LEADERSHIP SKILLS AWARENESS AND DEVELOPMENT VIA INTERACTIVE ENGINEERING COURSES OR WORKSHOPS

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Leadership is a critical skill as engineers seek advancement in their careers and life. Recruiters seek employees who show promise or have already demonstrated leadership skills during their formal education or personal activities. Although these facts are well-recognized, our engineering educational process does little to build awareness and develop the necessary leadership skills in students and early-career engineers. Appreciation for the lack of practice and experience in this realm generally becomes evident when the engineer is placed in a leadership or management role for the first time. Despite technical competency and good intentions, the outcome is frequently frustration and often a return (sometimes aided by supervisor or management decisions) to more hard-core technical activities.

An engineer's formal education primarily ensures that technical competency has been achieved and that the need for continuous learning has been established. We expect that passion and motivation for engineering/science and an interest in identifying and pursuing significant problems have also been instilled. Although these are critical and essential attributes and skills, they are not sufficient for a successful career in leadership or management. A large number of additional traits and abilities are required; these are generally designated as "soft" or professional skills.

Although opinions differ with respect to whether leaders are born or made, this is not a debate that is appropriate here. Some individuals have personality traits and characteristics that allow soft skills and leadership development to proceed rapidly with (seemingly) minimal obstruction, but improvement and heightened effectiveness are always possible. Irrespective of the initial conditions, most individuals' natural talents need enhancement if they are to become talented and effective leaders. This fact should be made clear to students and opportunities suggested or offered to further develop their abilities in this important area. This can be accomplished by encouraging them to be involved in leadership activities either within their department or university through student groups or organizations, or in extracurricular activities.

Faculty members often expect that professional or soft skills are learned by students working in teams in required courses such as unit operations, process control, and process or product design, or in internships, co-ops, or academic research groups. However, students are given little if any information describing expectations in such positions, how to function or behave in team activities, and how they might develop consensus, collegiality, and trust within the team. Faculty members often see the result of this missing expertise when a request is received to remove or "correct the behavior of" one of the team members. Of course, such pleas are not

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limited to academic institutions; industrial employees make analogous appeals.

The need for development of, training in, or exposure to leadership traits for students and early- to mid-career engineers and scientists has arisen from a number of sources. For example, recruiters assess leadership potential as part of the interview process and leadership continues to be a significant part of engineers' evaluation and career advancement opportunities. This point has been stated succinctly by Russell and Yao[1]:

> *An engineer is hired for his or her technical skills, fired for poor people skills, and promoted for leadership and management skills.*

In addition, a number of surveys, curriculum outcome evaluations, and discussions of future needs for engineering graduates have indicated the importance of developing professional or soft skills during the formal education process.[2-12] Furthermore, ABET Criterion 3 calls attention to the need to function on multidisciplinary teams, understand professional and ethical responsibility, communicate effectively, and understand the impact of engineering solutions in a context that includes global, economic, environmental, and societal issues.[13] A survey of engineering undergraduates who are within 10 years of completing their degrees reveals that, of the ABET competencies, the most important to engineering graduates are teamwork and communication, followed by data analysis, problem solving, math/science/engineering skills, and ethics.[8] Although skills such as decision making and ethical behavior receive limited attention in degree programs for engineers (and scientists), they are generally not integrated with other critical skills such as change management, risk taking, influencing others, resilience, building and running teams, and running effective meetings.

Studies have demonstrated that alternatives to the sole use of instructor lectures when offering course material are needed for the effective development of professional skills in students. For instance, problem-based learning can be implemented through the formation of student teams that discuss course content and address complex, open-ended, and ill-defined technical or people dilemmas, and thereby expose students to a variety of viewpoints and approaches.[14-18] These methods ensure that students participate directly in the learning process rather than remain passive learners. They also connect technical expertise to written and oral communication within and outside of the technical community; this subject has been referred to as sociotechnical communication.[17] Such activities also generate considerable knowledge of and insight into the risks, uncertainties, and tradeoffs involved in building consensus, making decisions, and effectively leading teams.

Formal technical leadership training and exposure to case studies have been undertaken by several engineering colleges within the United States.[5,6] Typically, these efforts comprise a minor or track that requires a minimum of four to six courses that are offered in business and engineering departments and may offer a study-abroad component. Although such programs supply depth in leadership theories and approaches, they are difficult to incorporate into a four- or even five-year B.S. program and thus can be unattractive to students.

TECHNICAL LEADERSHIP COURSE AND WORKSHOP DEVELOPMENT

To address the need for leadership awareness and education that can be incorporated into a four- or four-and-a-half-year B.S. program, and to integrate communication and ethics principles with situations typically encountered in engineering positions, formal courses for graduate and undergraduate students as well as workshops in technical leadership were developed and offered in the School of Chemical & Biomolecular Engineering at Georgia Tech; courses have been offered annually since 2015. Content and approach for the courses and workshops are described in the following sections. As with the introduction or incorporation of any new topic or focus within a curriculum, a template or guide is needed to avoid extensive faculty effort to gather and organize the necessary material. The notes developed for this purpose have been turned into in a textbook that facilitates coverage of appropriate topics and thus can serve as a resource for anyone interested in teaching this content to technically trained individuals, running workshops that cover specific leader attributes and dilemmas, incorporating leadership scenarios or examples into core courses, or learning more about the subject matter.[18]

Although the terms leadership and management are sometimes used interchangeably, the duties involved in the respective roles are not the same and it is important that students understand the difference. Leadership and management activities require the ability to deal with "people issues," indicating that some of the traits needed are similar in both roles; however, clear distinctions exist. For instance, leaders typically inspire others and promote a vision that represents a grand challenge; this demands risk-taking and considerable resilience because failure can be the outcome. Leaders also develop and mentor extensively those reporting to them. Managers primarily oversee current activities and ensure that standards are met, tasks completed on time, protocols followed, and that processes and product specifications are controlled closely. Risk is avoided because this can yield uncontrollable and irreproducible results. Clearly, leader and manager mindsets are therefore distinct and actions and directions divergent. Effective organizations require both skill sets, but they are generally assigned to different individuals.

The education garnered by an engineer predominantly assures that he/she learns problem-solving and critical thinking skills by solving numerous problems to gain perspective regarding how to tackle existing technical problems and thus

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develop the ability to address problems not previously encountered. This same formalism can be employed to prepare students and early-career engineers for leadership or management roles. Many students have encountered leadership or management problems in their internship, co-op, or research efforts, but little if any guidance or insight was supplied to deal with such matters. Most of us have learned ways of addressing these situations through our own (or others') positive and negative experiences; our attempts are described appropriately by a quote credited to several individuals (Mark Twain, Rita Mae Brown, and Will Rogers):

> *Good judgement is the result of experience and experience the result of bad judgement.*

Although effective, this approach has resulted in increased frustrations and in considerable time wasted. A number of mistakes, some of which can have long-lasting career and even personal consequences, are sometimes made as new leaders gain experience. Rather than relying on bad judgement to develop needed experience during initial leadership positions, success and comfort level are facilitated if practice in and insight into such roles and representative scenarios commonly encountered in early-career leadership are obtained during the formal education process. This type of proactive approach to development of the necessary skill set to function as proficient leaders can be invoked by introducing a variety of situations followed by the use of interactive discussion of viable approaches to resolve or at least manage such situations. This can be accomplished by formal courses, workshops, or lectures in the leadership arena.

Process and product design courses require time management, decision making, teamwork, communication, and organization skills that are characteristic of effective leaders; these experiences are common causes of frustration for students. Many years of teaching required chemical and process safety courses have demonstrated to me that students have little practice and perspective when making decisions where few, if any, right (or even wrong) answers exist, and few data and facts are available. Such problems require the generation of optimum solutions since numerous competing factors must be considered and the "best" or most appropriate one selected. Such scenarios are ubiquitous in leadership positions, because many possible paths or approaches can be taken and each has specific consequences, consistent with technical decisions in process and product design. In addition to performing scientific/engineering optimization, leaders must deal with biases, values, priorities, and personalities of team members, which is a complication unfamiliar and exasperating to most engineers at early (and sometimes later) stages in their career, but these issues are a significant and critical part of technical leadership. Analogous to the way students have learned to address technical problems or issues, this "new" skill set can be developed by offering opportunities to consider and debate possible approaches to dealing with realistic technical situations where discussions are held, decisions made, and consequences realized under emotional or ego-dominated circumstances.

The courses developed at Georgia Tech were initiated to address the lack of leadership education, awareness, and training characteristic of most chemical & biomolecular engineering (ChBE) graduates, as well as other engineering and science graduates. Initially, a course was offered to third- and fourth-year Ph.D. students as a 1-credit pass/not-pass elective titled, "Technical Leadership, Professionalism, and Decision Making." Background on leadership skills and approaches was discussed, and a number of situations encountered frequently by early-career leaders or managers posed. In small groups, the students discussed these situations and then presented summaries of their discussions to the class; subsequent debate and critique of the various alternatives presented identified consequences of the various approaches offered. Course evaluations from the 17 students enrolled indicated that the content was of considerable interest for and helpful to students. Representative comments were:

- *soft skill development was very useful*
- *useful for job search*
- *course was discussion-based so we could learn from each other*
- *should offer more scenarios and case studies for group discussion*
- *offer more reading assignments and homework to expand coverage*
- *anecdotes about personal experiences in leadership were very helpful*
- *should be required for all ChBE graduate students*

This outcome and feedback resulted in a discussion with Chair David Sholl about whether a leadership course would

be especially useful for last-semester junior or rising senior ChBE undergraduates since they are beginning their interview process. In addition, within a few years they will be placed in supervisory roles in manufacturing and production, and they can draw on this background during research efforts if graduate school is their destination. As a result, a 3-credit course of the same title was subsequently offered with essentially the same topical areas. However, the number and frequency of homework and reading assignments were greatly expanded; in addition, quizzes, literature critiques, in-class readings, and numerous discussion topics/questions were incorporated. We decided that the course should satisfy a requirement for the ChBE degree so that it would not necessitate finding time for yet another course. Since a B.S. degree in ChBE at Georgia Tech requires two ChBE electives and two technical (non-ChBE) electives, it was offered as a technical elective. After completion, student evaluations and comments regarding the undergraduate course were very similar to those offered by the graduate students. The only negative comments offered related to the request for still more examples and further discussion, despite the fraction of class time allocated to these activities (>40%).

Topics covered in the graduate and undergraduate courses are listed in Table 1. The first half of the course describes the background for leadership. An important focus in this section revolves around the specific traits, characteristics, and approaches typically used by technically trained individuals to solve problems that yield both positive and negative results in early- and mid-career leadership positions. Emphasis is on the reaction to and consequences of the technical mindset and behavior by subordinates, peers, and bosses/supervisors. This leads to a discussion of how to overcome these tendencies and build credibility and trust in leadership positions. Such discussions are especially important because engineers and scientists frequently feel that their technical capabilities and accomplishments should be sufficient to gain respect, credibility, trust, and success in leadership positions; this is seldom true. Personal values, ethical and professional behavior, emotional intelligence, the ability to manage time, the building of trust and credibility within a team or organization, and the enhancement of creativity and confidence that leads to risk taking are discussed because these are essential principles and abilities for effective leaders; extensive information on and methods to cultivate these skills can be found in a variety of references.[18,19-24] Furthermore, the ability to lead others is predicated on the ability to lead oneself as described below.

TABLE 1
Technical Leadership Topics

Leadership/Management Definitions/Distinctions
Frustrations for Engineers/Scientists in Early- and Mid-Career Leadership Positions
Positive and Negative Leader/Manager Traits/Skills
Ethics and Professionalism
Personal Values, Self-evaluation, Emotional Intelligence, and Interpersonal Leadership
Time Management
Building Credibility and Trust
Creativity and Risk Taking
Vision Creation
Team Building and Teamwork
Establishing a Questioning Team/Organization Culture
Running an Effective Meeting
Making Decisions and Managing Change
Conflict Management
Communication
Presenting Difficult Messages to Others

Emphasis is on the reaction to and consequences of the technical mindset and behavior by subordinates, peers, and bosses/supervisors. This leads to a discussion of how to overcome these tendencies and build credibility and trust in leadership positions. Such discussions are especially important because engineers and scientists frequently feel that their technical capabilities and accomplishments should be sufficient to gain respect, credibility, trust, and success in leadership positions; this is seldom true.

The second half of the course concentrates on application of the basic principles described initially to address typical situations encountered in early- and mid-career leadership. The trust and credibility established by the leader facilitates efficient and effective operation and functioning of a team. In addition to displaying creativity, a leader's role includes the formulation of a vision that the team/organization buys into so that team members desire to be part of a grand scheme, thereby

invoking motivation and drive. Creation of a team that is collaborative, collegial, and resilient requires that members are comfortable with, open to, and participate in critical evaluation of all efforts. When this culture exists, improved decisions result and the ability to change is facilitated. The leader must conduct meetings in an effective and efficient manner while promoting open discussion and encouraging input from those with alternative views. Of course, effective communication among all involved is essential to ensure that goals and directions are understood and to avoid misunderstanding and limit unjustified conflict. When conflict exists, this condition must be managed to permit appropriate decisions to be made and the project to be moved forward successfully with support or at least acceptance from all involved. When unpleasant news and difficult messages must be conveyed, leaders must perform these distasteful duties in ways that show respect and empathy for everyone involved.

TECHNICAL LEADERSHIP COURSE ACTIVITIES

There are a number of assignments and activities that comprise successful completion of the course. Assessment of student performance is based on several criteria. For the pass/not-pass graduate course, attendance and participation in the discussions are the primary consideration; only a few homework sets are assigned. In the undergraduate course, attendance, homework (including a paper on a technical visionary), quizzes, participation in class discussions, and oral presentations constitute the assessment criteria. The majority of these assignments are described in more detail in the following paragraphs.

In order to offer industrial perspective to students in the course(s), I frequently ask an engineer or scientist who has been employed for some time in industry to give a lecture. My suggestion for content is that they describe their experiences with leadership (personal and observed) as they progressed from their starting position to their current position; the person whom I have been fortunate to attract for this effort is Rick Zalesky, who is a retired vice president from Chevron. The students are intrigued by his description of situations and attitudes he encountered, how these situations/attitudes varied as his position changed, and how different situations were resolved or managed.

Leader Self-assessment

The starting point for effective leadership is for the leader to be self-aware, to recognize his/her biases, and to be able to control reactions and responses to situations that are stressful. As a result, I incorporate numerous homework questions that ask students to evaluate who they are, how they react to circumstances, and how their behavior might be better controlled. Therefore, each student is required to perform self-assessment of values, priorities, and biases. Example homework questions for self-assessment are shown in Table 2. Answers or responses to these questions are insightful both to the one responding and to the one listening and grading, and offer the opportunity to suggest ways of approaching or dealing with difficulties. Particularly important responses can be stated generically and discussed in class. Equally important is that such assignments build awareness of the students' own reactions and identify biases, beliefs, and priorities that may not have been recognized previously, but account for individual behavior. This sets the stage for students to recognize how their personal traits and characteristics affect the way they view situations, the manner in which they interact with others, and how their experiences affect decision-making.

Interactive Activities for Leadership Development

A central theme in the development of leadership skills and perspective in this course is interactive discussion of scenarios typically encountered by early-, mid-, and even later-career technically trained individuals. These discussions allow me to stress the fact that one technical leadership style does not fit every (or even most) individuals and situations, but that the leader

TABLE 2
Examples of Self-assessment Questions (from Reference 18)

What life- or career-changing events or experiences have led to your current situation or goals?
What obstacles are currently impeding the accomplishment of your goals?
After reading the list of values offered by C. Roberts (<http://www.selfcounseling.com/help/personalsuccess/personalvalues.html>): • Which 5 values are most important to you? • Which 5 values are least important to you? • What other (not listed) values are important for you personally and especially for you in a technical career or leadership position?
Describe a situation where you reacted negatively or in anger. • What caused this reaction? • What would have been a more effective reaction in this situation? Why did you not react this way? • Are there situations or frustrations that you are currently experiencing or that you anticipate in the near future where you may react badly? • How can you ensure that you will react appropriately? • Is anger ever an appropriate reaction to a situation?
Do you believe that leaders are born or made/developed? Explain.
Have you taken advantage of or sought opportunities in your professional or personal life to practice leadership within a small or large group? • If you have not, what has kept you from seeking such activities? • If you have, what were your successes and failures? • What traits are needed for you to be more effective in future leadership efforts?
Do you have aspirations to be a technical leader/manager at a middle administrative level (*e.g.*, academic department head, division head) or higher (dean, provost, VP, CEO) at some point in your career? • Why do you aspire to this goal or why do you want to avoid such positions? • What do you expect will be the rewards of such positions? • What do you expect will be the most frustrating part(s) of such positions?

must tailor his/her approach according to the existing circumstances. Discussions are implemented in the following way. I first present information on one of the topics listed in Table 1; generally, this is done with 5-10 PowerPoint slides. Following this background, I introduce a "Discussion Question," where a specific situation is described. Students are divided into groups/teams of four to five (fewer or larger sizes seem to limit the responses or allow students to be non-participatory, respectively). To permit students to get to know many of their classmates and to promote diversity in ideas, attitudes, and perspectives, I rotate the team membership once or twice during the semester. I typically limit course enrollment to 25-30 students, since more students and/or larger group sizes inhibit open discussion due to students' hesitation to share opinions and outlooks. Even in a workshop setting, the number of students should be limited to a few dozen to ensure facilitation of the discussion format that is critical to effective learning and debate.

After 5-7 minutes of group discussion, I ask each group to report their conclusions and suggestions; I insist that the "spokesperson" change with each discussion question so that everyone has a number of chances to summarize and describe the group conclusions, thereby supplying practice in oral communication. After each group has presented their views, the entire class discusses the most appropriate approaches and indicates the consequences (good and bad) of the various tactics suggested. When appropriate, I play "devil's advocate" to describe a likely outcome of certain approaches. This also gives me an opportunity to relate closely related situations and outcomes (individual names excluded) that I have experienced or heard about. Students are quite enthusiastic to learn about the actual outcome along with the ramifications of certain decisions or approaches. This supplies important perspective that they would garner only by making particular mistakes or having a variety of experiences. According to the evaluations at the end of the course, this activity and the evaluation of literature articles (see below), are the most effective and stimulating parts of the course.

The discussion scenario description sometimes yields an interesting response from one or more students: "I saw almost that exact situation during my (co-op or internship)." If I subsequently ask how the situation was resolved, a typical response has been "When I left the position, the issue had not been resolved." Such replies invite further discussion of how the situation might have been handled given the specific culture and personalities within that organization and thus what might be expected from different approaches.

The best way to indicate the types of questions that I pose is to offer a few examples. Table 3 presents a few discussion questions that I have used; many more are presented in Reference 18. As with most leadership dilemmas, there are numerous possible approaches to such scenarios and the "best or optimal" approach may differ depending upon the team or organization member personalities, culture, or time allotted to dealing with the situation. The lack of a definitive approach is often frustrating to technically trained individuals who have typically been taught to seek "the correct" answer rather than a spate of possibilities where none are ideal (the exception is in courses such as process or product design, but most students take these courses during their last semester in the program). Excessive training to identify the correct answer can translate into a closed-minded approach to alternative or diverse views of a situation where different priorities or demands exist. The questions offer the opportunity to expose students to open-ended problems and approaches that involve individuals' biases, emotions, experiences, priorities, and values; students have already seen a number of these situations, but many of them believe that if everyone had a technical background, logic would prevail and decisions would be simple. Clearly, that is not the case, since even individuals with technical backgrounds and mindsets make decisions based on emotions and (stated or unstated) biases.

TABLE 3
Examples of Leadership Discussion Questions
(adapted from Reference 18)

You have given a specific task that is part of a larger project to one of your team members. Despite significant time and suggestions from you and other team members, she has still not made progress toward the goal nor has she figured out why her attempts have been unsuccessful. During your meeting with her to understand what is limiting her ability to complete the task, she tells you that she has been struggling with this project, has lost enthusiasm and motivation, and feels that she is unable to complete the assignment. • How do you deal with this team member? • What options do you have to move the task and thus the overall project forward?
When building trust and credibility, discuss the relative importance of: • Technical competency and accomplishments. • People skills. • Suggest scenarios where one might be more important than the other versus when they would be equally important.
When building your team to attack a difficult process control problem, the team would benefit from the expertise of an employee who has an extensive and impressive skill set and numerous accomplishments relating to the problem at hand. However, this person is extraordinarily difficult to work with, is a naysayer, is confrontational, and alienates everyone around him. • Should you enlist him for the team? • What are the consequences if you do or do not enlist this person? • How does an effective leader deal with such individuals? • Are you sometimes this person? • What measures can you take to encourage everyone on the team to help or support each other?

Critical Evaluation of Literature Articles and Opinion Papers

Literature, opinion, and news articles that deal with various aspects of leadership (or the lack thereof) are rich sources of discussion and recognition of disparate outlooks. I assign at

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least three of these as literature critiques and a number more for homework and in-class readings. When the assignment is completed or the class members have finished reading the short article or editorial handed out in class, open discussion of the content and possible answers to questions posed is initiated. These sessions typically begin with a general question from me such as: "What were your primary impressions or take-home messages from this article?" By the time we begin such assignments (usually halfway through the course), the students have lost most of their inhibition about speaking up and debating the issues raised; normally, someone quickly responds and the debate/discussion is on.

Again, the most effective way to describe these activities is to give a few examples. Table 4 offers recent articles and associated questions raised in such assignments. Clearly there are no correct answers to such issues; rather the response depends upon the experience, values, and priorities associated with each individual. This fact leads to diverse approaches and views that build awareness of alternative ways to consider a specific scenario. Such considerations offer the opportunity to discuss reasons why conflict arises when making decisions and the importance of understanding the assumptions, beliefs, and values behind different opinions.

Quizzes

As in core courses, quizzes are used to assess the understanding of concepts discussed in class and ensure that the assigned reading material has been comprehended. Reading material can be articles or books; References 18 and 19-24 are good sources of background information on specific topics covered and supply additional details that can serve as fodder for questions. In addition to conceptual understanding, some questions ask the student to address situations that are posed.

Written Report on a Technical Visionary

To exemplify some of the traits that technical visionaries display and how they manifest in accomplishments, one of the course assignments asks students to select a technical visionary, whose accomplishments have altered the course of a technological or scientific field or opened an entirely new field of study. This person must have lived within the past 50 years. No two students may select the same visionary. Students prepare a written report of 1,200-1,500 words that includes background on the visionary (credentials, experience, personality), the specific vision developed, how realization of the vision altered previous paradigms in this field or

TABLE 4
Examples of Literature Articles or Opinion Papers for Discussion (from Reference 18)

Caroline Baillie (*Materials Today*, April 2009, p. 6) offers a view regarding decisions that a professional makes concerning how she/he can or should use their skills and to whom we should offer these skills in the workplace. The author did not want to write an article on the benefits of asbestos that her boss requested due to the safety concerns involved with that material. • Do you feel that the benefits of a material or technology are unimportant when safety concerns exist? Justify your answer. • The author commented that "I resigned from the PR job without writing the piece. Resigning cost me nothing—I would get another job." Do you agree with this action/conclusion? Explain. • Do you feel that if there are policies and practices in your organization with which you disagree, *e.g.*, safety concerns, ethical questions, technologies that could be used for war, that you should not accept such a position or that you should resign if already employed? Explain.
When corporate profits, technology, and social responsibility intersect, company decisions are called into question. Consider the situation related to the drastic increase in the price of EpiPens, used by many individuals to save lives when someone experiences allergic reactions (<https://www.usatoday.com/story/money/business/2016/08/22/two-senators-urge-scrutiny-epipen-price-boost/89129620/>) • How might corporations, consumers, insurance companies, and technical leaders resolve such issues? • What responsibilities do the various constituencies involved in this issue have? • Who or what organization should make the final decision? • What role does the technical leader play in such scenarios?
Read the article entitled, "The Stretch Goal Paradox" by Sitkin et al. (*Harvard Business Review*, January/February, 2017, p. 93). • What are the primary considerations that must be taken into account when establishing a stretch goal? • What is the difference between risk aversion and not pursuing stretch goals? • Could stretch goals be a major component in the failure of a large fraction of technical startup companies? Explain.
Read the articles "A Woman's Path to the C-Suite" (*Chemical Engineering Progress*, September, 2017, p. 33), and "Robert Langer: From an Ugly Duckling to Singular Swan" (*The Bent of Tau Beta Pi*, Fall, 2017, p. 24) and discuss the following: • How do the leadership paths that Carol Williams (Dow) and Bob Langer (MIT) took differ? Are these distinctions due to the fact that one was industrial and the other academic? • What aspects of their paths were similar? • What obstacles did each overcome to get to the level of achievement they realized, and what was their attitude about these obstacles?

developed a completely new approach/direction, and the ultimate impact the vision has had or is likely to have. A minimum of five references for the material amassed must be included, and Wikipedia can be only one of the sources. Some students have specific individuals whom they want to select for this assignment. However, I encourage them to consider a number of other possibilities before they make their choice. I ask that they look at lists of the members of the National Academy of Engineering, National Academy of Inventors, National Academy of Sciences, Nobel Prize Awardees, and topics in the Leonardo Project[25] before submitting their selection.

Oral Responses to Leadership Dilemmas

During the course, students are given considerable practice in written communication, because they critique a variety of articles and must expound on a number of personal issues as already described. I also require at least one oral presentation to simulate a situation where they have to respond to someone (subordinate, peer, or boss) regarding a sensitive issue. The leader's response must be succinct and informative, with clarity the primary goal. I assign a different scenario to each team, and each member independently formulates and ultimately presents their monologue which addresses directly the request by the subordinate, peer, or boss, or responds to a situation that has been posed. Each person is allowed 3 minutes to deliver his or her monologue. Following each presentation, evaluations are performed by other members of the class to assess the presentation quality, the content, and the ability to handle the issue assigned; I also enlist one or two other faculty members to assist the grading of these presentations. After all presentations for each scenario are completed (*i.e.*, each team member has presented on the scenario assigned) and the evaluation forms collected, the entire class, including faculty members present, discusses the most appropriate responses or approaches to deal with these situations and indicates the problems with various approaches. Two examples of scenarios that involve requests made by subordinates are shown in Table 5.

CONCLUDING THOUGHTS

Upon graduation, engineering (and science) undergraduate and graduate students are typically well-prepared for success in technical problem solving. However, they have had little exposure to the vagaries associated with the interplay of "people" and technical problems (sometimes referred to as sociotechnical efforts), especially as related to service as the leader of small or large groups. They also have had limited, if any, opportunity to integrate communication skills and ethical behavior with decision making, risk taking, and running meetings. Since well-defined rubrics to address such issues are not available, and "correct" solutions are evasive at best, students and early- to mid-career engineers frequently display frustration and anxiety when initially placed in such positions. Courses and workshops can offer background on technical leadership and build awareness of and approaches to typical problems encountered on teams. Interactive discussion of possible underlying causes for the emergence of these complex multi-faceted issues, along with consequences (good and bad) that ensue from the specific decisions made, assists development of the skill set needed to deal effectively with uncertainty and problems created by personalities, beliefs, biases, and emotions. Furthermore, these discussions offer the opportunity to indicate that although "correct or perfect" solutions to such problems are unlikely, approaches acceptable to the engineers, scientists, and administrators involved must be devised and decisions made. The discussions uncover biases, values, and priorities held by individuals and thus allow recognition of and appreciation for disparate views and beliefs that can subvert effective communication and decision making. Such exposure to limitations in making decisions and realizing consensus smooths the transition from technical expert to technical leader. Tangential benefits include preparation for interviews where leadership abilities and aptitudes are probed, and the development of better "followers" since these individuals will have a heightened appreciation for issues that must be dealt with by the leader.

Although courses and workshops that offer interactive approaches to technical leadership development would benefit virtually all engineering (and science) majors, practical limitations exist. Class sizes greater than ~30 limit both the instructor ability to interact closely with the teams established and the opportunity for each student to participate directly in the discussion and present oral reports. Since student evaluations indicate that the team discussion followed by class discussion of leader scenarios posed is the most instructive part of the course, class size should necessarily remain low. Faculty workload can therefore be affected and the number of students who can take the course/workshop restricted. Alternatively, specific examples or content can be incorporated into courses, especially laboratory or design (team-based) courses, to ensure core curriculum exposure to leadership approaches.

TABLE 5
Examples of Oral Discussion Scenarios (from Reference 18)

An individual who reports to you has requested two weeks of vacation time when a major deadline/report is approaching. The request has been made to take advantage of an extraordinarily inexpensive airfare and attend a family gathering.
One of the high-performing individuals who reports to you has requested a transfer to a different division because she refuses to continue to work on the same team with one of her colleagues.

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