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Implementation of Leadership and Service Learning in a First-Year Engineering Course Enhances Professional Skills*

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Successful engineering students should possess competence in both technical and professional traits such as creativity and leadership. This paper investigates how an engineering service learning module with a focus on leadership can affect engineering students' confidence level for technical and professional traits. This leadership module was offered as part of our first-year course that aims to expose freshmen to general engineering principles. The research question in this paper addresses what is the effect, if any, of an engineering service learning module on (1) the confidence levels of women and men as it relates to eleven National Academy of Engineering (NAE) and ABET engineering traits and (2) their confidence in and perceptions of leadership. Data were collected via two surveys administered at the beginning and end of the module. One hundred and thirteen students returned both NAE-ABET surveys and fifty-two returned both leadership surveys. A two-tailed Student's t-test with equal variance was utilized with a confidence level of both 95% and 90% to test for statistical significance. The results showed leadership module students increased in confidence in all NAE-ABET and leadership skills, while students not in the module increased less or decreased in confidence in most NAE-ABET skills. Women in our leadership module increased their confidence on all NAE-ABET skills, while other women experienced no significant increase in confidence level. Within the leadership module, women's confidence increased more than men's confidence in all but four NAE-ABET traits. The statistical trends of students' survey responses and qualitative analysis of the comments show no negative impact on their confidence in technical and professional skills when compared with students in the more technical modules. Moreover, qualitative responses from women indicate overwhelming appreciation for the experience and skills gained from the leadership module, as well as increased confidence for women as engineers.

Keywords: service learning; design; outreach; first-year; leadership; teamwork; professional skills

1. Introduction

A successful engineer is not only technically proficient but also possesses many skills exhibited by great leaders. Kumar and Hsiao have shown that leadership skills are closely aligned to the professional skill sets outlined by the Accreditation Board of Engineering Technology (ABET) and include the ability to (i) work within diverse teams to accomplish project goals; (ii) motivate, inspire, and respect team members; (iii) evaluate and take calculated risks for project performance; (iv) provide technical competence and ability to recruit team members with the necessary skills needed for the successful completion of the project; (v) value honesty, integrity, and high ethical standards in decision making; (vi) communicate effectively, both written and verbal; (vii) listen carefully and learn from others; (viii) understand the importance of responsiveness to clients; and (ix) recognize the civic duties of an engineer [1]. It is the responsibility of the academic institution to nurture and grow these skills in our engineering undergraduates.

The traditional engineering curriculum develops the strong analytical skills (competency) needed for this profession but often falls short in the realm of the professional skills of our young engineers. Ironically, it is often these "soft skills" centered upon communication, teamwork and leadership that are sought in industry; in fact, it is likely that it is these professional tools that are most valuable to the graduating engineer as he or she enters the workforce, graduate study, or other career path. The National Academy of Engineering has found that academic programs that engage students in team exercises and design challenges that connect to real-world problems are most successful in retaining its engineers [2]. The National Research Council (NRC) has recommended "including early exposure to 'real' engineering and more extensive exposure to

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interdisciplinary, hands-on, industrial practice aspects, team work, systems thinking, and creative design" [3, p. 4].

In the last few decades there has been a great deal of emphasis on developing the professional skill sets in the engineering curriculum. Shuman *et al.* [4] provide a thorough review of many successful pedagogical paths for the implementation of the professional skills in engineering academic programs. These authors emphasize the use of service learning in combination with engineering design projects to teach and reinforce outcome combinations. Lima and Oakes describe service learning as "a pedagogy or educational methodology that directly and intentionally integrates classroom learning with service to the community" [5].

Service learning provides an opportunity to incorporate real-world experiences into the engineering curriculum while providing a valuable service for an entity such as a nonprofit organization or a disadvantaged community without reducing academic content [6]. It has been shown that students engaged in such experiential learning opportunities have better retention of technical knowledge and are better able to apply what they have learned in college courses to real life situations after graduation [4, 7–10]. Moreover, service learning and professional skill development has been shown to have a positive impact on women engineers and may improve recruitment and retention of women into the field of engineering at the undergraduate level [11, 12]. Accordingly, we have developed a freshman engineering course module that teaches students the leadership skills that are essential for them to be exceptional engineers by placing them in team projects servicing real clients. Through a quick-paced five-week module, students worked in teams of three to six to improve a local science center's engineering exhibits through activities that teach the K-12 sector about the engineering design process.

1.1 Course description

Engineering Design and Analysis is a freshman level survey course that offers an introduction to the profession of engineering through a variety of modular projects and laboratories. The course comprises a series of overview lectures for all students in the class and two sets of modules that the students choose from three to four offerings (see the timeline shown in Fig. 1). The primary learning objectives of the course are based on criteria for graduating competent engineers as recommended by ABET [13]. The first four weeks of the semester comprise general lectures for all students that provide an overview of the engineering profession and include the topics of failure analysis, design methodology and human-centered design, societal context of engineering, as well as leadership and ethical considerations in engineering as a discipline. The next ten weeks of the semester consist of two consecutive sets of five-week modules, with students divided into smaller classes for each module. Students choose two of the various modules to take for the course. Historically, the modules have utilized hands-on laboratories spanning the traditional disciplines of engineering. Such modules include bioengineering (cell culture), civil engineering (stress analysis), industrial engineering (operations research), materials science (battery electrochemistry), and mechanical engineering (robotics design, sustainable energy, or human-centered design). In this past year, a new module entitled "Leadership and Service Learning for Broadening Engineering Ingenuity" also known as "Teaching as Leadership" was implemented using K-12 service learning for the professional development of our young engineers. This module was offered in collaboration with our

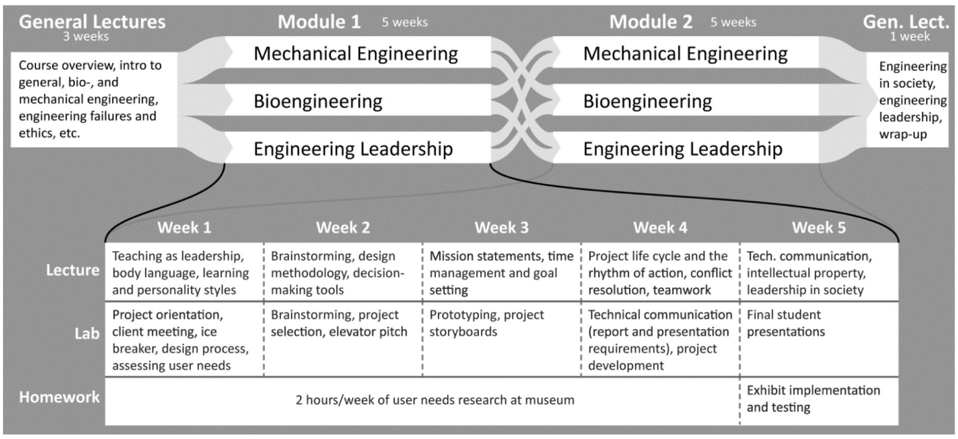

Fig. 1. Overview of the course structure and lecture topics for the freshman course, Engineering Design and *Analysis*. The bottom table shows the weekly breakdown of topics and activities covered in the engineering leadership module that students could choose to take for Module 1 or Module 2.

Table 1. Lecture topics in the leadership module

Development of self
Development of 3Cs of leadership: *competence*, *compassion*, and *chronos* (time management). Assessment of personal strengths and weaknesses. Building congruency, trust and ethical standards (development of a personal mission statement). Life balance and time management as a practice. Awareness of body language and voice. Strategic thinking and problem solving. Creativity, brainstorming and innovation. Review of primal leadership styles (visionary, coaching, affiliative, democratic, pacesetting, and commanding) [14]. Assessment of personal leadership styles.

Diversity and teamwork
Assessment of personality styles (Introverted vs. Extraverted; Intuitive vs. Sensing; Thinking vs. Feeling; Judging vs. Perceiving) [15]. Assessment of learning preferences (Global vs. Sequential; Intuitive vs. Sensing, Active vs. Reflective; Verbal vs. Visual) [16]. Decision trees and methods for mentoring. Group communication and conflict management tools [17]. Development of a plan of action (formulation, negotiation, fulfillment, and review). Project lifecycles and rhythm of action for teamwork.

K-12 outreach
Levels of learning based on the revised Bloom's taxonomy (remembering, understanding, applying, analyzing, evaluating, and creating) [18]. Teaching methodologies in the K-12 domain and the public sector. Assessment tools.

local science museum, the Lawrence Hall of Science (the Hall).

The motivation for adding the leadership module was to enhance professional skills in our first-year engineering students while broadening participation in engineering in the K-12 sector. It was our hypothesis that the activity of teaching to the K-12 sector in an informal science setting would improve engineering skill sets over those students who only participated in traditional modules. Moreover, because women tend to be drawn to engineering sectors that give back to society, we hypothesized that the confidence levels of women would reflect the benefit of the leadership module [11, 12].

The leadership module provides the framework for development of the core competencies of leadership [1]. A central focus of the leadership module is the development of the three "C"s of leadership in the students: competence, compassion, and chronos (time management). Central to this philosophy, the leadership module: presents mechanisms for developing personal and team leadership styles; addresses differences in learning and personality styles; provides pathways for implementing mission statements and plans of action; offers opportunities for strategic thinking, problem solving and brainstorming; utilizes teamwork in diverse settings; and implements K-12 service learning through outreach teaching activities. Table 1 provides a summary of the lecture topics provided within the leadership module framework. The technical foundation of this module is centered upon the process of engineering design and implementation of projects in collaboration with the Hall.

Within the leadership module, the freshmen have two primary options for their service learning design projects: they can choose to improve the design of an existing exhibit in the Hall or they can create a novel interactive exhibit that can later be developed into an exhibit on the main floor. Students choosing the first option are required to revise the facilitation process and add the encapsulation of the engineering design process (Fig. 2) to one of three interactive exhibits on the main floor, including the (i) *Fly High* exhibit that provides two types of wind tubes to test flying creations, (ii) *Design and Drive* exhibit that combines wheels, motors and treads to optimize vehicles for varying terrains, or (iii) *Build a Bridge* exhibit that utilizes simple structural elements to create unique bridge designs. Students choosing the second option make use of the *Ingenuity Lab,* which contains building blocks, motors, gears, programmable microchips, basic circuitry components and other materials, to develop a design challenge for visitors. The projects culminate with a technical report and oral presentation of the implementable design to the client (the Hall). Students submit self and team assessments after the project is completed.

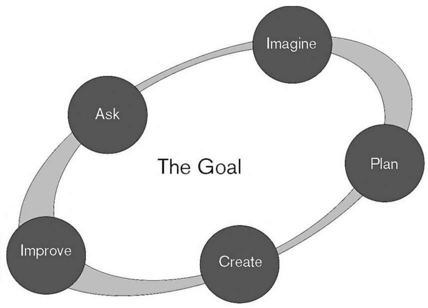

Fig. 2. Engineering is Elementary design loop (based on the design loop utilized by the Museum of Science, Boston [26]).

For the projects, the freshmen are assembled into teams of three to six based on variations in learning styles, the premise being that diverse groups can enhance outcomes and provide a more well-rounded educational exhibit for K-12 learners [16, 19, 20]. Undergraduate teams meet in a lab setting for three hours each week (15 hours total over the five-week module) and must also have two hours per week of user needs research through exhibit facilitation at the Hall (ten hours total over the five-week module). The service learning project requires the students to interact directly with K-12 learners in conducting user needs research and in implementing their final facilitation strategies and design challenges for making the engineering design process explicit to these learners at the Hall. This hands-on aspect of the leadership module is based on the "Engineering is Elementary" design process loop developed by the Museum of Science, Boston (Fig. 2).

2. Methodology

This paper presents data gathered from two sets of surveys during Spring 2011: one set (NAE–ABET course surveys) for all students in the first-year course and another (leadership module surveys) for only those in the leadership module. There were 125 students registered in the *Engineering Design and Analysis* course and 67 (54%) students took the leadership module while 58 (46%) students did not take it. We do note that these surveys are only self-assessments and not third party assessments of skills or abilities. However, these self-assessments reflect the students' confidence, which has been found to be correlated with achievement [21].

2.1 NAE–ABET survey

The NAE–ABET course survey was implemented in previous offerings of the Engineering Design and Analysis course in Spring 2008 and Spring 2009 [22]. We used this same survey in Spring 2011, and it was administered at the beginning and end of the course. Sixty-two of the 67 students that took the leadership module and 51 of the 58 students that did not take the leadership module returned both NAE–ABET course surveys; this provided us with a total response rate of 113 out of 125 students that turned in both the initial and final NAE–ABET course survey. The gender breakdown of the students within the leadership module that returned both surveys was 19 women and 43 men. The gender breakdown of the students not in the leadership module that returned both surveys was 15 women and 36 men.

The NAE–ABET course survey asked the students to "perform an honest self-assessment of the extent to which" they possess the engineering traits as described by the criteria in Table 2. The criteria are merged from the National Academy of Engineering Criteria for the Engineer of 2020 [23] as listed in Table 3 and the ABET accreditation criteria [13] as listed in Table 4. The students performed the self-assessment of the NAE–ABET engineering traits using a 1–5 Likert scale where 1 is Low, 2 is Medium–Low, 3 is Neutral, 4 is Medium–High, and 5 is High. In order to test for statistical significance, a two-tailed Student's t-test with equal variance was utilized with a confidence level of both 95% and 90%.

Table 2. Necessary skills for competent graduating engineers merged from NAE and ABET; 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

	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. National Academy of Engineering criteria for the Engineer of 2020 [23]

	National Academy of Engineering Criteria for The Engineer of 2020
1	Possess strong analytical skills
2	Exhibit practical ingenuity
3	Exhibit creativity
4	Good communication skills with multiple stakeholders
5	Possess business and management skills
6	Possess leadership skills
7	High ethical standards
8	Strong sense of professionalism
9	Possess dynamism, agility, resilience, and flexibility in an uncertain and changing world
10	Be lifelong learners

Table 4. ABET student outcomes criteria for engineering program accreditation [13]

	ABET engineering criteria
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 lifelong learning
j.	A knowledge of contemporary issues
k.	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

2.2 Leadership module survey

The leadership module survey was only given to those students taking the leadership module and was administered at the beginning and end of the five-week module. We have a response rate of 52 out of 67 students who took both the initial and final surveys.

The module survey is shown in Table 5. Questions were divided into two categories: one to rate individual confidence with regard to leadership qualities and another to evaluate how they perceive the role that leadership plays 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. As done with the NAE–ABET survey, the data was statistically evaluated using a two-tailed Student's t-test with equal variance at a confidence level of 95% and 90%.

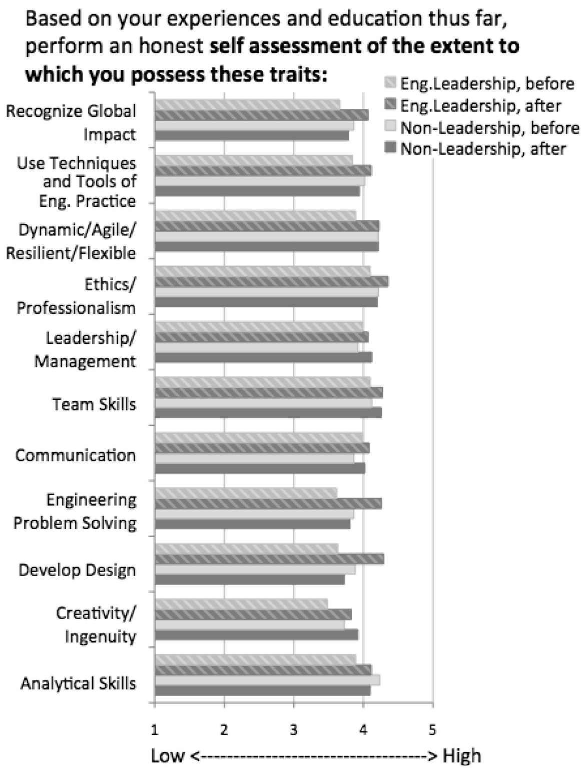

Fig. 3. Average before and after responses for self-assessment of NAE–ABET skills for students who did and did not take the engineering leadership module. $N = 62$ students in the leadership module (93% response rate); $N = 51$ students not in the leadership module (88% response rate).

3. Results

Within the leadership module, we found that students' confidence in engineering and leadership skills improved. We also found a greater positive change in confidence in engineering skills for students in the leadership module compared with other students in the course who were not in the leadership

Fig. 4. Average response of students' self-assessment of their leadership abilities, before and after they completed the engineering leadership module. $N = 52$ students (78% response rate).

Table 5. Questionnaire given to students in the leadership module 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.

module. However, we found little significant change in the leadership students' perception of engineering and leadership at the completion of the leadership module.

3.1 Leadership module improved confidence in engineering and leadership skills

All students in the course were given a pre- and post-survey, where students assessed their own engineering skills, as delineated by our NAE–ABET criteria. These skills are listed in Fig. 3 (and in Table 2) along with the average pre- and post-ratings for students in the leadership module and students not in the leadership module. As seen in Fig. 3 and Table 6, students in the leadership module increased their confidence in all eleven NAE–ABET skills of Table 2, with statistical significance in the following eight skills: strong analytical skills*, creativity**, develop design**, engineering problems**, ethical*, dynamic and agile**, use engineering techniques and tools*, and recognize global impact** (*$p < 0.10$, **$p < 0.05$). On the other hand, Fig. 3 and Table 7 show that students who did not take the leadership module experienced decreases in their confidence in the following skills: strong analytical skills, develop design, engineering problems, ethical, use engineering techniques and tools, and recognize global impact. It should be noted that these decreases were not statistically significant ($p > 0.10$) except for women's recognize global impact confidence level ($p = 0.07$).

3.2 Confidence in leadership skills within the leadership module

To specifically assess confidence in leadership skills, we looked at the pre- and post-surveys on leadership given to the students in the leadership module. We found a significant increase ($p < 0.05$) in confidence for all five leadership qualities for students in the leadership module (see Fig. 4 and Table 8).

Confidence in all five skills increased from an average of around 3–4 to above 4 on a 5-point Likert scale. Furthermore, within the perception component of the survey, we found that students rated the statement "I possess all the skills I need to become a good leader" significantly higher ($p = 0.02$) in the post-module survey (Fig. 5 and Table 9). A qualitative analysis of students' comments provides insights into the "skills" that the students stated they possessed to be a good leader. Students wrote that a leader must "*motivate/move others,*" "*train and integrate people into a system,*" "*identify priorities, . . . understand members of his [her]team and allocate them as resources,*" "*compromise and accept input from the people below him [her],*" "*be assertive . . . and have sharpened senses of time management,*" and have "*[a]ttention to administrative and logistical detail.*" A student emphasized the importance of patience: "*Patience! The ability to almost never get angry or lose one's temper.*" Finally, one student nicely summed up several key skills: "*To earn respect [from those he or she leads], a leader must demonstrate competence, a vision, and fairness. Competence includes . . . realizing potential in members.*"

3.3 Engineering and leadership perceptions

Despite the significant increased confidence of students in their engineering and leadership skills, we found that most of their engineering and leadership perceptions did not improve significantly. With the exception of the statement discussed previously, "I possess all the skills I need to become a good leader," leadership students only rated one other statement regarding engineering and leadership perceptions significantly better after the module: the students indicated an understanding that engineers do serve as leaders as they showed stronger disagreement with the statement "engineers rarely find themselves in leadership positions" ($p = 0.06$), as shown in Fig. 5 and Table 9.

3.4 Course impact on women and men

The completed responses from the NAE–ABET survey came from 19 women and 43 men in our leadership module and 15 women and 36 men in non-leadership modules. We found that women in our leadership module improved their confidence in all eleven NAE–ABET engineering skills (see Table 2). In particular, women in the leadership module improved considerably compared with men in all modules and women in the other modules. Furthermore, women in the other modules showed no significant increase in confidence in any skill at the end of the semester, and even decreased confidence in many skills. As seen in Fig. 6 and Tables 6–7, women in the leadership module increased the

Table 6. NAE–ABET skills confidence values for students who did take the engineering leadership module. Statistically significant results shown in bold ($p < 0.10$)

Criteria	Gender	Leadership	Mean	Sd dev.	$p \leq 0.100$
Recognize global impact	**All**	**Pre-Course**	**3.661**	**0.867**	**0.006**
		Post-Course	**4.065**	**0.721**	
	Female	Pre-Course	3.895	0.737	0.112
		Post-Course	4.263	0.653	
	Male	**Pre-Course**	**3.558**	**0.908**	**0.021**
		Post-Course	**3.977**	**0.740**	
Use techniques and tools of engineering practice	**All**	**Pre-Course**	**3.839**	**0.814**	**0.053**
		Post-Course	**4.113**	**0.749**	
	Female	**Pre-Course**	**3.789**	**0.535**	**0.006**
		Post-Course	**4.316**	**0.582**	
	Male	Pre-Course	3.860	0.915	0.383
		Post-Course	4.023	0.801	
Dynamic/Agile/Flexible	**All**	**Pre-Course**	**3.887**	**0.791**	**0.012**
		Post-Course	**4.226**	**0.688**	
	Female	Pre-Course	4.263	0.653	1.000
		Post-Course	4.263	0.733	
	Male	**Pre-Course**	**3.721**	**0.797**	**0.003**
		Post-Course	**4.209**	**0.675**	
Ethical	**All**	**Pre-Course**	**4.097**	**0.936**	**0.078**
		Post-Course	**4.355**	**0.655**	
	Female	Pre-Course	4.368	0.761	0.485
		Post-Course	4.526	0.612	
	Male	**Pre-Course**	**3.977**	**0.988**	**0.100**
		Post-Course	**4.279**	**0.666**	
Leadership	All	Pre-Course	3.984	0.896	0.587
		Post-Course	4.065	0.744	
	Female	Pre-Course	4.053	0.970	0.585
		Post-Course	4.211	0.787	
	Male	Pre-Course	3.953	0.872	0.788
		Post-Course	4.000	0.724	
Team Skills	All	Pre-Course	4.097	1.003	0.267
		Post-Course	4.274	0.750	
	Female	Pre-Course	4.211	0.976	0.345
		Post-Course	4.474	0.697	
	Male	Pre-Course	4.047	1.022	0.475
		Post-Course	4.186	0.764	
Communication	All	Pre-Course	3.984	0.983	0.535
		Post-Course	4.081	0.731	
	Female	Pre-Course	4.000	1.106	0.310
		Post-Course	4.316	0.749	
	Male	Pre-Course	3.977	0.938	1.000
		Post-Course	3.977	0.707	
Engineering problems	**All**	Pre-Course	3.613	0.754	**0.000**
		Post-Course	4.258	0.651	
	Female	**Pre-Course**	**3.368**	**0.684**	**0.000**
		Post-Course	**4.263**	**0.733**	
	Male	**Pre-Course**	**3.721**	**0.766**	**0.001**
		Post-Course	**4.256**	**0.621**	
Develop design	**All**	**Pre-Course**	**3.629**	**0.834**	**0.000**
		Post-Course	**4.290**	**0.663**	
	Female	**Pre-Course**	**3.316**	**0.946**	**0.003**
		Post-Course	**4.158**	**0.688**	
	Male	**Pre-Course**	**3.767**	**0.751**	**0.000**
		Post-Course	**4.349**	**0.650**	
Creativity	**All**	**Pre-Course**	**3.484**	**0.901**	**0.029**
		Post-Course	**3.823**	**0.800**	
	Female	Pre-Course	3.368	0.895	0.246
		Post-Course	3.684	0.749	
	Male	**Pre-Course**	**3.535**	**0.909**	**0.066**
		Post-Course	**3.884**	**0.823**	
Strong analytical skills	**All**	**Pre-Course**	**3.887**	**0.791**	**0.086**
		Post-Course	**4.113**	**0.655**	
	Female	**Pre-Course**	**3.632**	**0.597**	**0.070**
		Post-Course	**4.053**	**0.780**	
	Male	Pre-Course	4.000	0.845	0.380
		Post-Course	4.140	0.601	

Table 7. NAE–ABET skills confidence values for students who did not take the engineering leadership module. Statistically significant results shown in bold ($p < 0.10$)

Criteria	Gender	Non-leadership	Mean	Sd dev.	$p = 0.100$
Recognize global impact	All	Pre-Course	3.863	1.040	0.688
		Post-Course	3.784	0.923	
	Female	**Pre-Course**	**4.067**	**0.594**	**0.066**
		Post-Course	**3.600**	**0.737**	
	Male	Pre-Course	3.778	1.174	0.746
		Post-Course	3.861	0.990	
Use techniques and tools of engineering practice	All	Pre-Course	4.020	0.761	0.626
		Post-Course	3.941	0.858	
	Female	Pre-Course	3.800	0.775	0.682
		Post-Course	3.667	0.976	
	Male	Pre-Course	4.111	0.747	0.760
		Post-Course	4.056	0.791	
Dynamic/Agile/Flexible	All	Pre-Course	4.216	0.730	1,000
		Post-Course	4.216	0.879	
	Female	Pre-Course	4.267	0.799	1.000
		Post-Course	4.267	0.799	
	Male	Pre-Course	4.194	0.710	1.000
		Post-Course	4.194	0.920	
Ethical	All	Pre-Course	4.216	1.083	0.923
		Post-Course	4.196	0.960	
	Female	Pre-Course	4.733	0.594	0.382
		Post-Course	4.533	0.640	
	Male	Pre-Course	4.000	1.171	0.832
		Post-Course	4.056	1.040	
Leadership	All	Pre-Course	3.922	0.997	0.268
		Post-Course	4.118	0.765	
	Female	Pre-Course	4.067	0.594	0.532
		Post-Course	4.200	0.561	
	Male	Pre-Course	3.861	1.125	0.346
		Post-Course	4.083	0.841	
Team skills	All	Pre-Course	4.118	0.931	0.419
		Post-Course	4.255	0.771	
	Female	Pre-Course	4.400	0.632	0.776
		Post-Course	4.467	0.640	
	Male	Pre-Course	4.000	1.014	0.444
		Post-Course	4.167	0.811	
Communication	All	Pre-Course	3.863	1.077	0.446
		Post-Course	4.020	0.990	
	Female	Pre-Course	4.067	0.704	0.532
		Post-Course	4.200	0.414	
	Male	Pre-Course	3.778	1.198	0.548
		Post-Course	3.944	1.145	
Engineering problems	All	Pre-Course	3.863	0.775	0.707
		Post-Course	3.804	0.800	
	Female	Pre-Course	3.533	0.640	0.626
		Post-Course	3.400	0.828	
	Male	Pre-Course	4.000	0.793	0.878
		Post-Course	3.972	0.736	
Develop design	All	Pre-Course	3.882	0.683	0.315
		Post-Course	3.725	0.874	
	Female	Pre-Course	3.667	0.724	0.489
		Post-Course	3.467	0.834	
	Male	Pre-Course	3.972	0.654	0.449
		Post-Course	3.833	0.878	
Creativity	All	Pre-Course	3.725	0.981	0.293
		Post-Course	3.922	0.891	
	Female	Pre-Course	3.867	0.915	0.851
		Post-Course	3.800	1.014	
	Male	Pre-Course	3.667	1.014	0.169
		Post-Course	3.972	0.845	
Strong analytical skills	All	Pre-Course	4.235	0.790	0.355
		Post-Course	4.098	0.700	
	Female	Pre-Course	4.133	0.743	0.363
		Post-Course	3.867	0.834	
	Male	Pre-Course	4.278	0.815	0.624
		Post-Course	4.194	0.624	

Table 8. Leadership confidence values for all students that took the engineering leadership module. Statistically significant results shown in bold ($p < 0.05$).

General leadership qualities		**Confidence level (Leadership students)**		
As a leader, I . . .		**Mean**	**Sd dev.**	***p***
. . . can resolve conflicts with ease	**Pre-Module**	**3.577**	**0.776**	**0.033**
	Post-Module	**3.923**	**0.860**	
. . . have a strong sense of personal integrity	**Pre-Module**	**4.192**	**0.687**	**0.015**
	Post-Module	**4.500**	**0.577**	
. . . can define a clear vision	**Pre-Module**	**3.865**	**0.793**	**0.014**
	Post-Module	**4.212**	**0.605**	
. . . am empathetic	**Pre-Module**	**3.769**	**1.114**	**0.039**
	Post-Module	**4.173**	**0.834**	
. . . can communicate clearly	**Pre-Module**	**3.731**	**0.819**	**0.002**
	Post-Module	**4.192**	**0.658**	

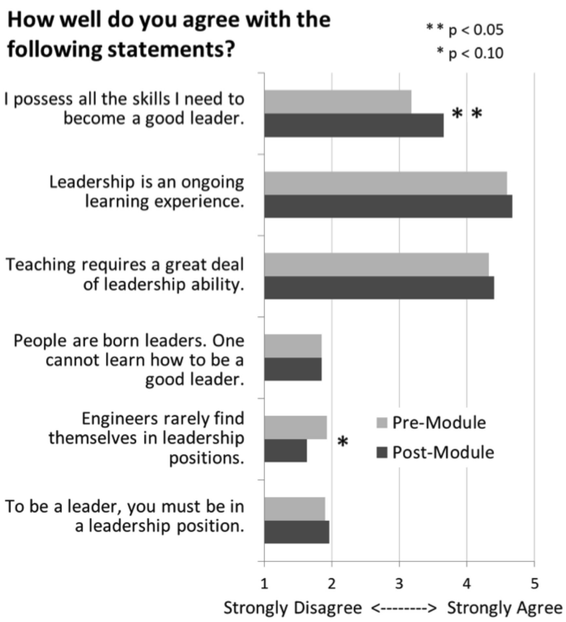

Fig. 5. Average response of students' perceptions of leadership statements, before and after completing the engineering leadership module. $N = 52$ students (78% response rate).

greatest on using techniques and tools of engineering practice, team skills, communication, engineering problems, developing design, and strong analytical skills. In contrast, men in the leadership module increased the most in recognizing global impact, being dynamic/agile/flexible, possessing high ethical standards, and creativity; men not in the leadership module increased the most in leadership.

Within the engineering leadership module, women's confidence increased more than men's confidence on all but four NAE–ABET criteria (see Fig. 6 and Table 6). Conversely, in all other modules, women did not surpass men in any positive change of confidence in NAE–ABET skills, and in most cases these women's self-assessed skills actually decreased after the modules. Figure 7(b) and Table 7 show that these women's self-ratings appeared to have evened out with the men's in the other modules, accordingly increasing or decreasing in confidence in NAE–ABET skills, whereas women in the leadership module increased in confidence across all skill sets, and many above the men in the class.

Table 9. Perception of leadership confidence values for all students who took the engineering leadership module. Statistically significant results shown in bold ($p < 0.10$)

Perception of leadership		**Confidence level (Leadership students)**		
Level of agreement: 1–5 Likert scale		Mean	Sd dev.	***p***
I possess all the skills I need to become a good leader	**Pre-Module**	**3.173**	**0.985**	**0.016**
	Post-Module	**3.654**	**1.008**	
Leadership is an ongoing learning experience	Pre-Module	4.596	0.693	0.542
	Post-Module	4.673	0.585	
Teaching requires a great deal of leadership ability	Pre-Module	4.327	0.648	0.560
	Post-Module	4.404	0.693	
People are born leaders. One cannot learn how to be a good leader	Pre-Module	1.846	0.697	1.000
	Post-Module	1.846	0.697	
Engineers rarely find themselves in leadership positions	**Pre-Module**	**1.923**	**0.813**	**0.057**
	Post-Module	**1.635**	**0.715**	
To be a leader, you must be in a leadership position	Pre-Module	1.904	0.823	0.731
	Post-Module	1.962	0.885	

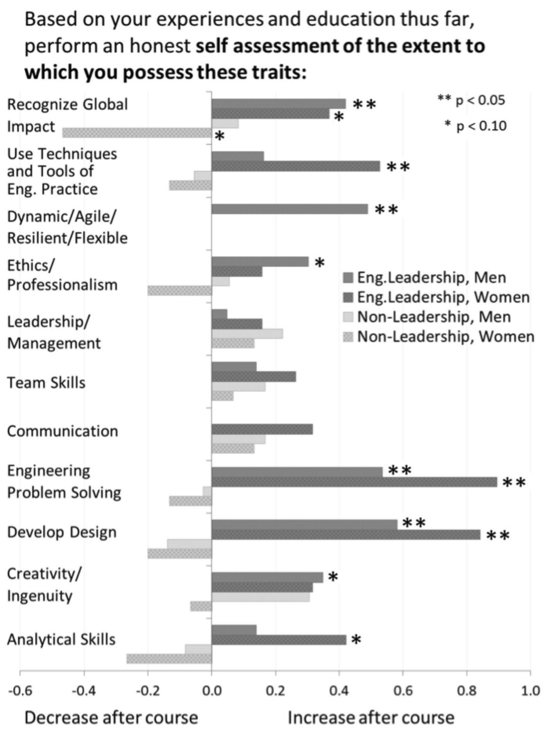

Fig. 6. Average change in men and women's self-assessment of NAE–ABET skills for students who took the engineering leadership module and students who did not take the leadership module. N = 62 students in the leadership module, 19 women and 43 men (93% response rate); N = 51 students not in the leadership module, 15 women and 36 men (88% response rate).

We do note that while the leadership students' confidence in three soft engineering skills particularly important to our leadership module (communication, team skills, and leadership) slightly increased, it was not statistically significant. However, Fig. 6 and Tables 6–7 show that all students in the engineering leadership module experienced no decrease in confidence in soft engineering skills while women students in the non-leadership modules experienced a negative change in confidence in soft engineering skills as it relates to creativity (avg. women confidence level before: 3.87; avg. women confidence level after: 3.80), ethics (avg. women confidence level before: 4.73; avg. women confidence level after: 4.53), and recognizing global impact (avg. women confidence level before: 4.07; avg. women confidence after: 3.60).

3.5 Comparison of women in leadership module with women in other modules

An astounding result is that women in our leadership module increased their confidence in all of the NAE–ABET skill criteria, while women in the other modules stayed the same or decreased their confidence in all NAE–ABET skills but communication, team skills, and leadership (see Fig. 6 and Tables 6–7). Statistically significant was the non-leadership women's decrease in their confidence to

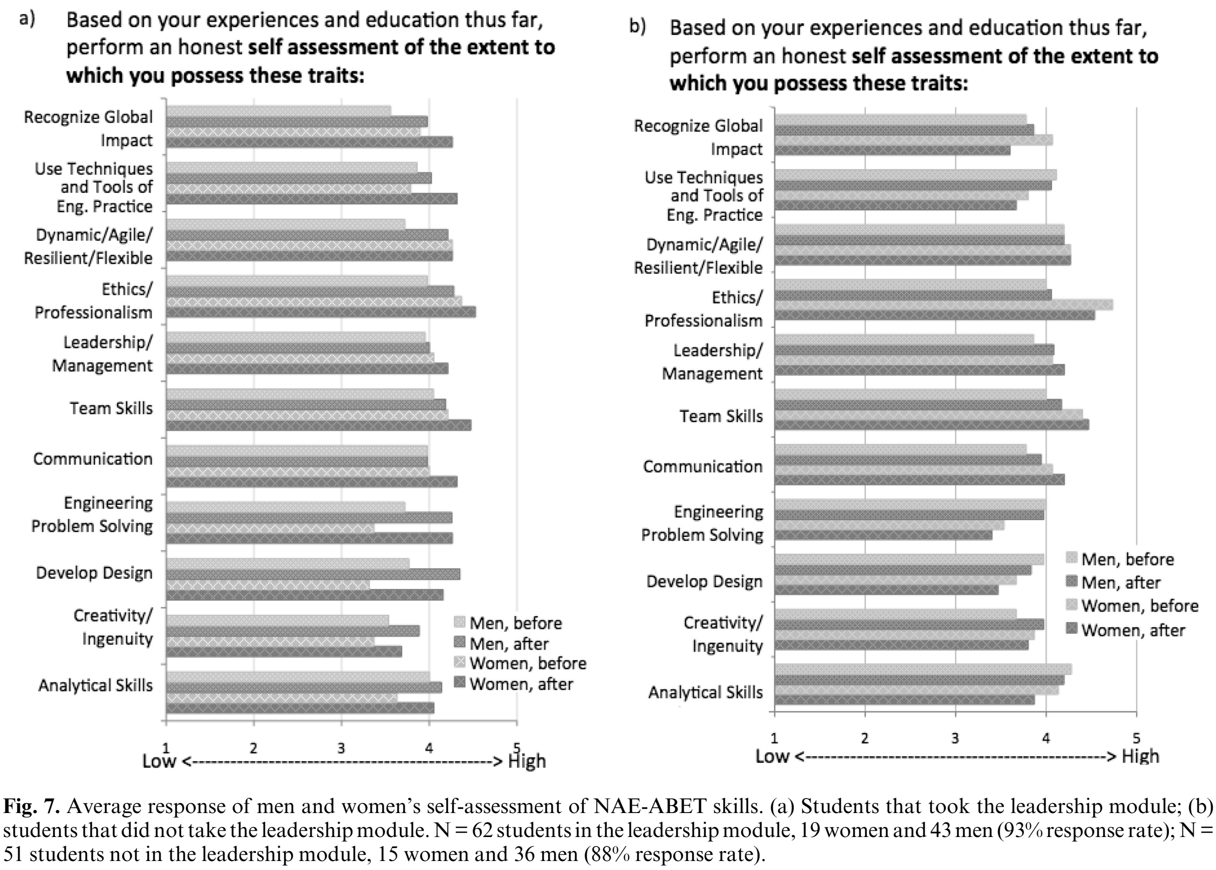

Fig. 7. Average response of men and women's self-assessment of NAE-ABET skills. (a) Students that took the leadership module; (b) students that did not take the leadership module. N = 62 students in the leadership module, 19 women and 43 men (93% response rate); N = 51 students not in the leadership module, 15 women and 36 men (88% response rate).

recognize global impact from 4.07 to 3.60 on a 5-point Likert scale ($p = 0.07$) and the leadership women's increased confidence in strong analytical skills ($p = 0.07$), the ability to develop design ($p = 0.003$), engineering problems ($p < 0.001$), and use of techniques and tools of engineering practice ($p = 0.006$).

4. Discussions

The leadership module in the first-year engineering course, Engineering Design and Analysis, diverged from other more technical modules typically offered in the survey course. The other traditional modules gave students weekly problem sets and laboratory assignments in addition to those from the students' other first-year courses. On the other hand, the leadership module provided students with the tools and resources to hone their leadership and professional skills and an opportunity to apply these skills in a service learning design project in teams. Dym *et al.* [24] conducted an extensive literature review of engineering education and recommended that cornerstone design project courses, or first-year design projects, should be implemented as they are strongly believed to increase interest, learning, performance, and retention of engineering students. Even though the benefits of these first-year projects are advocated, the lack of application and the sole focus on technical and theoretical aspects of engineering is still common in the first two years of engineering programs, thus providing students with little exposure to engineering practice [25]. By offering students the rare opportunity to engage in a hands-on real-world project in the first year, the leadership module allowed students to work with actual clients and end-users and with each other in teams. Through the service learning project and outreach teaching, students applied the skills they were learning in lecture to an authentic and personally relevant setting. Because this was a first-year course, the topics and projects were not overly technical, and consequently, the first-year students were still able to engage in the project at a level appropriate for their technical abilities.

Despite the focus on the softer professional skills of leadership, communication, teamwork, management, and ethics, we found no compromise in students' confidence in technical skills, which we believe to imply their actual technical abilities, as skills have been found to be correlated with confidence [21]. From our surveys, we found that students in our engineering leadership module had an increase in confidence in all NAE–ABET skills and leadership skills. For students not in the leadership module, we found either a smaller increase or even a decrease in confidence in most NAE–ABET skills when compared with our leadership students. Most striking, however, was the fact that the confidence of women in the leadership module improved significantly more than others in NAE–ABET engineering skills, especially in comparison with women in the non-leadership modules, who either decreased or had no change in their confidence in the majority of these skills. Women in the leadership module had the greatest increase in confidence on using techniques and tools of engineering practice, team skills, communication, engineering problems, developing design, and strong analytical skills. These results also show that the women in the leadership module had a greater positive change in most of the measured confidence in NAE–ABET skills compared with men in leadership and men in non-leadership modules, similar to results from previous research on the impact of service learning and professional skill development on women engineers [11, 12]. Furthermore, many minorities and women are drawn to careers that contribute to society [19, 22] and thus these service learning projects may improve recruitment and retention of these students. See [27] for more on the leadership module's impact on women.

The National Academy of Engineering found that current messages about engineering often ignore the soft skills that are crucial for success as a professional engineer [28]. The lack of improvement in our students' perception of leadership is possibly a result of this misconception of the profession of engineering. However, our study shows that courses can demonstrate the appeal of engineering and possibly increase retention by teaching engineers these important professional skills and providing an opportunity to put these skills in action in a real-world context. To exemplify, a majority of the post-module survey comments from students in the leadership module expressed overwhelming appreciation for the class, as they felt they had learned practical engineering and broader skills, and they enjoyed working in such a unique environment. One female student wrote:

> At the beginning, I [was] scared . . . and I even wanted to switch it to another module because of my limited speaking and leadership abilities. However, now I know that this class taught me a lot and opened the way to improve myself. . . I want to further improve my leadership skills and it was this module that showed me the necessity of it. Thank you for enlightening and supporting us!!

Our study is in line with another longer-term three-year study on a service learning design project for first-year mechanical engineering students to engage with K-12 learners [29]. Like the course studied in Tsang *et al.*'s paper [29], we received some resistance from students who were surprised by the leadership module's deviation from the norm. However, the majority of students reported statements similar to the female student's above, emphasizing the practicality and usefulness of the leadership skills for their engineering career and the invaluable experience working in teams as well as the amount of hard work required for the module, results also found by Tsang *et al.* Moreover, students felt that they were contributing to the community through this service to society. Unlike Tsang *et al.*, we further studied students' self-assessments of NAE–ABET skills, and the leadership students' statements confirm their greater increased confidence in recognizing global impact, using techniques and tools of engineering practice, ability to be flexible, ethics and professionalism, team skills, engineering problem solving, developing designs, creativity and ingenuity, and analytical skills when compared to students not in the module (see Fig. 3).

4.1 Limitations

Just as soft skills can be difficult to teach, they are also difficult to assess. A limitation of this study is that the surveys were students' self-assessments of their skills and we did not correlate confidence with module grades or other external assessments of skills. Also, the students who did not turn in both surveys were probably those not as engaged in the course and so the actual average increase in confidence might be slightly lower; however, completion rates of the ABET survey were similar for both leadership and non-leadership modules and should not affect the final trends. Furthermore, students may have self-selected into the leadership module, knowing the topic and content of the module beforehand and thus possibly inflating their self-assessment scores. However, most of the leadership students' initial self-assessments were lower than the non-leadership students' self-assessments. Another limitation is that all modules were taught by different instructors, and therefore some of the changes may be attributable to differences in teaching styles instead of differences in content. Similarly, the leadership module was taught by a female professor while the other modules were taught by males. Finally, women tend to rate themselves lower in terms of confidence [30, 31], and thus the results may have been negatively biased as indicators of their skills.

Future follow-up studies and longitudinal tracking of these students will provide better understanding of these students' retention and performance in engineering. Further studies on similar courses can also implement external assessments of skills in addition to students' self-assessments in order to explore and confirm the relationship between skill and confidence.

5. Conclusions

First-year engineering students benefited from our unique engineering leadership module, which emphasized professional "soft skills" in addition to the more traditionally taught hard technical skills. Students applied these skills in teams in a service learning design project, working with real clients and end-users. The NAE acknowledges that "engineers need to work in teams, communicate with multiple audiences, and immerse themselves in public policy debates and will need to do so more effectively in the future" [23, p. 43]. The engineering leadership module described in this paper is an approach to train the next generation of engineers who are well grounded in the fundamentals of math and science while also being grounded in effective leadership and communication skills. The statistical trends of students' survey responses and qualitative analysis of students' comments show no setback in their confidence in technical skills when compared with modules that were more traditionally taught, but instead show a gain in confidence across all engineering skills, soft and hard. In most NAE–ABET soft and hard engineering skills, leadership students' confidence increased more than the confidence of students not in the module. Therefore leadership skills may supplement and reinforce technical skills and can be taught and applied complementarily. In terms of the retention of women in engineering, Cech *et al.* [31] found in their study that the lack of confidence that women have in their professional ability and their ambiguity about how they fit into the engineering field contributes to their attrition in STEM fields. Our results therefore indicate that focus on the development of professional skills such as communication, teamwork, and leadership may be more effective in the recruitment and retention of women into engineering. Thus, professional skills should not be left out of the engineering curriculum and should instead be emphasized as early as possible to recruit, retain, and develop competent engineers.

References

1. S. Kumar and J. K. Hsiao, Engineers learn "Soft Skills the Hard Way": Planting a seed of leadership in engineering classes, *Leadership and Management in Engineering,* **7**(1), 2007, pp. 18–23.
2. National Academy of Engineering, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, Publication of the National Academy of Engineering, Washington, D.C., 2005.
3. National Research Council, *Engineering Education: Designing an Adaptive System*, National Academies Press, Washington, D.C., 1995.

4. L. Shuman, M. Besterfield-Sacre, and J. McGourty, The ABET "Professional Skills"—Can they be taught? Can they be assessed?, *Journal of Engineering Education*, **94**, 2005, pp. 41–55.
5. M. Lima and W. C. Oakes, *Service Learning: Engineering in your Community*, Great Lakes Press, Wildwood, 2006.
6. B. Amadei, Program in engineering for developing communities: Viewing the developing world as the classroom of the 21st century, *Annual Conference of the Frontiers in Education Conference, Institute of Electrical and Electronic Engineers*, November 5–8, 2003, Boulder, Colorado, pp. F3B1–6.
7. J. Duffy, *Projects That Matter: Concepts and Models for Service–Learning in Engineering: Service–Learning in a Variety of Engineering Courses*, American Association for Higher Education's Series on Service–Learning in the Disciplines, 2000, pp. 75–98.
8. K. Morton, A smart start to service–learning, *Journal of Business Ethics*, 15, 1996, pp. 21–32.
9. A. T. Jeffers, A. G. Safferman, and S. I. Safferman, Understanding K-12 engineering outreach programs*, Professional Issues in Engineering Education Practice,* **130** (2), 2004, pp. 95–108.
10. J. Eyler and D. E. Giles, *Where's the Learning in Service Learning?*, Josey-Bass Publishers, San Francisco, 1999.
11. National Research Council, *Engineering Education: Designing an Adaptive System*, National Academy Press, Washington, D.C., 1995.
12. S. Atwood, E. Patten, and L. Pruitt, Outreach teaching, communication, and interpersonal skills encourage women and may facilitate their recruitment and retention in the engineering curriculum, *Annual Meeting of the American Society for Engineering Education*, Louisville, KY, June 2010.
13. Accreditation Board for Engineering and Technology, Inc. (ABET), *ABET Engineering Criteria 2000*, ABET, Baltimore, 1998.
14. D. Goleman, R. Boyatzis, and A. McKee, *Primal Leadership: Realizing the Power of Emotional Intelligence*, The Harvard Business Review Press, Boston, 2002.
15. I. B. Myers and P. B. Myers, *Gifts Differing: Understanding Personality Type*, Consulting Psychologists Press, Palo Alto, 2nd edition, 1993.
16. R. M. Felder and L. K. Silverman, Learning and teaching styles in engineering education, *Engineering Education,* **78**(7), 1988, pp. 674–681.
17. S. Scott, *Fierce Conversations: Achieving Success at Work and in Life One Conversation at a Time*, Berkley Publishing, New York, 2008.
18. D. R. Krathwohl, A revision of Bloom's taxonomy: An overview, *Theory into Practice*, **41** (4), 2002, pp. 212–218.
19. E. Patten, S. Atwood, L. Pruitt, Use of Learning Styles for Teamwork and Professional Development in a Multidisciplinary Course, *Annual Meeting of the American Society for Engineering Education*, Louisville, KY, June, 2010.
20. P. Humphreys, V. Lo, F. Chan, and G. Duggan, Developing transferable group work skills for engineering students, *International Journal of Engineering Education,* **17**(1), 2001, pp. 59–66.
21. M. A. Hutchinson, D. K. Follman, M. Sumpter, and G. M. Bodner, Factors influencing the self-efficacy beliefs of first-year engineering students, *Journal of Engineering Education*, **100**(3), 2006, pp. 604–623.
22. L. Oehlberg, R. Shelby, A. Agogino, Sustainable product design: Designing for diversity in engineering education, *International Journal of Engineering Education*, **26**(2), 2010, pp. 489–498.
23. National Academy of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century*, Publication of the National Academy of Engineering, Washington, D.C., 2004.
24. C. L. Dym, A. M. Agogino, D. D. Frey, and L. J. Leifer, Engineering design thinking, teaching, and learning, *Journal of Engineering Education*, **94**(1), 2005, pp. 103–120.
25. National Science Board, *Moving Forward to Improve Engineering Education,* 2007, http://www.nsf.gov/pubs/2007/nsb07122/index.jsp, Accessed May 31, 2012.
26. Boston Museum of Science, *Engineering is Elementary*, www.mos.org/eie/, Accessed 13 January 2012.
27. J. Wang, E. Patten, R. Shelby, F. Ansari, and L. Pruitt, Leadership and service learning improves confidence of engineering skills in women, *Proceedings from the 119th ASEE Annual Conference & Exposition,* June 2012, San Antonio, TX.
28. National Academy of Engineering, *Changing the Conversation: Messages for Improving Public Understanding of Engineering*, National Academies Press, 2008.
29. E. Tsang, J. Van Haneghan, B. Johnson, E. J. Newman, and S. Van Eck, A report on service-learning and engineering design: Service-learning's effect on students learning engineering design in 'Introduction to Mechanical Engineering,' *International Journal of Engineering Education*, **17**(1), 2001, pp. 30–39.
30. S. H. Pulko and S. Parikh, Teaching 'soft' skills to engineers, *International Journal of Electrical Engineering Education*, **40**(4), 2003, pp. 243–254.
31. E. Cech, B. Rubineau, S. Silbey, and C. Seron, Professional role confidence and gendered persistence in engineering, *American Sociological Review,* **76**(5), 2011, pp. 641–666.

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