



Integrating Leadership Education into the Undergraduate Engineering Experience

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Building Undergraduate Engineering Leaders

Abstract

This paper contributes a description of efforts to infuse leadership concepts into undergraduate engineering programs. There is a strong national push for enhancing the undergraduate engineering educational experience. A short overview of the need and current practices is provided. A case study of the Engineering Leadership & Innovation Institute is provided. A detailed concept of operations is provided. The mission is to create a burning desire and confidence to create, innovate, collaborate and deliver world-changing solutions. This mission was developed through a review of other engineering leadership institutes, review of the literature, and guidance from industry. In the Engineering Leadership & Innovation Institute, a concept of operations is being implemented which provides awareness to all students while providing avenues for other students to self-select a deeper understanding. This concept of operations is developed to reinforce key skills (create, innovate, collaborate, and deliver) and support a student's accountabilities for becoming a leader (Learning the Most from Their Engineering Courses, Joining the Journey Expanding Their Resources, Experimenting with Creating and Innovating, Learning from Experiences, Gathering With Other Engineers & Disciplines, Learning from Leaders/Courses, Gaining Work Experiences, Reflecting on Themselves and Their Experiences). This paper provides the foundation for further impact assessment in the future. A person responsible for developing and running an engineering leadership effort can use this paper to identify potential approaches for their institute.

The Need for Leadership Education in Engineering

Engineering colleges are being driven to infuse leadership education into the engineering and computer science fields. The need for engineering leaders is being driven by the many challenges the nation faces (e.g., see the National Academy of Engineering's Grand Challenges 2010; <http://www.engineeringchallenges.org/>). Technology and engineered systems can provide solutions to these challenges. To bring forth these solutions, the nation needs engineering leaders. Many studies have explored the role of engineers and the need to change the educational system to produce these engineers. For example, see

- The Science and Engineering Workforce: Realizing America's Potential¹²
- Educating the Engineer of 2020¹⁴
- Engineering Research and America's Future: Meeting the Challenges of a Global Economy⁵
- The Engineer of 2020 (Parts I and II)⁴
- Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future³
- The National Innovation Initiative¹
- Educating Engineers: Theory, Practice, and Imagination¹⁵
- Moving Forward to Improve Engineering Education¹³
- The Vision for Civil Engineering in 2025²
- Engineering for a Changing World: A Roadmap to the Future of Engineering Practice, Research, and Education⁶.

A common theme across these reports is the need to build worldly leadership and professional skills within the engineering profession. Furthermore, according to Richard Greenwald in his

article “Today's Students Need Leadership Training like Never Before,” in The Chronicle of Higher Education¹⁰, “we are witnessing a growth in, and a new respect for, what we now call leadership studies. This is occurring in part because of the perception, at least, that America is suffering a crisis of leadership.” The educational system needs to produce the leaders who can deliver sustainable solutions to the world’s biggest challenges. Creating these engineers requires a unique educational experience and environment to learn these skills. This paper describes an emerging approach to deliver a new educational experience that infuses leadership concepts into the educational experience of engineering and computer science undergraduates.

Current State of Engineering Leadership Institutes

Many institutions are attempting to infuse leadership into the engineering curriculum. Graham, Crawley, and Mendelsohn⁹ provide a recent overview and review of engineering leadership related institutes and efforts. They also provide an initial list of engineering leadership institutes. From the benchmarks, three conclusions can be drawn. First, the current leadership institutes have an explicit focus or mission. For example, the current institutes are focusing on one or more topics such as entrepreneurship, innovation, or leadership. Second, the current institutes differ in the student populations they serve. For example, the institute may provide a service to all students or to a subset of interested students. Third, current institutes provide a method to help students distinguish themselves to employers. For example, an engineering leadership certificate or minor is being offered to highlight the additional training and experience the students have. The next section of this paper describes how one university is attempting to help students gain these experiences.

Case Study: UCF’s Engineering Leadership & Innovation Institute

The intent of this section is to describe one approach for infusing leadership education into the engineering and computer science fields. In this section the Engineering Leadership & Innovation Institute (eli²) is described. eli² is a college-wide initiative which responds to ABET’s and industry’s call for more well-rounded undergraduate engineering students. eli² is a collection of faculty, courses, programs, and labs. The intent of this case study is to provide a foundation description and understanding of eli². Detailed impact assessment is not yet available. Initial measurements are being developed and gathered.

eli²’s Mission & Goals

To respond to the need for engineering leaders, the University of Central Florida is implementing eli². eli² was initially started in 2006 as a leadership institute funded by Progress Energy. This initial effort provided the foundation to expand and grow from. In 2010 the college started an initiative to enhance the college’s efforts related to engineering leadership education. The result of this effort is eli². The mission of eli² is to:

Help students discover their burning desire and confidence to create, innovate, and collaborate to deliver world-changing solutions.

To deliver world-changing solutions, the eli² program believes the engineering leader needs to know how to create, innovate, collaborate, and deliver. There are many skills within these key competency areas. The specific skills depend on the current career expectations of the students. By students eli² means anyone looking to explore, study, and learn about engineering leadership. Students include: 1) traditional undergraduate students, 2) working professionals returning to the university to pursue an advanced degree, or 3) executives looking to learn with other executives.

eli² aims to create a learning environment and experience where students can discover the desire and confidence to be an engineering leader throughout their career. Our mission covers an engineer's complete career life-cycle. This life-cycle focus is consistent with the Accreditation Board for Engineering and Technology's (ABET) focus on the need for life-long learning⁷. eli² carries the mission across the entire life-cycle of an engineer's career. eli² offers programs unique to each of these three student populations. eli² supports the practicing engineer to become a project manager through a cohort-based professional program leading to a master's of science in engineering management. eli² support executive through communities of practice which provide a forum for executives to share challenges and best practices. This paper provides a detailed description of how eli² intends to support the undergraduate student.

Consistent with the overall eli² mission, at the undergraduate level our goal is to transform the undergraduate engineer into a working professional. A new undergraduate student comes to the university to become a new engineering graduate and professional. eli²'s role is to help transform the students to lead their self and to act as professionals in the corporate environment. At the undergraduate level our focus is to create the engineer who is a professional contributor and to ensure the new undergraduate has the skills and capabilities to hit the ground running and make a difference in the professional workplace on the first day they go to work.

Core Undergraduate Leadership Skills

To define the mission and focus of the institute at the undergraduate level, eli² first begins with the customers and stakeholders. To define customer needs the college's Dean's Industrial Advisory Board was used. The organizations on the board represent the primary employers of the UCF engineering and computer science graduates. To define stakeholder needs ABET was used as a primary stakeholder. ABET works with industry and provides a definition of the core skill needs. The ABET criteria can be parsed into two categories: "be a good engineer" and "be a professional in the workplace". Be a professional in the workplace is the primary focus of eli². ABET input was gathered by reviewing the ABET documents. The Dean's Advisory Board input was gathered through interviews first. These results were then gathered and confirmed with a survey to the Board members.

Table 1 summarizes the input from the Board and ABET. Furthermore, Kim¹¹ and Genco, Holtta-Otto, and Seepersad⁸ point to the need to bring creativity into the engineering curriculum. From these needs, two conclusions are drawn. First, the institute must augment the existing engineering curriculum with creativity, innovation, collaboration, and solution delivery skills for all students. Second, the institute must provide a method to help students distinguish themselves to employers (e.g., an engineering leadership certificate or minor).

Table 1

Customer & Stakeholder Needs Identify Core Leadership Skills

Stakeholder	Educational Requirements
UCF CECS Dean's Industrial Advisory Board	<ul style="list-style-type: none"> • Continue producing good, technical engineers • Enhance professional skills • Ensure the students can be productive team members when they come to the job on day 1 • Ensure the students know how to participate in team activities • Provide a way for students to distinguish themselves (e.g., a certificate)
ABET⁷	<p>Be a Good Engineer</p> <ul style="list-style-type: none"> • (a) an ability to apply knowledge of mathematics, science, and engineering • (b) an ability to design and conduct experiments, as well as to analyze and interpret data • (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability • (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice <p>Be a Professional in the Workplace</p> <ul style="list-style-type: none"> • (d) an ability to function on multidisciplinary teams • (e) an ability to identify, formulate, and solve engineering problems • (f) an understanding of professional and ethical responsibility • (g) an ability to communicate effectively • (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context • (i) a recognition of the need for, and an ability to engage in life-long learning • (j) a knowledge of contemporary issues

To be professional contributors and engineering leaders who deliver world-changing solutions, the new engineer needs competencies beyond the core engineering skills. They need competencies to:

- 1) Produce good technical solutions (engineer)
- 2) Generate creative ideas (create)
- 3) Convert ideas to value (innovate)
- 4) Succeed in the corporate environment (collaborate)
- 5) Delivery solutions (solution delivery).

Table 2 provides a more detailed list of the characteristics associated with these five competencies. In addition to the competencies, the student needs to have the attitude to be a leader. The student needs to have the desire and confidence to be proactive, take risks, and be a contributing member of the team. The student needs to bring passion to the game of engineering.

Table 2

Summary of Competencies

Global Outcome	Competencies	Daily Outcomes	Characteristics
To deliver world changing solutions, we need to	Engineer	Be a Good Engineer	Technically Sound
			Appreciates/Values Being an Engineer
	Create	Generates New Ideas	Creative
			Builder
	Innovate	Converts Ideas to Business Value	Innovative
			Entrepreneurial
			Business/Financially Savvy
	Collaborate	Works in a Team as a Professional	Team Player
			Ethical & Trustworthy
			Good Communicator
			Professional
	Deliver Solutions	Brings Solutions	Socially Responsible
			Critical & Systems Thinker
Disciplined			
Connected to and “InSync” with the Project			
			Learner/Reflective Practitioner

Student Responsibilities

In our planning and talking with engineering leaders, the need for the student to make the choice to be a leader was identified. This choice to enhance their skills leads to the students having nine responsibilities proactively grow through:

- 1) **Learning the Most from Their Engineering Courses.** As shown in the industry’s assessment of the skills (see Table 2), being technically sound is the most important skill. The foundation of engineering leadership is being technically sound. The student must ensure they have the required technical background.
- 2) **Joining the Leadership Journey.** The student must make the choice to start the leadership journey. The student makes the choice to explore and participate in the many growth opportunities.
- 3) **Expanding Their Resources.** The student will need to look beyond the typical text book resources. They will need to expand their tool box to include the leadership concepts and tools.
- 4) **Experimenting with Creating and Innovating.** The student should experiment with creating new ideas and turning those ideas into tangible products. The student will learn how to create and innovate through doing.
- 5) **Learning from Experiences.** The student will need to have the opportunity to experience hands on engineering. The student will need to be able to work beyond the problems in the textbook.
- 6) **Gathering With Other Engineers & Disciplines.** Engineering is a social process. Engineering world-changing solution requires a team of many people. The student will need to learn how to work with people with diverse thoughts and concepts.
- 7) **Learning from Leaders/Courses.** The student will need to learn from current leaders. The student will need to learn the lessons learned gained from experienced leaders.

- 8) **Gaining Work Experiences.** The student will need to learn how to work in a corporate setting. This work experience can be obtained through experiences such as co-operative education or internships.
- 9) **Reflect on Themselves and Their Experiences.** The student will need to reflect on their experience and what they have learned. The student will need to define their view of the engineering profession and how they intend to create, innovate, and collaborate to deliver world-changing solutions.

The intent of eli² is to help the student in these nine focus areas.

Undergraduate Educational Objectives

eli² is driven to address a set of educational objectives. These objectives include focus on increase a student's:

- 1) Burning desire to create, innovate, collaborate and deliver world-changing solutions.
- 2) Confidence to create, innovate, collaborate and deliver world-changing solutions.
- 3) Skills to create, innovate, collaborate and deliver world-changing solutions.

The concept of operations is developed to achieve these educational objectives. The impact assessment of these objectives is being developed to measure how well these objectives are being achieved.

Concept of Operations

eli² has designed a concept of operations to offer a program which supports these nine student responsibilities. eli² defined the concept of operations to meet the undergraduate goal and four requirements. The concept of operations provides a high-level description of what the undergraduate student will experience. Table 3 summarizes these program elements.

eli² is attempting to infuse the leadership skills across all disciplines and students. The challenge is that the "leadership" concepts and courses cannot be substituted in for the engineering and technical courses. The eli² concepts are layered into the curriculum through 3 options:

- 1) Infuse into existing courses for awareness
- 2) Make available for general use
- 3) Provide as additional "above and beyond" courses.

Table 3

Summary of eli² Program Elements

Student Role	Role of eli²	Program Elements	Infusion Approach
Learning the Most from Their Engineering Courses	Infuse Concepts Into Courses	<ul style="list-style-type: none"> • Case studies and discussion topics tying leadership concepts into the courses 	<ul style="list-style-type: none"> • Infuse
Joining the Journey	Invitations to the Journey	<ul style="list-style-type: none"> • Specific invite to engineering freshman 	<ul style="list-style-type: none"> • Infuse
Expanding Their Resources	Resources to Apply	<ul style="list-style-type: none"> • Online resources 	<ul style="list-style-type: none"> • Available for all
Experimenting with Creating and Innovating	Places to Experiment In	<ul style="list-style-type: none"> • Gathering lab • Idea/Creativity lab • Innovation lab 	<ul style="list-style-type: none"> • Infuse • Available for all • Course
Learning from Experiences	Experiences to Apply to	<ul style="list-style-type: none"> • Senior design professional skills • Senior design symposium 	<ul style="list-style-type: none"> • Infuse
Gathering With Other Engineers & Disciplines	Places to Gather With	<ul style="list-style-type: none"> • Gathering lab • Social media sites 	<ul style="list-style-type: none"> • Available for all
Learning from Leaders/Courses	Courses to Learn From	<ul style="list-style-type: none"> • Seminar series • Engineering Leadership Minor • Engineering Leadership Certificate • Professional Development Workshops 	<ul style="list-style-type: none"> • Courses
Gaining Work Experiences	Connections to Work Experiences	<ul style="list-style-type: none"> • Connections to career services and professional internship organizations 	<ul style="list-style-type: none"> • Infuse
Reflecting on Themselves and Their Experiences	Tools to Allow Self-Reflection	<ul style="list-style-type: none"> • Professional Practices Self-Reflection Portfolio 	<ul style="list-style-type: none"> • Course

These activities represent the vision for the concept of operations. eli² has many of the elements in place. eli² continues to pilot and learn with the concepts.

Seminar Series. The intent of the seminar series is to provide practical professional development and career advice to students. Specific objectives include: 1) Enhance a student’s desire, confidence, and knowledge to create, innovate, collaborate and deliver world-changing solutions and 2) Enhance a student’s belief that engineering is a noble profession. eli² invites leaders from engineering and technical fields to share their experiences and provide advice on how to be successful and responsible as members of a corporate environment. Each speaker in the series addresses one or more of the core competencies. Student complete a one-page reflection paper for each speaker.

Engineering Leadership Minor & Certificate. The engineering leadership minor and certificate programs are offered to provide students a knowledge base in engineering leadership principles and practices as well as management techniques in a technical environment. The students will take a series of classes covering engineering design, leadership, ethics, and innovation. Both the minor and certificate will end with an engineering leadership capstone course. This capstone course provides the student with an opportunity to develop their view on what it means to be a professional in the workplace. This course is meant to be the final “lessons learned” in their academic career. Both the minor and certificate will be formally recognized on the student’s transcript.

Professional Development Workshops. In addition to the seminar series and certificate, professional development workshops are provided. These workshops provide targeted learning experiences focused on a specific skill. Example workshops could focus on: making professional presentations, professional etiquette, engineering sales, or patent law.

Places to Gather With. To help engineers build relationships with other engineers, spaces for them to gather are provided. Engineering, creativity, innovation, leadership, and solution delivery is a social experience. eli² fosters these social interactions. Both a physical gathering place (i.e., an atrium location) and a virtual gathering place (i.e., a social media tool) are provided.

Senior Design Professional Skills. Each discipline in the college completes some form of a senior design project. The senior design professional skills offering will provide senior design teams with the knowledge and tools for infusing creativity, innovation, collaboration, and solution delivery practices into their senior design efforts. A generalized approach is being developed for all disciplines to use.

Senior Design Symposium. The intent of the senior design symposium is to help our students understand how to share/sell a project. The symposium provides a forum for student teams to share their senior design projects. Both presentations and panels/posters are provided by the students. Students can further understand how to translate the creative and innovative ideas into a sellable story.

Professional Practices Self-Reflection Portfolio. eli² provides students with a professional practices self-reflection portfolio tool. The intent of the tool is to provide students with a capability to:

- Capture and describe professional development experiences (e.g., class projects or work experiences)
- Evaluate the creativity, innovation, collaboration, and solution delivery practices and results from the professional experiences
- Self-reflect on how the student would change (i.e., start, stop, or continue) his/her behavior on the.

When the student is preparing for a job interview they can review this portfolio with prospective employers. Part of the focus of the Engineering Leadership Capstone course within the minor and certificate will focus the student on developing their final portfolio.

Idea/Creativity & Innovation Labs. To help students understand the skills, places where they can do hands-on engineering and build things are provided. They need to have the exposure to hands-on prototype development. “Idea/creativity” and “innovation” labs which will allow students to apply what they are learning in the classroom are being provided.

The idea/creativity lab provides a place for students to learn creativity tools and to use those tools to generate new ideas. The lab will provide an environment that fosters creativity and the materials to capture the novel ideas. A key activity of engineering and innovation is to identify the breakthrough ideas. Students can take the ideas generated in the creativity lab into the

innovation lab. The innovation lab is a space for students to apply their engineering “textbook” lessons to building real-world systems. The innovation lab provides a place for students to experiment and build prototypes. The lab will be introduced in the freshman course and will be available to students to use in the sophomore competition and senior design course. The lab will be outfitted with the latest prototyping equipment such as laser cutters, CNC mills, and 3D printers along with plenty of space to collaborate on projects.

Conclusion

There is an increasing recognition of the need to infuse leadership concepts into the educational experience of engineering students. Many institutions are taking proactive steps in this effort. The intent of this paper was to describe eli²'s goal of transforming the undergraduate engineer. eli²'s mission is to help students discover their burning desire and confidence to create, innovate, and collaborate to deliver world changing solutions. Consistent with this mission eli² engages the engineer across the life-cycle of their professional career.

Based on our initial experience, we offer three recommendations. First, follow a systematic process to translate industry needs into program elements. eli² has followed a systematic process to understand needs, translate these needs to competencies, and develop a program to infuse these competencies. Second, develop the impact assessment model as part of the design process. eli² is also beginning to measure the impact of these program elements. Further works is under developed to implement a more formal impact assessment approach. Third, focus on learning by doing. You can wait to implement a program until all of the pieces are defined or you can begin with a vision, implement, and learn. We have chosen to have a vision and build as we go. eli² is continuing to learn more about infusing leadership in the engineering undergraduate degree. eli² will continue to refine our concept of operations as we learn more from our efforts and from the emerging best practices of other institutions.

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