AC 2012-4462: DEVELOPING AND ASSESSING LEADERSHIP IN ENGINEERING STUDENTS

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Teaching and Assessing Leadership in Engineering

Abstract

The College of Engineering and Technology at Brigham Young University is focusing on five initiatives: Leadership, Innovation, Global Awareness, Character, and Technical Excellence. Efforts in the realm of leadership include freshmen leadership seminars and a required sophomore course entitled Global Leadership in a Technological World. Departments within the college are expected to build on this foundation in the junior and senior years.

The Chemical Engineering Department has developed an effective and efficient program to further develop and assess leadership skills. The first challenge in this process was to come up with a working definition of "leadership" with enough substance that we could deal in concrete principles and practices. Through discussions with our Industrial Advisory Board, we developed a list of leadership characteristics important in engineering practice which constitutes this working definition.

Although there are team experiences in most of our courses, we have designated one course in each semester from the second semester of the sophomore year through graduation in which to focus on and assess leadership skills. In each team experience in these courses, students use the list of leadership characteristics as a basis for giving feedback to their teammates. Then each student uses the feedback from his/her teammates to develop a brief plan to make improvements. This plan is then implemented in the next team experience which may be later in the same course, or in a subsequent semester. Feedback, improvement plans, and closing-the-loop evaluations are all compiled in a web-based portfolio which grows with each subsequent experience so that by graduation each student has a rich record of leadership experiences with successes, challenges, and improvements neatly documented. This process of continuous-improvement efforts tied to periodic feedback mimics the professional practice of regular performance evaluations.

The entire process is student-driven so that it adds very little to faculty work load. Student engagement and their efforts to implement goals can be assessed from the portfolio for the purposes of grading. Also, students readily see the value of cultivating their leadership skills, and therefore student buy-in is high.

Introduction

It has been widely emphasized that the engineer of today and of the future needs much more than technical competence to successfully face the challenges and opportunities of a globalized, competitive economy. James J. Duderstadt, director of the University of Michigan's Millenium Project, a research center that explores the impact of emerging technologies on society, said "In addition to analytic skills, which are well provided by the current education system, companies want engineers with passion, some systems thinking, an ability to innovate, an ability to work in multi-cultural environments, an ability to understand the business context of engineering,

interdisciplinary skills, communication skills, leadership skills, an ability to adapt to changing conditions, and an eagerness for lifelong learning. This is a different kind of engineer from the norm that is being produced now." [1]

In "The Engineer of 2020. Visions of Engineering in the New Century," The National Academy of Engineering included leadership in their recommended attributes of the engineer that is prepared to meet the challenges of this century. They said, ". . . engineers must understand the principles of leadership and be able to practice them in growing proportions as their careers advance." [2]

While president of ASEE, Ronald Barr said, "We have to produce American engineers who are not only obviously technically well-grounded but more talented at things like creativity, leadership, communication and professionalism so that when a company hires an American engineer it expects him or her to lead that company or an international group of engineers." [3]

In 2005 the College of Engineering and Technology at Brigham Young University launched a program consisting of five initiatives aimed at preparing our graduates to meet the challenges of engineering in the twenty-first century.[4] These initiatives are Leadership, Innovation, Global Awareness, Character, and Technical Excellence. The expectations inherent to these initiatives have been developed over the past several years as different committees of faculty have been charged with defining and formulating the concepts and practices for the realization of these goals.

Leadership

A faculty committee formulated a process to teach and develop leadership skills that consists of introductory seminars in the freshmen year, a course entitled "Moral Leadership in a Technological World" for sophomores, and then department-developed activities and assessment in the junior and senior years. These upper division activities are to build on the foundation developed in the sophomore course, in which students are taught and given opportunities to practice leadership principles.[5, 6]

Even with the foundational work in the sophomore course, it has proved challenging to succinctly define the concept of leadership for the purpose of developing upper-division activities, particularly in terms of curricular expectations. It has also been challenging to assess value added by these activities, since students come into our program with a wide variety of leadership experience.

To arrive at a working definition of leadership that would best serve our purposes, we made it a focus for our annual meeting with our Industrial Advisory Board. We asked this group of professional and industrial leaders to list leadership attributes and expectations that are important in their organizations. These were compiled and further refined to produce a list of attributes that constitutes our functional definition of leadership. This list is shown in Table 1. This list of leadership traits encompasses principles of management of self, interactions with others, and organizational effectiveness.

Table 1. Leadership Qualities of a BYU Chemical Engineer.

A BYU chemical engineer is a leader in a globalized society because she/he:

1. Exhibits high ethical standards.
2. Is reliable and can be counted on to accomplish tasks in a manner that exceeds expectations.
3. Takes initiative rather than waits for assignments.
4. Follows as well as leads.
5. Identifies problems ***and*** solutions.
6. Takes time to evaluate personal performance as a team member and improves when needed.
7. Receives criticism and makes changes where appropriate.
8. Demonstrates a good attitude on life and is pleasant to work with.
9. Is an effective communicator, including being a good listener.
10. Gives honest feedback to others and helps them succeed in their responsibilities.
11. Understands the personality traits of self and others and can work with others in accomplishing tasks.
12. Is culturally sensitive and works effectively with people from diverse backgrounds.
13. Develops vision in his/her scope of responsibility.

Notable in this list is the prominence of teamwork skills. Many leadership skills are equally well and commonly labeled teamwork skills. This list is probably not perfect, but it is a good, functional list and it is ours. That ownership has contributed to a higher degree of faculty enthusiasm for the implementation process than if we had adopted a list from an outside author or organization. As mentioned earlier, we struggled in the initial stages of development of this program because we struggled to formulate a working definition of leadership; however, this list became our working definition, and there was immediately a sense of clarity about what we were trying to accomplish and how we might approach assessment.

Students come into our program with a wide variety of leadership experience. Contrast this with a typical chemical engineering science topic, such as the second law of thermodynamics. Most incoming students have very little experience with such a principle and so everyone is starting at the same place, and therefore structuring curricular activities to develop an understanding of such a principle is fairly straightforward. Assessment is also straightforward, since we have a clear expectation for mastery of the topic. However, with the principles of leadership the starting point is varied, and so it seemed wise to develop a personalized process in which students could progress from where they are through a self-stylized plan.

Proposed Process

There are several team project experiences built into most engineering curricula. These are natural opportunities to learn, think about, and apply leadership skills. The essence of our proposed process is for students to use these experiences to develop their own skills in a continual process - from one team project to the next - of practicing, receiving feedback, making plans for improvement, and then practicing again. However, since most courses have but one project experience, the process has to be programmatic - spanning several semesters - so that each student experiences multiple cycles.

We have designated one course in each semester beginning in the second semester of the sophomore year and continuing through the senior year (two courses are used in the second semester of the senior year), in which to institute and document this process. These courses include the sophomore Material and Energy Balances course, the junior Energy, Environment and Safety course and the Heat and Mass Transfer course, and the senior Unit Operations Laboratory courses and the Process and Plant Design course.

In each of these courses students receive some instruction about teamwork and leadership pertinent to the class project and are reminded of our working list of leadership attributes. Then near the end of the project, students complete team evaluation surveys which include providing written feedback about leadership/teamwork skills and practices for each member of their team.

Each student takes the feedback from all of their teammates, evaluates their own performance, and formulates a plan, consisting of a couple of goals dealing with these teamwork/leadership skills, to focus on in the next team experience. This "next" experience will, except in the case of the Unit Operations lab, occur in the next semester. (The Unit Operations laboratory courses includes several projects allowing the cycle to be completed several times in each semester.) A typical statement of this feedback and improvement plan assignment is shown in Table 2.

Table 2. Feedback and Improvement Plan Assignment

- Referring to the List of Leadership Qualities [in Table 1], provide for each member of your team a description of one or two strengths he or she possesses and one or two aspects of teamwork or leadership where improvements could be made. These will be compiled with feedback from the other members of your team and distributed to the appropriate individual.

- Once you have received the feedback from your team members, submit (1) a brief summary of the feedback, (2) an evaluation of your own performance (including a reflection on your goals from your previous team project), and (3) a statement of your plan of how you will improve your teamwork and leadership abilities in your next team experience.

In the next team experience students focus on this plan that they previously developed to improve their leadership skills. At the end of this experience students again give and receive feedback,

they evaluate themselves, make new goals, and the cycle repeats itself. By the time students graduate they have a record of about ten meaningful team/leadership experiences with documented feedback and their efforts and progress in developing these skills.

In addition to the intrinsic value of this process in developing skills, the record itself will be a valuable resource for interviewing when a recruiter asks about leadership and teamwork experiences. This process also helps students prepare for workplace where receiving and responding to criticism is a regular part of professional practice.

To manage the communications and documentation of this process we have developed a web portfolio tool. Student feedback is given and accumulated via this tool, and the plans for improvement are also input there. With each new project student refer to the documentation in their portfolio to remind them of the goals they have set. Faculty can see (for the purposes of monitoring and grading) the communication, but there is virtually no added workload for faculty. The student workload in also minimal. Evaluations have always been an expectation in team projects, but this process adds the vision of specified leadership skills to the process. The added workload is the formulation of an improvement plan with each team experience and building on this in subsequent experiences. This is an exercise that takes approximately 30 minutes each time. We perceive that the cost/benefit ratio for this activity is very favorable.

These portfolios are valuable records for the students, but also a great resource for faculty as documentation of the impact of this program and for accreditation.

Results and Conclusion

This process has been used over the past two years and our experience leads to two significant observations:

1. Students are enthusiastic about the process. This enthusiasm comes from their recognition of the relevance and importance of these skills for their future pursuits, whatever they might be.

2. Student skills are improving. From student assessment of the process, individualized improvement plans, and documented efforts to improve we have evidence that student skills are improving.

Table 3 below shows a small sample of student statements included in their plans for improvement. These demonstrate the enthusiasm for the process and hint at the potential impact.

Table 3. Student Statements in Their Improvement Plans

Student 1 (Sophomore)

"This was really the first group that I've worked on that lacked a strong leader, and I could tell that we all were wishing that one of us was a stronger leader. So, from this experience, I really want to focus on my initiative, and really taking control of situations as they come up.

Something that I am going to do to achieve this goal is to prepare myself for group meetings, come prepared with an outline of how I personally think that the project should be carried out, instead of just expecting things to be done at the meeting.

Student 2 (Senior)

Strengths Identified by Teammates:

Good at being proactive and getting ahead on work
Easy to work with
Willing to help and completed tasks in a timely manner
Good team work, took your share of the load

Areas for Improvement Identified by Teammates

Be more organized in writing, I repeated myself a couple of times in the draft
Share more ideas, you have good ideas.
Speak up a bit more and continue to offer your opinion even if unsure about it
Take control of a situation if we are off task and try to split up work so we can accomplish more

Specific Goals for the Next Lab Experience

Seeing as how two of them deal with speaking up more, I will speak up more and offer my opinions and say what I think about the situations and problems.

Student 3 (Senior)

The other members of my group mentioned that I am technically competent but that I need to work on my communication skills as well as my ability to delegate responsibilities. I agree with both of these criticisms. I have been working to improve my communication skills for a few years now (at the request of associates and now my wife) but I know that there is still room to improve. I have been reading the book *How to Win Friends and Influence People* which provides a lot of valuable insights on how to effectively communicate and work with others. As I start my new job after graduation, I plan to use every opportunity to stretch myself and practice the leadership skills I have learned in the Chem E program.

Table 4 shows an example for a student who has closed the loop by working on the goals from one project in the next. This example comes from the Unit Operations Laboratory in which there are several projects and hence several opportunities to complete the cycle in each semester.

Table 4. Example of Student Improvement in Leadership/Teamwork Through Closing the Loop.

Student (Senior)

Project 3

Strengths Identified by Teammates

- Good at being proactive and getting ahead on work
- Easy to work with
- Willing to help and completed tasks in a timely manner
- Good team work, took your share of the load

Areas for Improvement Identified by Teammates

- Be more organized in writing, I repeated myself a couple of times in the draft
- Share more ideas, you have good ideas
- Speak up a bit more and continue to offer your opinion even if unsure about it
- Take control of a situation if we are off task and try to split up work so we can accomplish more

Specific Goals for the Next Lab Experience

Seeing as how two of them deal with speaking up more, I will speak up more and offer my opinions and say what I think about the situations and problems.

Project 4

Goal Based on Project 3

I will speak up more and offer my opinions and say what I think about the situations and problems.

Efforts in Relation to Goal

I spoke up a lot more at the beginning of the project but I think I tailed-off a little more towards the end as one of my teammates mentions in one of the weaknesses, but overall I do think that i have improved on speaking up more

Strengths Identified

- Good at getting work done. You are good at focusing and getting stuff done
- Nice analyzation skills. Good at taking initiative
- Really easy to work with
- Understands assignments and gets them done promptly

Areas of Improvement

- Not good at knowing weaknesses
- You seemed a little quiet at times. I don't know if you were confused or if you understood it perfectly but it kind of threw me off. Be more assertive

Specific Goals for the Next Lab Experience

I think although I have improved on what my original goal was I want to continue improving that weakness until it becomes a strength, so my goal is to speak up even more and make verbal contributions.

The involvement of students in the process of giving and receiving feedback and of working to improve is monitored by the instructor in order to assign credit. Students who enthusiastically participate typically get full credit, whereas students who make superficial efforts, or do not

make efforts to close the loop get less credit. However, this is not a time-consuming grading activity, since it is fairly easy to tell if students are serious about this process. Our experience is that almost all of our students invest themselves in the process.

One key to this process is its individualized nature. We have chosen to not specify a one-size-fits-all standard of leadership skills that is expected of all of our students, partly because of the difficulty in managing the diversity of student experience coming into the program. Also, it is prohibitively difficult to quantify a standard in these types of skills. Instead we have chosen to focus on a value-added approach, tailoring a system that takes each student from where they are when they enter the program to a higher place.

We are excited about this low-cost, high-impact process and expect it to continue to pay dividends in the lives of our students. However, a couple of concerns should be considered as this type of activity is contemplated. It is important to optimize the number of team project experiences to build into the system: too few and the potential benefits of the process will be only partially realized; too many and students may lose their enthusiasm for the process, as the exercises becomes too closely spaced and too redundant. Since our process is fairly new, there may be some adjustments made in the number of courses we include in future years. A second concern is that projects are typically placed at the end of the semester when there are numerous course evaluation surveys for students to complete. The potential for students to benefit from the process of giving and receiving feedback and setting goals may be diminished if students become jaded by the burden of too many evaluation/feedback exercises all at once. Scheduling projects a little earlier in the semester can help to alleviate this problem.

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