The Engineer as Leader: Course Design

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ABSTRACT

Engineers must possess leadership skills even as new graduates. These skills can distinguish graduates from one institution and another. The Industrial Advisory Board of the Wichita State University (WSU) College of Engineering has committed to direct involvement in the delivery of "The Engineer as Leader" course. The objective of developing a course that provides a significant learning experience is realized through a constructivist approach. This paper presents the motivation, content, and the development process of such a course.

MOTIVATION

The College has a very active Industrial Advisory Board that suggested an elective course in leadership based on their experience with similar programs developed in their firms. These industry-based programs are focused on developing leaders in their engineering organizations. Several of the committee members asked to be part of the course delivery. Therefore, the objectives for the course require the integration of a variety of perspectives with implications on content, delivery, and pedagogy.

A quick review of other leadership courses developed by colleges of engineering indicates that they too were developed at the request of an industrial advisory group (Crawford 1998, Farr 2009, Martinazzi 2004). The external stimuli for the development of this type of course may point to the difficulty of identifying faculty and departments that view this topic as being within their expertise. Leadership is not typically part of an engineering faculty members graduate training.

The strategic vision of the college also provided impetus for the course. As part of the strategic plan of the College of Engineering the objectives relating to curriculum are to:

- Ensure that students have a quality educational experience,
- Become recognized for its "experience–based" education model, and
- Be the Engineering academic programs of choice in the region.

In response to these, the College instituted an Engineer 2020 program that requires graduates to complete three of six activities (Whitman, et al. 2007):

- Undergraduate Research
- Cooperative Education/Internship
- Global Learning/Study Abroad
- Service Learning
- Leadership
- Multi-Disciplinary Education

These activities were identified through the National Academy of Engineering's "The Engineer of 2020: Visions of Engineering in the New Century" and ABET Criterion 3 (Table 1). The

resulting interest in technical and civic leadership, points to the "maturing" of the engineering profession. "As technological innovation plays an ever more critical role in sustaining the nation's economic prosperity, security, and social well-being, engineering practice will be challenged to shift from traditional problem solving and design skills toward more innovative solutions imbedded in a complex array of social, environmental, cultural, and ethical issues." (Duderstadt)

Table 1 The characteristics of engineers identified by the National Academy of Engineering and the Accreditation Board for Engineering and Technology

Attributes of Engineers 2020 (NAE 2004)	ABET Required Outcomes 3(a-k)
Strong analytical skills	an ability to apply knowledge of mathematics, science, and engineering an ability to design and conduct experiments, as well as to analyze and interpret data (a)
Practical ingenuity	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 (c)
Creativity	an ability to identify, formulate, and solve engineering problems (e)
Communication	an ability to communicate effectively (g)
Business and management	an ability to function on multi-disciplinary teams (d) Broad education to understand the impact of engineering solutions in a global and societal context (h), and knowledge of contemporary issues (j)
Leadership	Functioning on multidisciplinary teams (d)
High ethical standards and professionalism	an understanding of professional and ethical responsibility (f)
Dynamism, agility, resilience, and flexibility	
Lifelong learners	A recognition of the need for and the ability to engage in lifelong learning (i)

CONTENT

The purpose of this course is to increase the effectiveness of individuals in organized efforts, not to teach about leadership. Leadership has been long studied and a wide variety of theories developed involving personal traits, charisma, or behavior have been proposed. Other theories have focused more on the situation (power or function) and yet others on the integration of personal and situational factors (contingency theory). "We view leadership as a process directed toward assisting a group to accomplish a goal, vision, or common purpose" (Crawford, 1998).

Farr correctly identifies the importance of individual development in leadership. "This focus on building strengths and skills sees in each individual the ability to become a better and more effective leader. It is a moot discussion to debate whether leaders are born or made – rather they are all born with varying abilities, and some are developed better and hone those abilities more than others." (Farr, 2009)

Table 2 Topics identified by the Industrial Advisory Board as important for an engineering leadership course.

Overview	Fundamentals of Leadership (Overview and Self Awareness)
Self Development	Developing our Leadership Capability, Capacity & Know-How (Personal Development…putting it all together)
Inspiring	Inspiring the Technical Professional & the Team and the Boss (Key Competency)
Technical Environment	Fundamentals of Effective Leadership in a Technical Environment (Overview of Fundamentals)
Technical Teams	Fundamentals of Leading and Managing a Team in a Technical Environment (Application of Fundamentals)
Communication	Effective Communication as a Technical Professional (Key Competency)
Strategy	Concepts in Strategic Leadership (Facing Business Realities)
Systems Thinking	Systems Thinking - What Engineers Bring to the Game (Key Competency)
Global Perspective	Working and Leading within a Global Value Chain (Facing Business Realities)
Innovation	On the Job Innovation, Creativity and Risk Taking (Facing Business Realities)

ENGR 301, "The Engineer as Leader" is an undergraduate three credit hour course at the Junior-Senior level. It was scheduled as a three-hour period one night a week in order to minimize conflict with other courses and is designed to present the topics identified by the Industrial Advisory Board (Table 2), in the context of the "softer" attributes identified by the NAE and outcomes (Schuman, et.al, 2005) expected by ABET (Table 1). The basic concepts identified by the Industrial Advisory Board are addressed in the leadership attributes identified by a variety of authors (Table 3). The commonalty of these topics provides the opportunity for providing students a variety of alternative presentations of important concepts.

Table 3 A selection of published leadership attributes.

Skills of effective leaders & citizens (Crawford, 1998))	Five key leadership practices (Brown & Posner, 2001)	Visionary Leadership Behaviors (Dixon, 2009)	Leadership Attributes (Farr, 2009)	Pillars of Servant Leadership (Greenleaf, 2002)
Knowledge and Thinking Skills	Challenging the Process	Capable Management	Big Thinker	Character
Personal Skills	Inspiring Shared Vision	Reward Equity	Ethical & Courageous	Others
Relationship Skills	Enabling Others to Act	Communication Leadership	Masters Change	Skilled Communicator
Group Facilitation Skills	Modeling the Way	Credible Leadership	Risk Taker	Compassionate Communicator
Goal Management Skills	Encouraging the Heart	Caring Leadership	Mission that Matters	Foresight
Visioning Skills		Creative Leadership	Decision Maker	Systems Thinker
Political Skills		Follower-Centered Leadership	Uses Power Wisely	Moral Authority
Social Responsibility Skills & Ethics		Visionary Leadership	Team Builder	
		Principled Leadership	Good Communicator	

A concept not explicitly addressed by most of these authors is "followership." Dixon observed that higher levels of follower behavior are demonstrated at higher levels of the organization than at the lower levels. This is expected given the increased importance of team based focused and collaborative nature of modern organizations. "Effective Leader-Follower cohorts have evolutionary potential to address the most difficult problems" (Dixon, 2009). She identifies the effective follower behaviors as:

- Assume Responsibility. Followers take responsibility for themselves and the organization by demonstrating a sense of ownership.
- Serve. Followers show similar strength of conviction and commitment as does the leader in pursuing the common purpose
- Challenge. Followers work diligently in helping the leader to be consistent in word and deed and are willing to initiate confrontation in order to examine the actions of the leader and group when appropriate.
- Participate in Transformation. Followers recognize the need for transformation and champion the need for change.
- Take Moral Action. Self-growth or organizational-digression may require a courageous follower to separate from the leader(s).

Incorporation of experience in developing effective follower behavior should be part of any discussion of leadership. The structure of an organization incorporating effective Leader/Follower cohorts is illustrated in Figure 1 with the leader/follower relationship changing as domains of knowledge and skill change throughout a project.

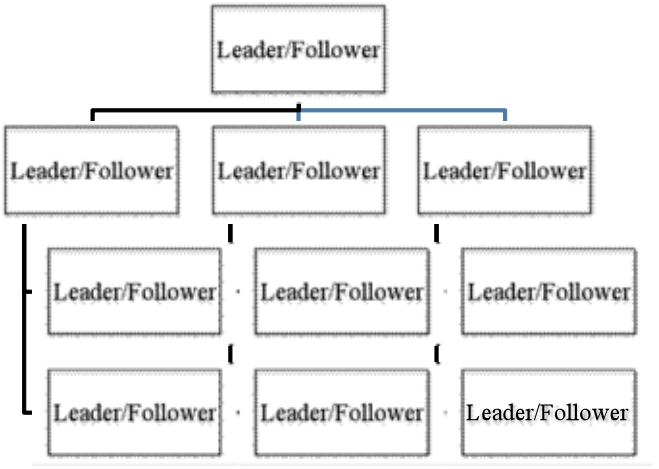

Figure 1 The Leader/Follower model for multi-disciplinary teams.

These "follower" behaviors and the transitioning to and from leadership roles is a unique component of the course under development.

This course is design to provide a significant learning experience that produces a significant long-term change in behavior. Fink concludes that significant learning experiences are characterized by:

- "A process:
  - Engaged: Students are engaged in their learning
  - High energy: Class has high energy level
- Results, Impact, Outcomes:
  - Significant and lasting change: Course results in significant changes in the students, changes that continue after the course is over and even after the students have graduated.
  - Value in life: What the students learn has a high potential for being of value in their lives after the course is over, by enhancing their individual lives, preparing them to participate in multiple communities, or preparing them for the world of work." (Fink, 2002)

Brown and Posner (2001) state that "leadership development programs and approaches need to reach leaders at a personal and emotional level, triggering critical self-reflection, and providing support for meaning making including creating learning and leadership mindsets, and for experimentation." This is a different kind of experience than is typical in an engineering course. Figure 2 illustrates one of the differences. Most engineering courses focus on external (observable) knowledge/awareness and skill. The typical learning process (lecture and reading) and the assessment process (examinations and assignments) demonstrate this. Leadership development requires significant internal (observable only to self) knowledge/awareness (who am I?, what do I want?) and skill/ability (how do I manage my desires and emotions?). When

these internal developments are expressed in external behavior, they may be assessable, but that may be too far removed from the initiation to provide effective learning.

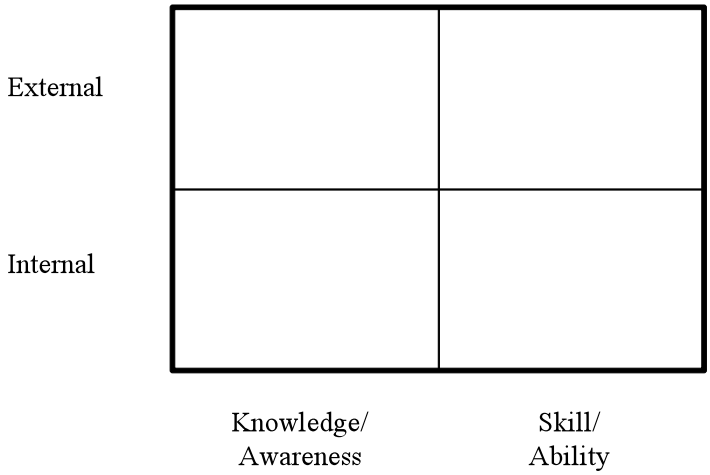

Figure 2 Domains of learning and assessment.

PROCESS

We have chosen to follow Dee Fink's (2002) guidance in designing the course. He suggests that we execute a **"**Backward design" of a course. The typical order of course design is:

- Identify content to be covered (pick a book)
- Sequence/schedule topics (assign chapters to calendar)
- Develop lecture content (develop slides and assignments for topics)
- Develop learning goals for topics (based upon the lectures developed above)
- Generate assessment (from selected homework like problems and "trick" questions)
- Modify to fit "situational" factors (snow days, lectures that went bad)

A "Backward design" orders these activities

- Identify important situational factors (identify resources, constraints, and external factors)
- Prescribe learning goals (specific expectations of behavior change)
- Develop assessment and feedback processes (these address the nature of each learning goal)
- Develop teaching and learning activities (with goals and assessments identified there is a wider range of potential learning activities available)
- Connect and integrate (develop the "story" of the course that provide the affective and cognitive "hook.")

Situational Factors

Some of the relevant situational factors considered for the course "The Engineer as Leader" are that it includes students from all engineering disciplines, it is not part of a capstone project and students have little or no formal experience in business or training in teamwork. Another

important consideration is the difference between the experience of undergraduate students and the experience of those for whom most leadership development programs are targeted. Table 4 highlights some of the differences between industry and university students of leadership.

Table 4 Situational comparison of Leadership Development environment for industry and university participants.

Professionals	Students
Identified by others as having leadership potential	Taking a course for credit
Demonstrated commitment to continuing professional development	Currently participating in structured curriculum
Investing effort for likely economic/professional payoff	Investing effort for grade
Acceptance of and integration with organizational culture	Learning their role in society
Experience in long term (more than a year) projects	Experience in semester projects
Experience with multi-disciplinary teams	Experience in teams with members much like them
Experience with complex organizations	Experience with simple organizations (teams)
Some awareness of personal competencies/weaknesses	Little awareness of personal competencies/weaknesses
Strategic (big picture) perspective of individual activity/competence	Personal perspective of individual activity/competency

The nature of the discretionary effort (motivation) expended to develop leadership capabilities may be quite different for the groups. Professionals see this as an opportunity to advance in their organizations by participating in a visible program, already a form of recognition. They also bring with them an intuitive understanding of the culture, values, and competencies relevant to their respective cultures. The rewards, both intrinsic and extrinsic, to students are much less well defined and they really have not developed a very sophisticated intuition when it comes to dealing with organized human action. The course itself must provide the armature for experiential learning that they lack. The pedagogy of a course in leadership must consider these situational effects.

Learning Goals

There were over 100 learning outcomes identified and these are currently being refined by industry representatives, faculty, and education specialists. Each is stated in the form "Upon successful completion of this course, students shall:

- List the expectations of a leader
- Summarize personal leadership attributes (strengths and weaknesses)
- Transition between an individual contributor and a leadership role

- Demonstrate competence in multiple team roles
- Accept personal and team responsibility
- Demonstrate ethics and integrity
- Differentiate between inspiring and motivating
- Build trust with the team
- ….etc."

The experiential dimension of the course content requires special attention. A significant element of this is self-assessment, something that may be challenging for students. With self-awareness, a foundation is developed for personal development, peer and superior feedback, mentoring, and life-long learning (moving from the internal to the external quadrants of Figure 2). Another important characteristic of the student experience must be to undertake a challenging task. One where there is not a correct answer in the back of the book and requires that they access personal abilities that they were heretofore unaware.
It is important that this personal development take place within the context of support from others in the same situation to whom they can turn in order to help them make sense of the experiences they have had.

Assessment and Feedback

The constuctivists' approach to teaching and learning posits that the individual learner actively "builds" new knowledge and skills upon their current constructs (schema) rather than the external environment. Externals provide only the "opportunity" for learning.

In order for a student to improve and move toward their personal development goals, they require feedback on their performance. This feedback differs from assessment. The source of feedback can be the instructor, other students, or experts, and is formative in purpose. It should be frequent, immediate, discriminating, and supporting. Assessment is the perogitive of the instuctor and has as its audience both the student, those outside the course, and is normative.

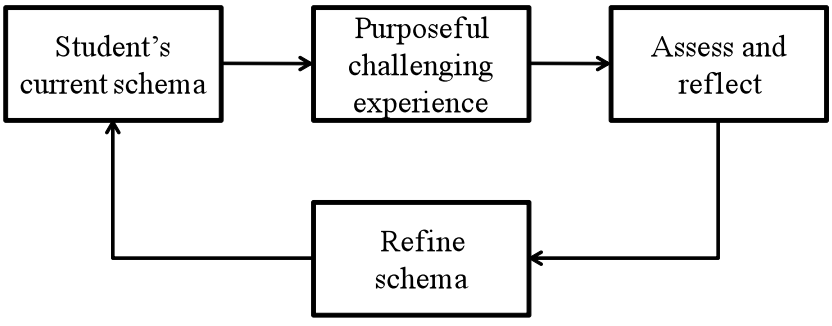

Figure 3 Constructivist model of learning.

For each of the learning objectives, their position on the grid in Figure 2 will be identified. The internal quadrants imply self-assessment but these assessments may reference external standards (Meyers-Briggs Type Indicator, Belbin Team Inventory, or Index of Learning Styles). The external quadrants provide for a variety of feedback mechanisms: instructor feedback, individual peer feedback, feedback on group product, expert feedback, etc. All of this feedback should be forward looking with an objective of student development.

Teaching and Learning Activities

A unique aspect of this course is the commitment of very successful engineering leaders to take an active role in the course. The "Leaders teaching Leaders" model of practicing professionals can serve as successful role models, lead discussions in class, and verify the relevance of experiences that students have in the course. Typically, they will lead a discussion of one or two articles that have been assigned beforehand. Each engineering leader will be provided a "prep" sheet to help the guide the discussion and provide opportunities for "war stories" illustrating points.

Constructivism (McHenry et.al. 2005, Prince and Felder, 2006) implies that educators focus on providing students opportunities for connecting previous learning with a new more sophisticated understanding. Typically, this requires a high level of student activity performing challenging tasks. These student-centered activities impose more responsibility on students for their own learning. This also implies that students play a more significant role in their personal assessment.

The following are potential course elements under consideration:

- Identify several "Big Questions" in Engineers as Leaders to structure the course
    - Provides a macro structure or theme for the course (real time case study)
    - Provide structure for constructivist learning and development
    - Initial personal essay on topic before each session (current schema)
    - Formulate a tem response. Identify, formalize, and communicate (social commitment) and receive feedback
    - Return to topics intermittently to encourage and assess development (new schema)
    - Monitor maturity of responses for external feedback
- Split meetings into different topics for each half
    - The three hour class period is too long for student attention
    - Meet in two different rooms
    - Pair topics with in class period for two different learning streams
    - This reduces the rate for each topic. Allow soak and development time as a single topic covers multiple class sessions.
- Use appropriate Harvard Business Review case studies as learning probes and assessments of leadership development
    - Respond individually early in semester, then group (without access to experts)
    - Present for discussion
    - Repeat same cases at end to assess development
- Use the development of an Engineering Leadership wiki as team activity
    - Students would benefit from a meaningful and challenging team activity
    - Active learning of leadership/followership
    - Provide the basis for cooperative learning (Zemke, 2004)
    - Each team take a different aspect of Engineering Leadership
    - Provide the basis for 360 assessment of teams skills
    - Integrate the team developments and publish wiki

Several of these may be included in the final design and other learning activities will be included as the final structure is developed.

SUMMARY

We are in the process of developing a new course "The Engineer as Leader." There are unique resources available in the commitment of experienced engineering leaders to take a direct role in realizing the course. The design of course content and process is based upon a constructivist orientation to creating a significant learning experience that provides student the opportunity for lasting change.

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