - to mentor these young adults in a meaningful way. They must be willing to engage in the gritty reality of life alongside their students as they navigate the challenges and successes that come along the way. Educators – both faculty and student affairs staff - are uniquely poised to engage in the lives of young adults in this way. Yet to fulfill this responsibility with integrity, the instructors and mentors in the program must fully espouse the intentionally selected leadership values and skills taught in the program. Their actions and behaviors must model for students how to act and behave. Congruence between stated values and actions must exist for the program to have legitimacy and efficacy.

In addition, the students must have access to quality mentors in the profession who can help them navigate their emerging leadership journey in the corporate, technical and/or entrepreneurial environment.^[8]

Conclusion

As engineering leadership programs proliferate on college campuses, the need for intentionality in design and delivery of the program is critical. As evidenced through the intentional development of the E-Lead Program at Marquette University, the resulting impact on students can be life and career changing. Programs should start with a vision that is supported by college leadership and industry professionals and root the program in the mission and values of the

hosting institution. The curriculum should be developed with a blend of classroom based and experiential elements, grounded in an understanding of the developmental needs of the intended audience (in this case, college student development theory and emerging adult psychology), and should include ample opportunities for individual and group reflection. Impact of the program should be measured through a student's time in the program and a plan for assessing learning outcomes should be designed and implemented from the beginning. The desired blend of participants should also be articulated at the outset and the participants' needs and ability to contribute to the learning environment should be valued equally with program staff. The program staff should be able to clearly articulate a personal leadership philosophy that is in line with the stated values of the program and as such, their actions and practice should be congruent with these stated values. Finally, the staff should have the capacity to provide a high-touch mentoring environment for student participants. Attention to these items should help campuses develop an engineering leadership program and curriculum that will prepare twenty-first century engineers to guide change, solve problems, and serve others.

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