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A Follow-Up Study of a First-Year Leadership and Service Learning Module

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Ryan Shelby is a joint 2013-2014 Millennium Challenge Corporation-Arizona State University Science and Technology Fellow at the Millennium Challenge Corporation (MCC). His research project at MCC focuses on the design and implementation of microgrids to aid the expansion of modern electricity services in six Sub Saharan African countries: (1) Sierra Leone, (2) Liberia, (3) Ghana, (4) Benin, (5) Tanzania, and (6) Malawi. Prior to his current position at MCC, Shelby was a dual J. Herbert Hollomon and Christine Mirzayan Science & Technology Policy fellow within the National Academy of Engineering (NAE) working on engineering education initiatives and the application of operational system engineering techniques for peace building and diplomacy endeavors in Libya, Kenya, and Haiti. Shelby recently completed his Ph.D. at UC Berkeley in mechanical engineering where he focused on the user needs analysis, co-design and implementation of sustainable homes and energy systems that meets the cultural sovereignty, economic, climate adaptation, and tribal sovereignty needs of Native American tribes in northern California. Shelby received his M.S. in Mechanical Engineering from the University of California, Berkeley with a concentration in design, and his B.S. in Mechanical Engineering from Alabama Agricultural & Mechanical University with a concentration in propulsion systems. Shelby also received certifications for his completion of the Engineering and Business for Sustainability and the Management of Technology programs at UC Berkeley in 2008 and 2010 respectively. Shelby is an ardent supporter of engineering education and community based design research. He has received several awards for his teaching and community partnership activities such as the Center for Research on Social Change Graduate Fellows Award in 2011, the Chancellor's Awards for Public Service, Community Assessment of Renewable Energy and Sustainability-Pinoleville Pomo Nation Partnership in 2010, Outstanding Graduate Student Instructor Award in 2010, and the National Collegiate Inventors and Innovators Alliance's Advanced E-Team Community Assessment of Renewable Energy and Sustainability Award in 2007.

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Dr, Lisa Pruitt's research is focused on structure–property relationships in orthopedic tissues, biomaterials and medical polymers. Her current projects include the assessment of fatigue fracture mechanisms and tribological performance of orthopedic biomaterials, as well as characterization of tissues and associated devices. Surface modifications using plasma chemistry are used to optimize polymers for medical applications. Attention is focused on wear, fatigue, fracture and multiaxial loading. Retrievals of orthopedic implants are characterized to model in vivo degradation and physiological loading. Medical implant analysis for structure-function-performance is performed to optimize device design. Her pedagogical experience includes curriculum development in mechanical engineering and bioengineering. Dr. Pruitt's teaching experience includes the freshman course entitled Introduction to Engineering Design and Analysis, undergraduate courses on Mechanical Behavior Materials, Structural Aspects of Biomaterials, and Principles of Bioengineering; graduate courses on Fracture Mechanics, Mechanical Behavior of Materials, Polymer Engineering, and Teaching Methodologies for Graduate Student Instructors.

A Follow-Up Study of a First-Year Leadership and Service Learning Module

Abstract

A five-week module focusing on leadership and service learning was implemented as part of a first-year engineering course. This module presented mechanisms for developing professional skills and provided hands-on application of these skills through a K-12 service learning project at a science museum. The other modules offered in the course emphasized traditional engineering topics. This longitudinal study focuses on the students from the course as they enter their third year in engineering.

Our previous study demonstrated that incorporating leadership studies into a freshman-level engineering course correlated with increased confidence in students' abilities just after completion of the course, which could positively impact retention. Eighty-seven students from both leadership and non-leadership modules were assessed over one year later using the same online survey based on ABET/National Academy of Engineering (NAE) criteria with additional open-ended questions. Follow-up data reveal that alumni of the leadership module had a significant net increase in confidence in six professional/technical skills and are generally more aware of the role of leadership in engineering. Qualitative comments show these students felt they gained influential early exposure to what a successful engineer needs, and they reported more active leadership roles both on campus and in industry through internships. While increases in confidence did occur for students in the leadership module, decreases in other categories suggest a need for continued professional development in undergraduate engineering education to complement technical competencies addressed during junior and senior years.

Introduction

Professional skills, such as leadership, teamwork, and communication, are necessary qualities in a successful engineer. However, these "soft skills" are often neglected in traditional engineering curricula, despite a strong dependence between professional attributes and engineering educational experiences.[1] Studies have demonstrated how courses that incorporate service learning as a novel pedagogical approach nurture professional skills while integrating design methodologies.[2-6] Furthermore, such teaching models have an enhanced positive impact on women in particular.[7,8] We developed, taught and evaluated the impact of a design module on first-year engineering students that utilized a service learning project in the context of developing both professional and leadership skills.[9,10] Our analysis revealed an increase in students' confidence in both their technical and professional abilities immediately following the leadership module, especially for the women students.[9,10] This study explores the potential impact of this freshman experience through assessment of students' confidence over one year after completion of the course.

Professional Skills

A survey of engineers in academia and industry revealed a gap between engineering education curricula and the skills needed for engineers in a professional environment.[11] Such a gap is evident in many engineering programs, which place a strong emphasis on technical competence but little if any training in non-technical attributes.[12] As a result, students enter industry with limited training in communication, management, leadership, teamwork and other professional skills, and are forced to learn "on the job."[2,11-13] Skills outlined by ABET criteria further reflect the necessity for integrating such attributes in engineering education, including: (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; (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; and (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.[14]

Service Learning

Previous work demonstrates that professional skills can be taught in an engaging and fruitful experience for students.[2,13,15] In particular, service learning projects through real world experience provide innovative grounds for active and cooperative learning that can directly target and nurture these skills.[2,12,16] Service learning integrates classroom learning with community-based service.[17] This provides students with an opportunity to actively utilize their design and engineering skills in a real world experience that is beneficial not only to the students themselves but also to the community and local organizations.[18] Engagement in such experiential learning opportunities encourages students' retention of technical knowledge and exposes them to real life situations that can facilitate the transition from college to industry[3-6,19.] Furthermore, these benefits of service learning are reflected in the ABET criteria (listed above).[20,21]

The National Science Board[22] noted that students "develop little identity as engineers in their first two years of college because they take math and science courses and have little exposure to the engineering practice." First-year courses that incorporate service learning serve to expose students to engineering practice early on, as recommended by the National Research Council, can have a positive influence on the education of young engineers.[7] Studies have demonstrated the implementation and subsequent success of such first-year design or cornerstone courses.[23-25] Moreover, such courses particularly enhance student confidence and retention rates among women and minorities. [13, 14, 23]

Course Format

Engineering Design and Analysis is a freshman-level course that introduces students to the engineering professions through general lecture, modular activities and laboratory projects. The learning objective of the course reflects criteria recommended by the National Academy of Engineering (NAE)[1] and ABET[14]. In our offering of this course, four weeks of general lecture provided an overview of the engineering profession, with a focus on topics of failure analysis, design methodology, human-centered design, engineering in society, leadership and ethics. Students then partook in two sets of five-week modules.

In the Fall of 2010, a 5-week leadership module was incorporated into the freshman engineering design course; it was offered as the mechanical engineering module alongside traditional engineering topics in civil engineering, materials science and industrial engineering. During the Spring of 2011, an "engineering leadership" module was officially offered in addition to traditional engineering modules of bioengineering and mechanical engineering. Each module was taught by a different instructor; the same instructor taught both leadership-focused modules in the spring and fall. Students chose two modules to complete during the semester they were enrolled in the course.

The leadership module focused on professional skill development through weekly lectures and a hands-on K-12 service learning project at a local science museum. This project allowed students to participate in outreach teaching and develop an exhibit activity that would not only demonstrate engineering skills, but also enabled museum visitors to engage with the engineering design process and "real engineers." In essence, students worked with their client, the local science museum, to provide an optimal design for their stakeholders, the museum visitors, which further transferred knowledge of the engineering design process from the student to the public in an interactive exhibit.

Lecture topics covered in the leadership module provided a framework for developing the core competencies of successful leaders[14]. One central theme was the three "C"s of leadership: competence, compassion and chronos (time management). The module offered methods for developing personal and team leadership styles; addressed differences in learning and personality styles; presented pathways for implementing mission statements and plans of action; offered opportunities for strategic thinking, problem solving and brainstorming; utilized teamwork in diverse settings; and implemented K-12 service learning through outreach teaching activities.[9,10]

Students were placed into teams of three to six based on their learning styles[26] to diversify groups and thereby enhance educational perspectives and optimize design outcomes.[27,28] Teams completed three-hour labs at the local science museum each week to conduct brainstorming and prototyping exercises based on the "Engineering is Elementary" design process loop developed by the Museum of Science, Boston (**Figure 1**).[29] In addition, each team independently conducted user needs research through museum exhibit facilitation for two hours per week. This allowed each student to interact directly with K-12 learners and apply the strategies they learned during facilitation to their own exhibit design. At the end of four weeks, teams submitted written reports summarizing their work and gave oral presentations on their research and final exhibit design to museum employees. The professional report asked students to outline their own engineering design process and describe their design in a way that a layperson could understand the "thought process of an engineer." The oral presentation engaged freshmen in a professional "marketing" pitch to their client (the museum). Module grades were assigned for the team projects and based on the quality of their implemented project as well as the technical presentation of their work in both written and oral form.

An overview of the course format and lecture topics is shown in **Figure 2**.

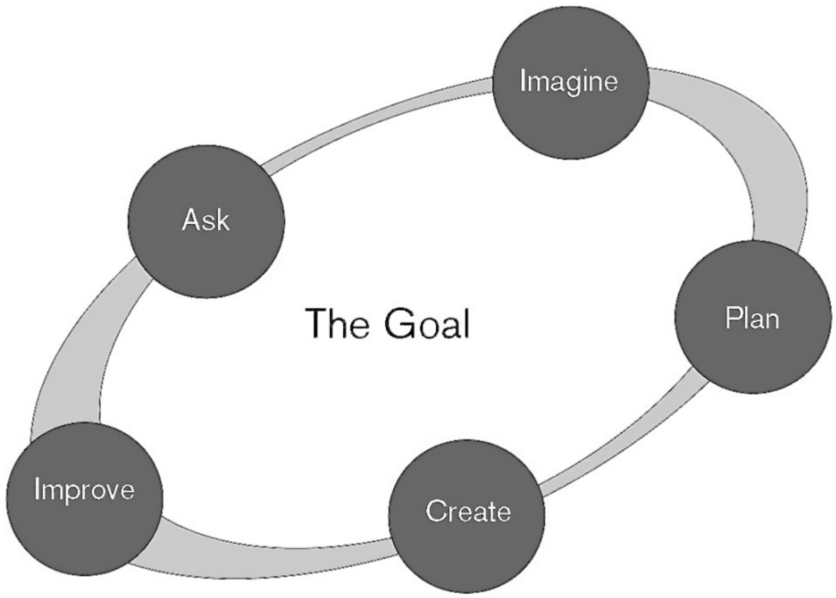

Figure 1. Engineering is Elementary design loop (Museum of Science, Boston) [26].

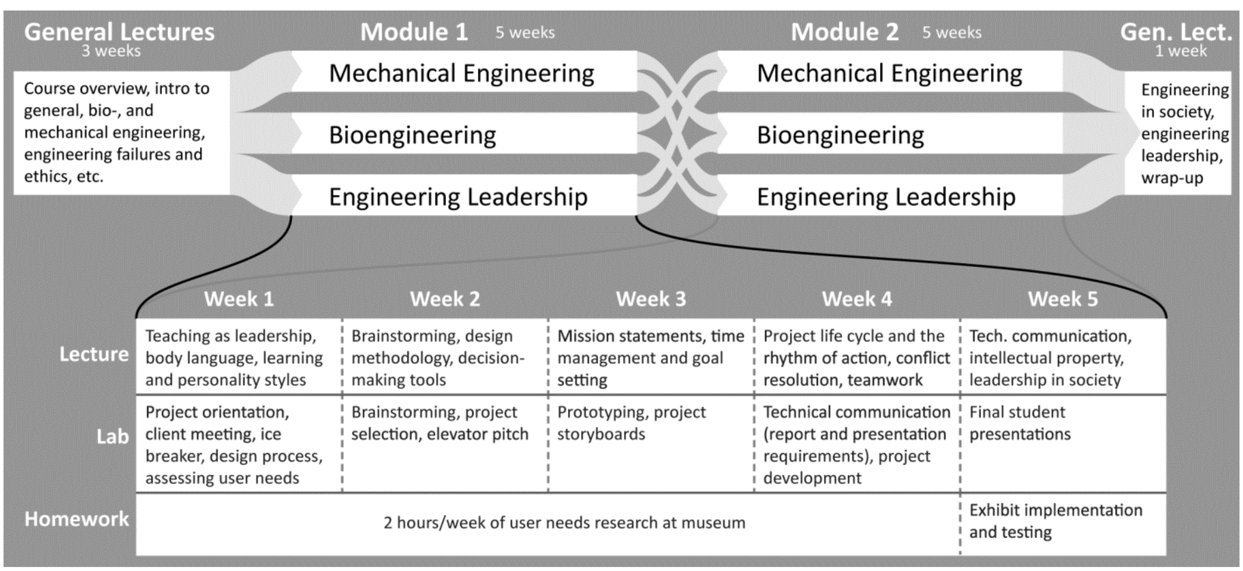

Figure 2. Overview of the course structure and lecture topics for the freshmen course, *Engineering Design and Analysis*. The bottom table shows the weekly breakdown of topics and activities covered in the engineering leadership module, which students could choose to take for Module 1 or Module 2.

Primary Course Assessment

This study follows up on a previous study to understand the impact of a leadership and service learning module on the engineering students' confidence. Our previous data included surveys during and immediately after the course. We found that students in the leadership module increased their confidence in several engineering skills after the course when compared to students not in the leadership module.[9,10] This effect was even greater when focusing on the women in the course.[10] The goal of this study is to determine if these differences would still be present after two years and to understand any additional long-term impacts of the leadership module.

Research Questions

One aim of our follow-up assessment was to understand the impact of a service learning module in a first-year engineering course. We examined how students' confidence in engineering skills and their perceptions of leadership changed from before and immediately after the course, and in their third year of undergraduate studies. We also addressed how the course and other experiences have increased the students' understanding of engineering and leadership, as well as how the course (and module) could have been improved. Finally, we looked at the module's potential impact on retention. Our research questions were:

1. What is the impact of a first-year service learning module on engineering students in terms of their confidence in engineering skills, perceptions of engineering and leadership, and potential to persist in engineering and leadership activities?
2. How can a first-year course be shaped to productively help students better understand and apply engineering and leadership?

Methods

Participants

The survey link was sent via an email to all students who participated in the Fall 2010 and Spring 2011 *Engineering Design and Analysis* first-year course. Follow-up surveys were completed by 87 students, of which 54 (62% of follow-up surveys) completed the leadership module (students were not required to take the leadership module as they could choose any two modules offered within the course). These 54 accounted for 24% of all students that took the leadership module. The remaining 33 accounted for 18% of all students that did not take the leadership module. From this, a subset of paired data from before the module ("pre-module") and at follow up was available for 53 (23%) leadership students and 14 (8%) non-leadership students. See **Table 1** for the breakdown of the number of participants for each portion.

Table 1: Number of surveys analyzed for students who both took and did not take the leadership module. Response rates from total number of students that participated are listed.

	Follow Up Data	**Paired Pre-Module/Follow Up Data**
Leadership Module Participants	**54 (24%)**	**53 (23%)**
Women	14	14
Men	40	39
Non-Leadership Module Participants	**33 (18%)**	**14 (8%)**
Women	10	5
Men	23	9

Surveys

The pre- and post-surveys were given to students at the beginning and end of the first-year course.[9,10] The follow-up survey was given to students during their third year of undergraduate studies. Surveys consisted of both quantitative and qualitative questions to understand students' confidence and perceptions, as well as any other perceptions of the course and any influential experiences outside the course.

All three surveys asked students to "perform an honest self-assessment of the extent to which they possess the engineering traits" based on a 1-5 Likert scale, where 1 is Low, 2 is Medium-Low, 3 is Neutral, 4 is Medium-High, and 5 is High. The engineering traits are listed in **Table 2**, and represent a combination of NAE and ABET desired skills for engineers.[1,14]

The follow-up surveys also asked students to rate individual confidence with regard to leadership qualities and their perceptions of the role of leadership in the engineering field and their education as a whole. Students assessed their confidence on a 1-5, low-high Likert scale and their perception on a 1-5, agree-disagree Likert scale. See **Table 3** for a list of the questions asked.

Table 2: NAE-ABET engineering criteria. Engineering traits designated "professional" traits (soft skills) are highlighted. Students were asked to self-assess themselves with respect to each of these traits before and after the course, as well as in the follow-up survey.

	Engineering Traits
a.	Possess strong analytical skills
b.	Exhibit creativity and practical ingenuity
c.	Ability to develop designs that meet needs, constraints and objectives
d.	Ability to identify, formulate, and solve engineering problems
e.	Good communication skills with multiple stakeholders
f.	Good team skills with people from diverse backgrounds and disciplines
g.	Leadership and management skills
h.	High ethical standards and a strong sense of professionalism
i.	Dynamic/agile/resilient/flexible
j.	Ability to learn and use the techniques and tools used in engineering practice
k.	Ability to recognize the global, economic, environmental, and societal impact of engineering design and analysis

Table 3: Leadership questions included in all surveys to assess confidence of leadership abilities and perception of leadership in engineering.

Rate your confidence for the following leadership qualities.
Communication
Empathy
Development of a Vision
Personal Integrity
Conflict Resolution
Rate how well you agree with the following statements regarding leadership perspective.
To be a leader, you must be in a leadership position.
Engineers rarely find themselves in leadership positions.
People are born leaders. One cannot learn how to be a good leader.
Teaching requires a great deal of leadership ability.
Leadership is an ongoing learning experience.
I possess all the skills I need to become a good leader.

The final part of the follow-up survey asked several qualitative questions to assess the impact of the course on the students as well as outside experiences that have influenced their engineering understanding and that may have been impacted by the course. It also asked students what they wanted out of the course, in addition to students' intended major, reasons for leaving engineering if they are no longer in engineering, and plans after graduation. See **Table 4** for the list of qualitative questions.

Table 4: Qualitative questions regarding *Engineering Design and Analysis* included in the follow-up survey given to students in their third year.

	Follow-up survey qualitative questions
Q1	One year later, do you feel this course added to your understanding of engineering? Why or why not?
Q2	Besides this course, what other experiences have helped solidify your understanding of engineering? Of leadership?
Q3	What are leadership roles you've taken on since this course? If so, how has this course helped you in this regard?
Q4	What did you wish you had learned in this course?
Q5	What is your intended major?
Q6	If you are no longer in engineering, what were your reasons for leaving?
Q7	What do you plan to do after you graduate?

Analysis

All quantitative data regarding confidence levels and perceptions of professional and technical skills were statistically evaluated at a confidence level of 95% and 90%. The follow-up quantitative data (NAE-ABET, leadership and perception) were compared between students in the leadership module (leadership students) and those not in the leadership module (non-leadership students) using a two-tailed Student's t-test with unequal variances in Microsoft Excel. Available data from students who submitted pre-module and follow-up NAE-ABET surveys were assessed using a paired two-tailed Student's t-test to assess any significant changes in confidence levels from first to third year comparing leadership and non-leadership students, as well as men and women.

The qualitative questions were coded using an emergent scheme to aid analysis. Q1 (see **Table 4**) was coded for yes, no, and maybe. Common reasons were summarized for each of the three types of responses. Q2 was coded into several categories: research, extracurricular, projects and classes, internships, teaching, interaction with role models, and personal experiences. Q3 was coded for whether students had any or no leadership experiences, whether they had any major roles in these leadership experiences, and whether and how the course has helped in these experiences. Q4 was coded into the most common responses about desired content, activities, and purpose of the course. Q5 and Q6 were analyzed with respect to how many students left engineering and their reasons for leaving. Q7 was coded into grad school, industry, undecided between grad school and industry, and other. Any differences between leadership and non-leadership module students were assessed for all qualitative questions.

Results

Changes in confidence from first to third year reveal significant overall positive increases for leadership students in both professional and technical skills. Students in the leadership module did significantly better acknowledge the role that leadership plays in both teaching and engineering careers. This was also reflected in their qualitative data, which provided a deeper understanding for the benefit of leadership studies and service learning activities in students' undergraduate experiences. Qualitative data was otherwise split over the benefits of the leadership and service learning first-year course. Quantitative data revealed little significant difference in confidence at follow-up between students in the leadership module versus those who did not complete the module.

Minimal difference in leadership and non-leadership students' confidence at follow up

Follow up survey data from the NAE-ABET criteria revealed no significant difference between students in the leadership module versus non-leadership students who enrolled only in traditional engineering modules in all but one NAE-ABET criteria (**Figure 3**). Leadership students displayed slightly more confidence in their ability to develop designs than did non-leadership students ($p<0.10$). Trends demonstrated higher confidence levels for leadership students in three professional skills (leadership and management, teamwork, and communication) and two technical skills (recognition of global impact and development of designs). Non-leadership students possessed higher mean confidence levels for three professional skills (creativity and ingenuity; ethics and professionalism; dynamics and agility) and three technical skills (use of techniques and tools of engineering practice, engineering problem solving, and analytical skills).

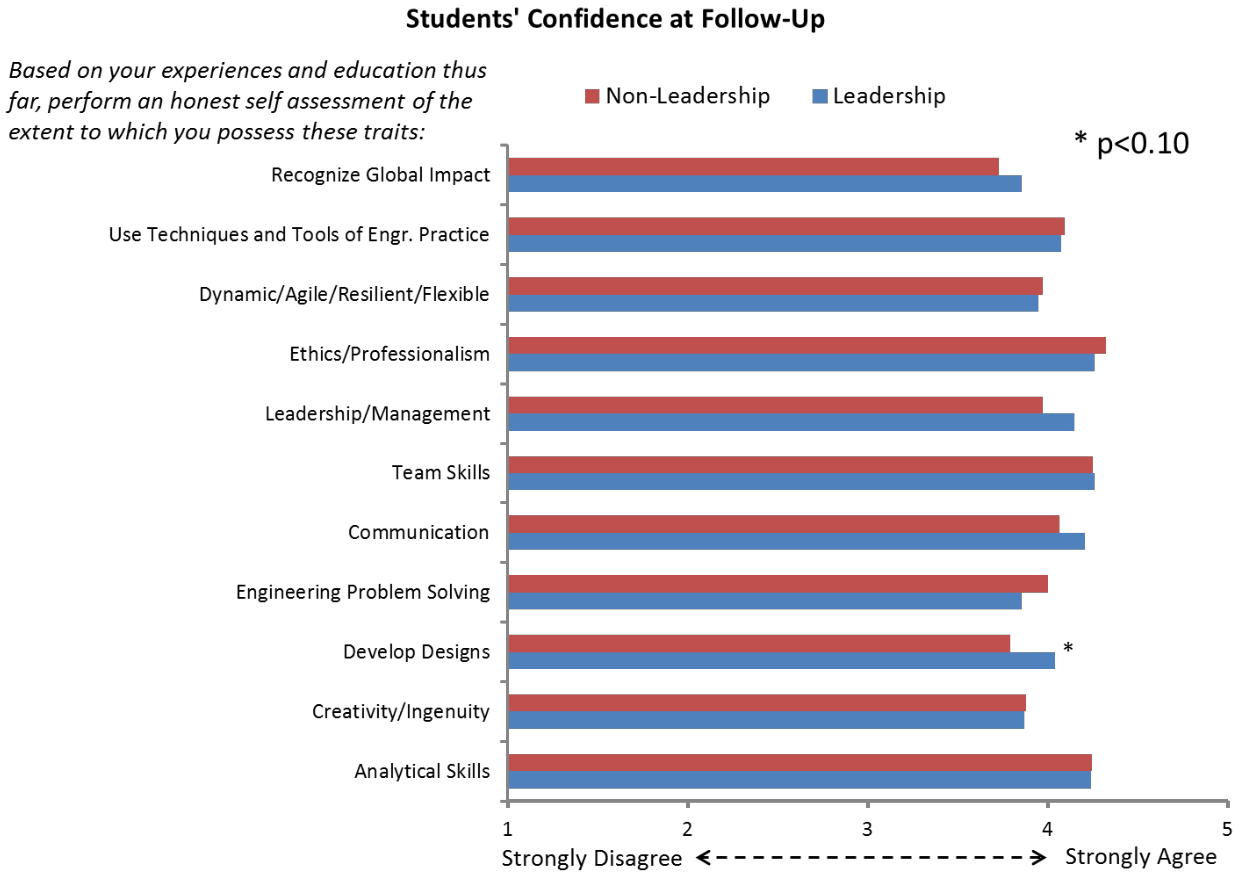

Figure 3. Follow-up data of average confidence levels for NAE-ABET skills as self-assessed by students who completed the leadership module ("Follow-Up Leadership", n = 54) and those that did not ("Follow-Up Non-Leadership", n=33).

In addition, there were no significant differences in confidence between leadership and non-leadership students when asked specifically about their leadership abilities (**Figure 4**). Leadership students displayed slightly higher mean values for conflict resolution, personal integrity and communication, while non-leadership students' confidence was slightly higher in an ability to develop a vision for an engineering challenge. Both groups had equal confidence in their ability to feel empathy.

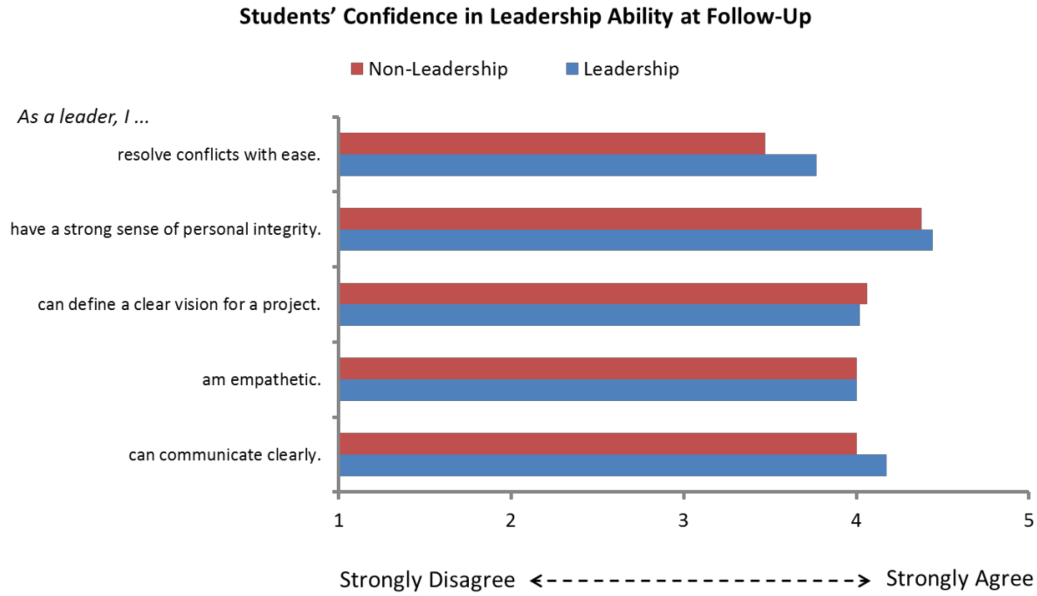

Figure 4. Follow-up data of average confidence levels for leadership qualities as self-assessed by students who completed the leadership module ("Follow-Up Leadership," n = 54) and those that did not ("Follow-Up Non-Leadership," n=33).

Changes in students' confidence from pre-module to two-year follow-up reveal significant increasing trends for leadership students

Paired data (from pre-module and follow-up NAE/ABET surveys) were evaluated to observe changes in students' confidence between their first and third years (**Figure 5**). Leadership students showed an increase in mean confidence across all ten NAE/ABET categories. Significant changes were seen for leadership students for the following six NAE/ABET skills: analytical skills**, creativity/ingenuity**, develop designs*, communication**, team skills**, and leadership and management** (**p <0.05, *p< 0.10). No significant changes were observed for non-leadership students. Furthermore, the only negative change was observed for non-leadership students, whose confidence in developing designs decreased from pre-module to follow-up.

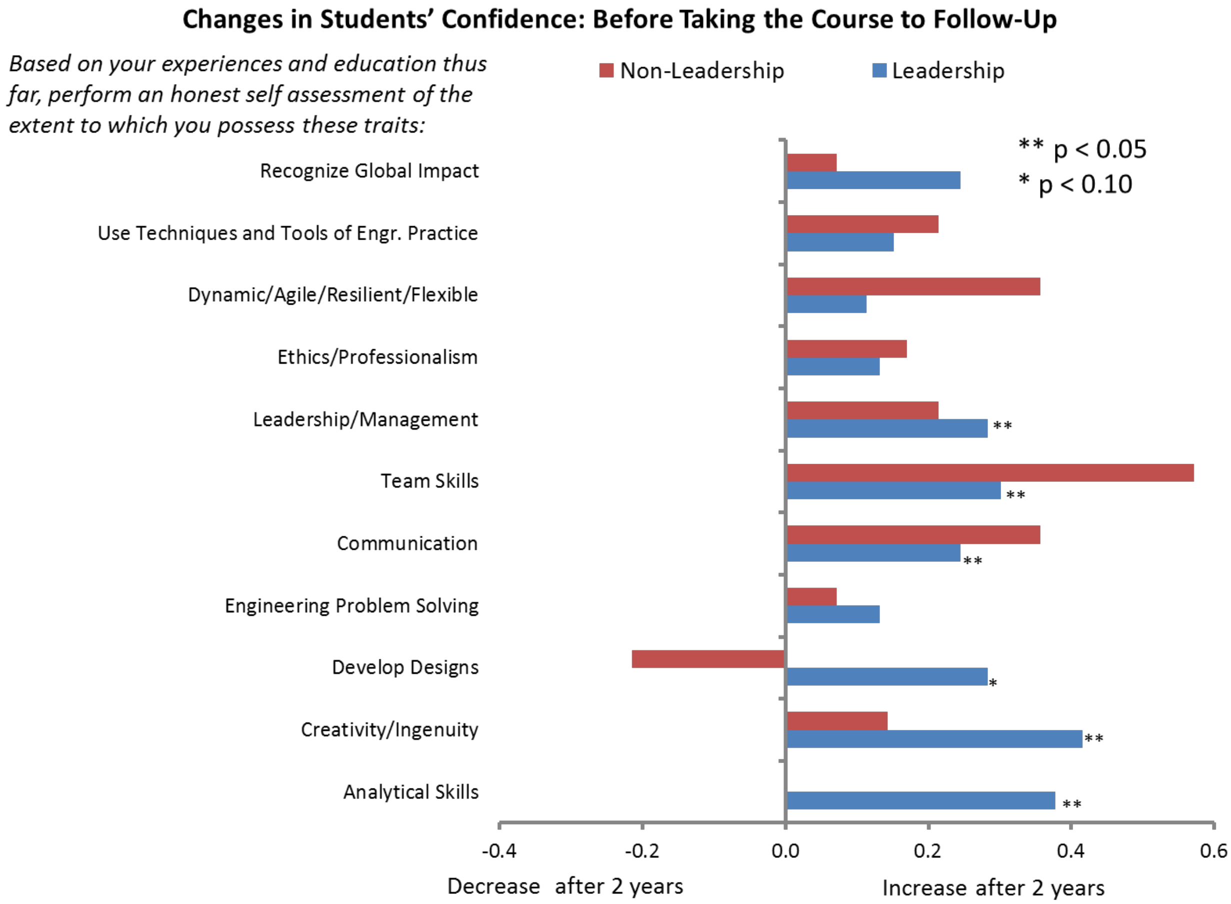

Figure 5. Changes in confidence from before the module (pre-module) to students' third year (follow-up) for students who completed the leadership module ("Pre-Module to Follow-Up Leadership," n = 33) and those that did not ("Pre-Module Follow-Up Non-Leadership," n=14).

When compared to non-leadership students, leadership students had a greater increase in mean confidence over the two-year period for more technical skill categories (global impact, engineering problems solving, develop designs, and analytical skills) than professional skills (leadership and management, creativity and ingenuity) (**Figure 5**). Non-leadership students demonstrated greater increases in mean confidence for four professional skills (dynamic and agile, ethics and professionalism, teamwork, and communication) and one technical skill (using engineering techniques and tools) than did leadership students. Since data for non-leadership students was not significant, no direct statistical comparisons were made between the two groups.

Breakdown of pre-module to follow-up changes in confidence by gender

Changes in confidence from the NAE/ABET data (**Figure 5**) was broken down by gender, as seen in **Figure 6**. Significant increasing trends (**p <0.05, *p< 0.10) were observed for leadership women in three technical skills (recognizing global impact*, engineering problem solving*, analytical skills**); leadership men in two professional skills (leadership and management* and communication **) and one technical skill (analytical skills*); and non-leadership men in two professional skills (team skills** and creativity and ingenuity**). Non-leadership women saw large non-significant decreases in mean confidence across five categories, both technical and professional (ethics and professionalism, develop designs, engineering problem solving, recognizing global impact, creativity and ingenuity). Slight decreases in confidence also occurred for leadership women in two professional skills of teamwork and ethics and professionalism. No comparisons between leadership and non-leadership data by gender category could be made due to a lack of paired significant data.

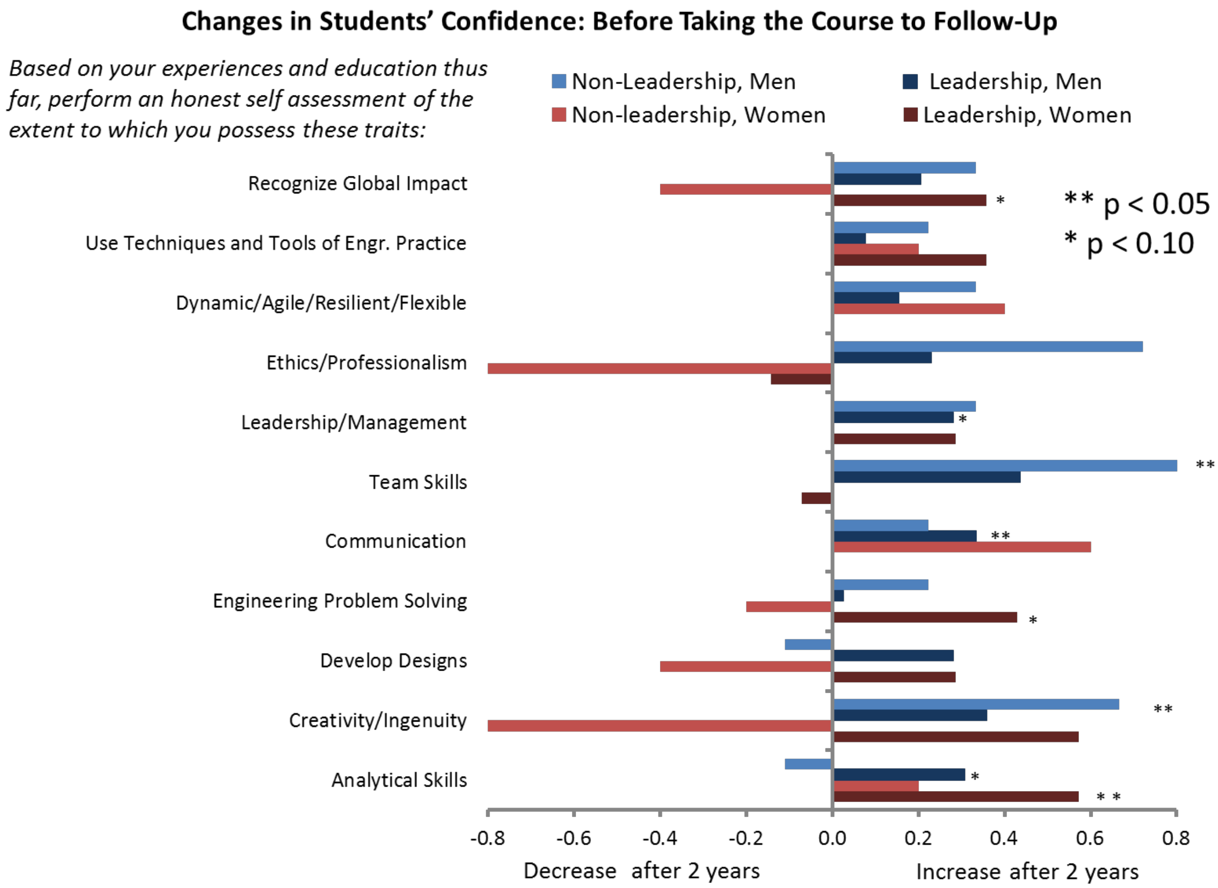

Figure 6. Changes in student confidence from before the module ("pre-module") to their third year ("follow-up"). Bars extended to the left show a net drop in confidence; bars to the right show a net increase in confidence. Significant data is marked by asterisks as indicated in the legend. Data is broken down between students who completed the leadership module ("leadership") and those that did not ("non-leadership"), as well as by gender (red tones for women, blue tones for men).

Leadership students demonstrated greater acknowledgement of their need and ability to develop leadership skills as both engineers and teachers

Leadership students consistently demonstrated greater confidence in the role of leadership in engineering and teaching careers (**Figure 7**). Leadership students agreed more than non-leadership students that they possessed all the skills they needed to become a good leader; leadership is an ongoing experience**; and teaching requires a great deal of leadership ability* (**p<0.05, *p<0.10). They also disagreed more than non-leadership students with the statements that people are born leaders; engineers rarely find themselves in leadership positions; and to be a leader, you must be in a leadership position.

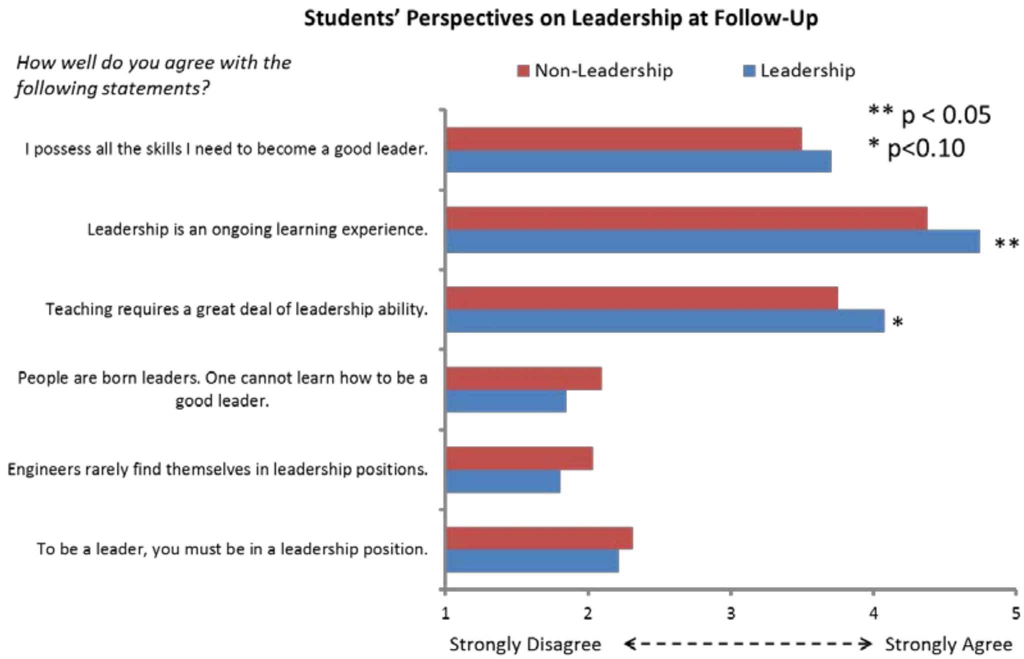

Figure 7. Students' perception of leadership at follow-up, for both students who took the leadership module ("Follow-Up Leadership", n = 54) and those that did not ("Follow-Up Non-Leadership", n=33).

Outside experiences, especially extracurricular activities, helped students' understanding of engineering and leadership

Qualitative responses indicated that many students had not thought much about the course since their first year. However, for those who mentioned that the course helped, communication and collaborating with others were important skills they gained from the course. This was more commonly mentioned among students in the leadership module, who also indicated project management and working in a realistic engineering environment. See **Table 5** for sample comments.

Another noteworthy finding is that almost all students mentioned outside experiences helped their understanding of engineering and leadership (**Table 6**). In terms of understanding engineering, students referred to undergraduate research, extracurricular activities, projects, courses, internships, and role models. In terms of understanding leadership, students mentioned extracurricular activities, teaching, projects, personal experiences, and role models. Extracurricular activities were most commonly discussed, consisting of both engineering and non-engineering student groups as having given students hands-on experience in real engineering projects, managing projects and collaborating with others, and communicating. Courses mentioned were project courses and lab courses, in addition to some business courses. Role models that students discussed were professors, speakers, and other personal and professional connections. Internships, research, and extracurricular activities gave students opportunities to apply their skills in the real world. Students, however, did also note that leadership is hard to teach in a course because it is part of life experiences that are unteachable.

Table 5: Comments on the course's impact in terms of students' understanding of engineering and leadership.

Leadership	Non-leadership
Honestly, I do not think about [the course] very often anymore, but I'm sure that some of the communication and project planning skills that I learned in the ME [leadership] module have helped me out. *[The course] helped me understand that communication makes a big difference in getting the job done, therefore when I assume a leadership position, I make sure that I am speaking to everyone.* *It helped me understand that there are different types of people and we need to account for how different people learn.* *It taught me how to speak in public, and be eloquent and articulate in my opinions.* *By anticipating these issues through thinking out potential problems ahead of time, things run much more smoothly. In the bridge building module [part of the leadership module], I noticed a lot of kids made the same mistakes (not using triangular shapes,) so I prepared a few different demos to help them understand the problems.*	*Group work in [the course] taught me the importance of communication in a group, which has been very helpful.*

Leadership students mention broader experiences in engineering and leadership

Even though both leadership and non-leadership students mentioned outside experiences as being important to their understanding of engineering and leadership, leadership students mentioned broader experiences. Almost 20% referred to personal or life experiences, while none of those who did not take the leadership module mentioned such experiences. Furthermore, over twice the percentage of leadership students mentioned internships as learning experiences – 25.6% of leadership students versus 11.5% of non-leadership students. Finally, slightly more leadership students mentioned significant leadership roles (founder, president, or vice president) than non-leadership students (6/39, or 15.4%, leadership students versus 3/26, or 11.5%, non-leadership students), including one leadership student who is a founding member of a student chapter for Design for America.

Table 6: Sample quotes about impactful engineering experiences

	Outside experiences that helped students' understanding of engineering
Research/Internship	*My internships and upper division design classes have really given me an understanding of engineering and leadership. These have been the closest thing college has given me to real world experiences.*
	My understanding of engineering has been most significantly impacted by internship experience. Courses teach valuable knowledge that I often use on the job, but to get a good picture of how exactly I was going to use it, I needed to get my hands dirty in industry.
	I worked with a couple of programmers in Buenos Aires. They were very technically gifted, but lacked some sense of business understanding, a common trait in educationally rich but still developing nations (along with India, Turkey, etc.) They were head and shoulders above me in technical skills, but the organizational aspect dealing with budgets and timetables were not taken as seriously as they should have been, and I had to help explain and guide the process.
	Having an engineering internship for two summers was also huge in learning what being an engineer is actually like, ie what he does, how he does it
Engineering extracurricular	*I joined [the Solar Vehicle Team] and am now project manager of the team, so I have had a lot of practical experience with engineering and leadership, and have had an opportunity to make my own mistakes, which has greatly improved my learning process.*
	… Solar Vehicle Team has taught me some of what I consider to be the most important life and engineering lessons that school can't even hope to teach.
	Joining a competition team (SMV) as a freshman was great because I saw how engineering a complicated project with a ton of people worked.
Non-engineering extracurricular	*The extra-curricular groups certainly have. Leadership really comes when you have a project that needs to get done and people who are willing to do it, but don't exactly know how to coordinate themselves. Someone just tends to come along and fill up that directional gap, and it usually boils down to the person who has the right amount of conviction at the right time.*

Role models	*... some incredible professors …who I want to emulate have shaped the way I approach certain classes and commitments in my life.* *As for leadership, I've mostly come to understand that through observing the various leaders (spiritual, club-related, [TA]s...) in my life.* *Engineers I know in real life have given me a good example of how leadership plays in the engineering business world.* *Watching keynote speakers at conferences too.*
Classes	*The most valuable experiences in leadership that I have encountered were during group projects and labs in my upper division courses. They gave very good practical experience regarding work delegation and relationship management in the context of non-trivial, interdisciplinary engineering tasks.* *Team projects in other classes have exposed me to various team dynamics and have shown me how unique personalities can impact coordination within a given team, and that adaptability to those traits is crucial to the accomplishment of the team's goal.*

One female leadership student discussed how her experience in the leadership module impacted her extracurricular involvement:

I have taken on a chair position in [a leadership lecture series and dance student group], as well as serving on the Vice Chancellor's Student Advisory Committee. I am also a general member of [a university-based magazine] and was a mentor for [an engineering student-led K-12 mentoring program]. Without the push that the [leadership] module gave me, I would never have become as interested in getting involved as I did.

In contrast, one non-leadership student stated:

I don't have a solid understanding of leadership.

Extreme opinions about the value of the freshman engineering design course

In regards to the value of the course, students had very extreme opinions, mostly very positive or very negative. There was no significant difference between women and men's opinions on the course. However, slightly more leadership students said "yes" or "maybe" about the course adding to their understanding of engineering (67.5% of leadership students versus 63% of non-leadership students). The leadership students mentioned learning applicable skills and characteristics of successful engineers while non-leadership students mentioned gaining a broad overview and general understanding of engineering. However, both groups noted that the course was a waste of time, poorly put together, focused on content rather than process, lacking in hands-on experiences, or too rushed, specific, difficult, and/or general. See **Table 7** for sample comments.

Students who left engineering

Out of the 69 students who answered the questions on retention, five had left engineering. Three were men who took the leadership module, one was a woman who did not take leadership, and one was a man who did not take leadership. However, all stayed in STEM and related majors: Economics and Applied Mathematics, Geophysics, Chemical Biology, Cognitive Science, and Computer Science. The men left engineering because they had other interests. The woman who left engineering stated her reason:

Realized that either I dislike the way engineering classes are learned and experienced OR the teachers here simply aren't very good at giving students the right positive POV [point-of-view] towards engineering (or at least the subject matters of their class(es)).

Table 7: Students' opinions on how the course added to their understanding of engineering.

	Leadership	**Non-leadership**
Positive Opinions	*I thought the most useful module was engineering leadership by far. It really taught the values of what it takes to be a successful engineer.* *The most important skill I got came from the bridge building station in the Leadership module. I had to teach little kids how things worked on their level, and that obviously required a bit of careful explaining due to their age and inexperience. I find that when trying to explain technical things to non engineers, you can't just throw out technical terms like 'shear stress' or 'bulk modulus' when explaining how something works. You have to think like someone else.*	*I feel it introduced me to some interesting topics, especially the MSE module, but we glossed over so much in such a short period of time that it's hard to say that I learned a great deal. I was and am still under the impression that this class is really just to get engineers to meet other engineers, form study groups, make friends, and realize that their professional duties are consequential (and could kill people if done incorrectly).*
Negative Opinions	*In the [leadership] module, we had to spend a great deal of time working with children at the [science center]. This was even more worthless than the MSE module, as it did not give me a working or theoretical understanding of engineering.*	*We do not have enough understanding of physics or math at the time to get any real meaning out of the class.* *The modules were highly theoretical - way too much for an incoming freshman.* *Class material was worthless. If you wanted to improve new students' understanding of engineering, you should not have separated into modules. Too many people were focused on the content of each module, rather than the skills you probably intended to teach*

An ideal first-year course: Key student perspectives

Students' responses to the types of experiences, including the course, that helped their understanding of engineering as well as their responses to the question, "What do you wish you had learned in [the course]?," provide insight into an ideal first-year engineering course. Outside experiences especially helpful were (1) research and internship experiences, which gave them better understanding of and experience with science and engineering in the real world as well as leadership and communication experiences; (2) engineering extracurricular activities, which provided them with opportunities to apply technical and professional skills, such as communication, leadership, and project management; (3) non-engineering extracurricular activities and student organizations, which gave them opportunities to apply similar professional skills; (4) role models, which gave students insight into how engineers work in the real world; and (5) classes, which, through projects and labs, gave students exposure to team work and hands-on application of technical skills. **Table 6** provides some sample quotes.

In terms of what students stated they wanted out of their first-year course, they mentioned hands-on projects that would give them practical skills such as management and communication. They also wanted to learn more about the discipline of engineering – what it's like to work as an engineer, examples of research and applications, and case studies. Students further requested some more technical specifics in the various disciplines. Additionally, they wanted more of an overall introduction to the many different kinds of engineering. See **Table 8** for sample quotes.

Table 8: Student reflections on what they wish they had learned in the first-year engineering course.

	Leadership	**Non-leadership**
Hands-on and practical skills	*As a first [semester] freshman, I think a lot of people wanted more of a hands on project, or more about the discipline of engineering, esp. since not everyone knew their majors and the other first yr classes were not hands on or very engineering related.* *More communications skills*	*It would have been more useful/fun if it had been a hands on type class.* *I wish I was able to build up an 'engineering toolkit' of skills that way.* *Tip on how to make the most of undergraduate years as an engineering*
Career as an engineer	*I wished I learned more in-depth experience on some industry aspects on becoming an engineer.* *More emphasis on what its like to be a working engineer in these fields, or what the current research and projects in these fields are.* *More of the background of engineering and future career paths.*	*Things about the profession of engineering and the practical aspects that aren't taught in other classes.* *How much work it takes to be an engineer, a freshman-digestible look at the exciting trends in different engineering fields. Basically, I wish I had more (and better) exposure to other engineering disciplines, I never was very interested in them as a freshman.*

Technical content	*I wish I had learned more principles of Engineering design: basic concepts like lift, drag, structural capabilities-- that we go into more detail in other classes.*	*Gotten a more basic understanding of the subjects.*
Overview of different engineering disciplines	*I wish we could have explored all the branches, instead of being forced to choose just two. It made the experience feel incomplete.*	*I wish we could have sampled more than just two types of engineering*

Discussion

This study sought to evaluate the potential impact of a first-year service learning and leadership module on engineering students' confidence in their professional and technical skills and seek ways to improve upon course content to help students better understand and apply engineering and leadership. While our previous work demonstrated an immediate jump in confidence levels after completion of the course, this study seeks to evaluate those confidence levels over a year later during students' junior year.

Leadership students maintained their confidence in engineering skills

Overall, surveys of students during their third year of study revealed a statistically significant net increase in confidence across six NAE-ABET skillsets for students who took the leadership module, while students who did not take the module did not display a significant increase or decrease from pre-module to follow-up. Leadership students reported this increase in four professional skills, indicating that there is a potential benefit of a leadership and service learning module in the freshman engineering course. Although we did not control for experiences between the course and the follow-up survey, students' qualitative comments directly discuss the benefits of the first-year design course (**Table 5**): key skillsets such as communication, management, adaptability and empathy are specifically attributed to the leadership module. One student even drew upon his service learning experience at the museum, exposing the potential lasting impact that a hands-on service learning project, even during the first year, can have on a junior (see **Table 7**, Leadership column, second quote in Positive Opinions).

Similar levels of confidence in professional and technical skills in both leadership and non-leadership students, but leadership students may be more likely to persist in leadership activities

Both the NAE-ABET and leadership qualities survey data demonstrated little significant differences in confidence levels at follow-up between non-leadership and leadership students. Furthermore, mean levels of confidence for leadership and non-leadership cohorts did not exhibit favor toward professional or technical skills, suggesting a variety of experiences since the course that could have contributed to each individual student's self-evaluation. Despite this leveling of confidence values across both subject groups, leadership students did demonstrate a better perception of the role that leadership plays in an engineering career as well as value for continued professional skill development. This heightened awareness of their own leadership responsibilities and potential growth reflects their likelihood to not only be in a leadership position one day, but also possess a more optimistic attitude toward preparing for such a position. This was supported by qualitative responses, in which more leadership students partook in a wider variety of leadership activities outside the classroom and attributed their professional skill development to these experiences. Almost twice the percentage of leadership students discussed internships, which may mean that they were more successful and more likely to take on internships than students who did not take the leadership module. Almost 20% of leadership students mentioned personal and life experiences, while none of the non-leadership students made reference to such activities. The greater mention of internships and personal experiences may imply that leadership students are more likely to see a broader range of experiences as leadership experiences. Thus, they may be more likely to persist in and learn from leadership activities.

Women in engineering: The need for continued service learning experiences to improve retention

Our previous work demonstrated that women who completed the leadership module saw statistically significant increases in confidence in using techniques and tools of engineering practice, team skills, communication, engineering problem solving, developing designs and analytical skills.[9,10] Follow-up data revealed that a statistically significant confidence increase in engineering problem solving and analytical skills was maintained; leadership women also gained more confidence in their ability to recognize global impact by their third year. However, no significant increase occurred for other categories, and confidence in team skills decreased over the two year period for leadership women. In comparison, survey data from non-leadership women demonstrated the largest decreases in confidence and in the most categories compared to women in the leadership module and all men. Though data from this cohort was not significant mostly due to a small sample size (n=5), the drops in confidence were not skewed by a single respondent and standard deviation values were equal to or less than those calculated for the other cohorts. These dramatic differences suggest that service learning and leadership studies may have a particularly impactful effect on women both in the short term[9] and long term.

Studies have demonstrated that service learning and professional skills can positively impact women's engineering confidence levels.[7,8] Furthermore, many women and minorities are historically drawn to socially-conscious careers in engineering (e.g. energy, medicine, and the environment).[28,30] Survey data obtained just after completion of the module suggest a strong, direct impact of service learning experiences on women's confidence, which can enhance recruitment and retention efforts after the first year. However, sustained confidence for leadership women was restricted to only technical skills, most likely reflecting students' heavy exposure to traditional engineering courses during their sophomore and junior years, and minimal real world group projects that are typically reserved for senior years of study. Continued experiences in service learning or community-based projects alongside core technical coursework could help to maintain high confidence levels in both professional and technical skills for women throughout their undergraduate education. This was reflected in the female student’s qualitative comment regarding her decision to leave the engineering field. While the men who opted out of engineering indicated that they had other interests and pursued them, the only woman who left disliked how engineering was taught and felt she did not receive a positive perspective on the field. This points out the importance of portraying engineering positively and teaching the subject in a more widely accessible manner. Service learning and open-ended projects have been shown to be more accessible to a wide range of learners.[15,21,31,32]

An ideal first-year course consists of an overview of all kinds of engineering, what it's like to be an engineer, and a hands-on project

From the qualitative comments on students' influential outside experiences as well as what they wish they learned in the course, a semester-long 14-week course could begin with one week for an overview on the profession of engineering and possible career pathways. It could then progress to one week for each type of engineering, covering what it's like to work in that discipline, research and applications, case studies, and technical specifics, and include speakers from the discipline. The final four to five weeks could be a short hands-on project where they learn and implement practical skills in the discipline of their choice along with lectures covering professional skills and leadership. Finally, the course could be pass/fail to minimize grading issues.

The following is a quote from one student who took the leadership module:

> *For me, leadership education is really about what the student learns, not what the teacher teaches. It's not like math. To that end, [the course] was wildly successful. I'm sure if the curriculum was changed up, I would have gleaned different lessons, but whether those other lessons would be better or worse than the lessons I did learn is impossible to tell.*

The student nicely describes a learner-centered approach to instruction, as opposed to the more traditional and still commonly implemented teacher-centered approach in engineering. Rather than transmission of content from teachers to students, good instruction, especially in a practical field like engineering, involves the learner in open-ended hands-on activities through which the learner can uniquely explore for more personalized and meaningful learning.[33] This student appreciated the approach and felt he was really able to learn. Service learning engages learners in these hands-on experiences.

Limitations

As this study was not a lab-based randomized controlled trial, there are many other potentially influential variables between the time that the students first took the pre-module survey to the follow-up survey two years later. Because we were working with engineering students in a real course, the environment was very complex, and we must view the findings with the limitations in mind. Thus, only correlations may be drawn from the findings, and further controlled studies should be implemented to verify our findings.

We also note that because the students' initial preferences for the modules were mostly accommodated, there may have been a self-selection bias in that students who were already more likely to pursue leadership activities selected the leadership module.

Analysis of survey data was limited by a lack of statistically significant data for students who did not participate in the leadership module. This is most likely attributed to the low sample size for paired data (pre-module to follow-up surveys). As a result, direct comparisons between the impact of the leadership module on confidence levels between leadership and non-leadership students was limited. This was especially true for women who did not take the leadership module – only five individuals provided self-assessments both before and two years after the course. Despite limited data for non-leadership students, significant data reported by leadership students as well as qualitative data did suggest a sustained benefit of the course as well as valuable input for improvement.

Another limitation of the quantitative data is the time at which it was collected. The survey was sent to students in the middle of the Fall semester of their third year, during a potentially stressful time due to impending midterms and project deadlines. Compared to pre-module surveys, which was sent at the very beginning of the course during their first year, follow-up surveys may have reported slightly deflated confidence levels. In assessing how self-reported confidence calibration levels change over the course of a semester-long course, Hadwin et al. noted a decreasing sense of optimism and confidence over repeated evaluations, potentially due to an inflated perception of their own abilities.[34] Hadwin et al. also noted that confidence levels were most strongly based on current task evaluation and not necessarily past experience. Thus, leadership students' decreased confidence in certain professional skills may be the result of a specific term project or group assignment occurring at the time they filled out the survey, as opposed to a collection of experiences over the two years since the leadership module.

Extreme opinions seen in qualitative data suggest a slight skew in available survey data. Students who chose to complete the survey may have greatly benefited from or seriously disagreed with the course content, and hence wished to contribute. Even with a potential skew in the qualitative data, quantitative data still leveled out for follow-up data for both leadership and non-leadership cohorts. In addition, since two years had passed between surveys, student bias in self-evaluations may have been reduced since students did not have access to their previous survey results.

Future studies will collect survey data at the end of students' undergraduate education to reduce any influences of academic stress from other courses. Furthermore, surveying students once they have entered an industry or academic career path will provide additional perspective on the worth of a first-year leadership course in a professional or undergraduate student environment, especially for those students who work in a leadership or team-based role.

Conclusion

Follow-up increases in student confidence suggest the positive impact of service learning and leadership studies during students' first year of study. However, students' open-ended responses reveal a need for more hands-on work to better learn professional skills. Quantitative data further support sustained service learning experiences to continue building confidence in professional skills, especially for women.

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