Bernard M. Gordon-MIT Engineering Leadership Program

Capabilities of Effective Engineering Leaders
Version 3.6
June 2011

Engineers design and build things that meet the needs of customers, beneficiaries and ultimately society. These tasks can only be accomplished by the concerted action of many people aligned and rallied by effective leadership. The Bernard M. Gordon-MIT Engineering Leadership Program is dedicated to empowering MIT students to make the very most of their talents and to help them set and achieve personal goals, including the leading or founding of teams and organizations which tackle and solve the problems of the market and society that can be addressed (at least in part) by technical solutions.

Specifically, we seek to educate and develop the character of outstanding MIT students as the potential future leaders of engineering practice and development. In this program, *engineering leadership* is defined as the technical leadership of change: the *innovative* conception, design and *implementation* of new products/processes/projects/materials/ molecules/software/systems, supported by the *invention* of enabling technologies, to meet the needs of customers and society.

We start with the assumption that many students entering university have already demonstrated leadership potential. At the same time, we observe that with a focus on engineering science, many engineering curricula do not adequately emphasize the development of engineering leadership. In this program, our educational task is to provide opportunities for all engineering students to further develop, deepen, and broaden their engineering leadership attitudes and skills.

We want students to graduate having developed the *attitudes* of leadership: core values and character. They need to have developed the *skills* of leadership, represented below under the headings of: relating to others, making sense of context, creating visions and realizing the vision. Finally, in order to be effective engineering leaders, they of course need to have developed a deep understanding of the underlying *knowledge* of engineering, science and technology.

These capabilities of engineering leadership were anchored in the scholarship of leadership, and a consensus building process among engineering leaders. One of the ways to describe leadership is the "skills approach", which places emphasis on the skills or abilities that can be learned or developed (Northouse 2010). The Gordon – MIT Engineering Leadership Program *Capabilities of an Engineering Leader* was based on one such capabilities model – the Four Capabilities model, developed at the MIT Sloan School of Management (Ancona 2007). During the Winter and Spring of 2008, a series of

workshops were held at MIT, bringing together program stakeholders with diverse view of engineering leadership: alumni, students, faculty, leaders from industry, military leaders, community leaders and those from other leadership programs at MIT. The first draft of the *Capabilities of an Engineering Leader* emerged as a consensus of this group, *specializing* the general Four Capabilities model to engineering. In several subsequent stakeholder engagements with engineering leaders from industry, the document has evolved to its present form.

We believe engineering leadership can best be taught and developed by linking in a timely and systematic way:

- Coursework that provides the analytical concepts and frameworks for understanding engineering leadership;
- Opportunities on and off-campus to experience and practice leadership,
- Opportunities to reflect, discuss, and gain feedback from peers, faculty and experienced engineering mentors on lessons learned from leadership activities.

In some greater detail, these leadership capabilities can be described as presented below.

1. **The Attitudes of Leadership - Core Personal Values and Character:** students should reflect on their beliefs and attitudes, and further evolve their sense of responsibility and the personal capabilities that form a foundation for effective leadership. For effective engineering leaders, these include:

    - Initiative – Ability and willingness to assess risk and to take initiative, to create a vision and course of action, without the help or advice of others. [2.4.1]

    - *Decision Making in the Face of Uncertainty* –Ability and willingness to make decisions informed by the information at hand, factoring in risks, uncertainty and potentially conflicting objectives. [2.4.1]

    - Responsibility, *Urgency and Will to Deliver* – Determination to accomplish one's objectives, and those of the team, pragmatically and in the face of constraints, obstacles, and errors by you and others. Commitment to the absolute responsibility to persevere and deliver on time, pursuing necessary follow-up. Focus on the tasks at hand with passion, discipline, intensity. [2.4.2]

    - Resourcefulness, Flexibility and *Change* – Ability and willingness to approach problems, tasks and situations making ingenious use of the resources of the situation and group, and to manage the use of time. A willingness to accept and respond to change, embrace various views, be adaptable, and maintain and take alternative courses of action when necessary. [2.4.2]

- Ethical Action, Integrity and Courage – An adherence to ethical standards and principles, and demonstration of the courage to act ethically and with integrity, and to practice according to the norms of professional responsibility and one's responsibility to society. [2.5.1](f)

- *Trust and Loyalty* – Commitment to actions that will instill trust, and to the principle that loyalty to the team yields loyalty to the leader and vision. Working to empower those around you, to make the people around you successful. [2.5.6]

- *Equity and Diversity* – Commitment to treat others as equals, regardless of status or background, and to embrace diversity in organizations. [2.5.5]

- *Vision and Intention in Life* – Determining a pathway to one's eventual contribution to and impact on society, and how engineering plays a role in ones intentions. Committing to a personal vision, and the intention to inspire others. [2.5.3]

- Self-Awareness and Self-Improvement – Awareness of one's own personal, interpersonal and professional skills, and strengths and weaknesses. [2.4.5] Being prepared to continue learning, and proactively planning for one's continuing education, self-improvement, and future career. [2.4.6, 2.5.3, 2.5.4] (i)

2. **Relating:** developing key relationships and networks within and across organizations, including listening to others to understand their views, and advocating for your position. For effective engineering leaders, these specialize to:

    - *Inquiring* and *Dialoging* –Listening to others with the intention of genuinely understanding their thoughts and feelings. Creating constructive dialog, and recognizing the ideas of others may be better than yours. Listening to and being willing to learn from everybody. [3.2.7]

    - *Negotiation, Compromise and Conflict Resolution*. Appreciating the need to identify potential disagreements, tensions or conflicts, and being able to negotiate to find mutually acceptable solutions. [3.2.8]

    - *Advocacy* – The ability to clearly explain one's own point of view or approach, advocate a position, and explain how one reached their interpretation and conclusion. Proactively assessing the extent to which you are understood. Being able to do so to those with and without technical backgrounds, and from different cultures. [3.2.9]

- *Diverse Connections and Grouping* – Appreciating, engaging and connecting widely with those with different skills, cultures, and experiences. Building a sense of group within direct participants, and building extended networks of those that can help achieve the goals and technical solution. [3.2.10]

- Interpersonal Skills – Understanding and respecting the needs and characteristics of individuals and the group, and the resources that individuals with different backgrounds can bring to an organization. Coaching and teaching, providing and receiving evaluation and feedback, and the essential elements of gracious professionalism necessary to be an effective engineering leader. [3.1] (d)

- Structured Communications – Being able to create a strategy and structure to formal communications, and present information orally, in written and graphical form to both engineers and non-engineers in a clear and concise manner. [3.2, 3.3] (g)

3. **Making Sense of Context:** making sense of the world around us, and coming to understand the context in which the leader is operating - making a mental map of the complex environment, and explaining it simply to others. For effective engineering leaders, these specialize to:

    - Awareness of the Societal and Natural Context – An awareness and understanding of the world's problems, challenges, and opportunities, and the historical and contemporary role of engineering in addressing them. An understanding of the natural context, and the need for sustainability. Specifically identifying opportunities for new (or previously not implemented) engineering solutions and systems to address these needs. [4.1] (j, h)

    - Awareness of the Needs of the Customer or Beneficiary – An understanding of the specific needs of those who will benefit from the envisioned engineering solution: the customers who will buy it, the users who will use it, the beneficiaries who will directly or indirectly benefit from it. [4.3.1]

    - Enterprise Awareness – Understanding the goals and culture of the enterprise in which one works, the shared beliefs, goals and strategies of the enterprise, and norms for working successfully and bringing about change. Literacy in broader business concepts and analysis, and in particular engineering project finance. [4.2]

    - *Appreciating New Technology* – Understanding the emergence and implications of new science and technology, and how they might enable or enhance new solutions and systems. [4.2.6]

- Systems Thinking – Thinking holistically. Possessing an ability to view complexity, focus on critical features, identify inter-relationships and emergent qualities, and create abstractions and models that simplify comprehension. [2.3]

4. **Visioning:** creating purposeful, compelling and transformational images of the future, and identifying what could and should be. For effective engineering leaders, these specialize to:

   - *Identifying the Issue, Problem or Paradox* – Synthesizing the understanding or needs or opportunities. Clarifying the central issues, framing the problem to be solved, or identifying the underlying paradox to be examined. [4.3.1]

   - Thinking Creatively, and *Imagining and Communicating Possibilities* – Understanding how to create new ideas and approaches. Creating and communicating visions for new technical products and systems, and new engineering-based enterprises, that deliver new capabilities. [2.4.3]

   - Defining the Solution – Identifying a vision for the solution, and setting achievable goals for performance (including quality), budget and schedule. These are guided by the views of the customer, reflect the possibilities of technology, meet regulatory and political constraints, and consider competitive forces and the needs of internal stakeholders. [4.3.1]

   - Creating the Solution Concept – Creating and selecting the concept and architecture for the technical solution, which might be innovative or evolutionary, and then defining the specifications and interfaces of the solution so that realization can be effective. [4.3.2, 4.3.3]

5. **Delivering on the Vision:** leading transformation by designing processes and approaches to delivering on the vision, to move from abstraction to innovation, invention and implementation, i.e., to get the engineering done. For effective engineering leaders, these specialize to:

   - Building and Leading an Organization *and Extended Organization* – Building an organization by recruiting key players with complementary and superior skills, defining team processes, roles and responsibilities, setting expectations, creating incentives and motivating the team. Lead an organization by employing appropriate modes of leadership under various conditions, and leading group decision-making. Assess organizational and individual performance. Observe, reflect and build on the leadership qualities of others. Develop approaches to incorporating competence outside of one's enterprise in an extended organization. Understand how to manage change. [4.2.4] If desirable, create a new engineering-based entrepreneurial enterprise. [4.2.3]

- *Planning* and Managing a Project to Completion – Choosing a development strategy (waterfall, spiral, etc.), and devising a plan of action, and alternative plans if needed, to achieve the goals and deliver on time. Identifying and removing obstacles. Controlling the project to the plan. Identifying when the project is off plan and re-planning appropriately. Managing and apportioning the resources of the team, to achieve the desired outcome within the human, time, financial and technological resources available. Controlling and managing program margins, risk, configuration and documentation. Understanding the financing and the economics of the project. [4.3.4]

- *Exercising Project/Solution Judgment* and Critical Reasoning– Questioning and critically evaluating and applying judgment to solutions proposed by others, and to corroborating inputs. Evaluating evidence, and identifying the validity of key assumptions - Critical thinking [2.4.4] Understanding alternatives that may be developed or are being developed by others, including competitors. Taking into account the evolution of existing systems when proposing new systems.

- Innovation – Designing and introducing new goods and services to the marketplace. Based on goals and concept, identify, advocate for and amass the required resources (financial, etc.), design a solution with the appropriate balance of existing and new technology, reuse and new development, and flexibility and adaptability. Consider current and future competition. Consider sustainability in the design and implementation. Validate the effectiveness of the outcomes. [4.4] (c)

- *Invention* – Imagining possibilities based on emerging technology or science, and inventing a practical device, material, process or way of working that enables or enhances a new good or service. Adhere to and exploit intellectual property regimes.

- Implementation and Operation – Applying the methods of engineering development to implementation of engineering outcomes and systems. Consider quality, variability, robustness and appropriate testing. Operate the solution effectively in such a way that the needs of the customer and society are repeatably and reliably met. Design, implement and operate the project, product or system [4.5, 4.6], or model, manipulate and make the material or bio-molecule.

6. **Technical Knowledge and Reasoning:** Essential to the effective execution of engineering leadership is a deep working knowledge of a technology or discipline. While normally developed in the standard curricular course of study, this knowledge is no less essential for an engineering leader. It includes an ability to understand, decompose and recombine different elements of a technical problem through application of a deep understanding of technical knowledge [1.0] (a,k),

engineering reasoning and problem solving [2.1] (e), and the approaches to inquiry and experimentation that may be necessary to develop or refine a new technology needed for a product, process or system [2.2] (b).

Notes on Sources:
The important inputs for this description of capabilities are:

1. The MIT Sloan Leadership Model, reflected in the Harvard Business Review article "In Praise of the Incomplete Leader" by Deborah Ancona, Thomas W. Malone, Wanda J. Orlikowski, and Peter M. Senge (February 2007). The topical organization of the above capabilities into Sensemaking, Relating, Visioning and Realizing the Vision (called by them Inventing) is due to this work.
2. The "CDIO Syllabus, a Statement of Goals for Undergraduate Engineering Education" a taxonomy of desirable engineering knowledge, skills and attitudes of engineers, originally presented in a report by Edward Crawley in January 2001 (see www.cdio.org) and later included in the book Rethinking Engineering Education, the CDIO Approach by Edward Crawley, Johan Malmqvist, Soren Ostlund, and Doris Brodeur, Springer, 2007. The notations in [square brackets] above correlates topics with the CDIO Syllabus, and notations in italics show significant additions to the topics in the CDIO Syllabus. The CDIO Syllabus was updated in June 2011 to capture many of the topics in italics.
3. The accreditation standards for engineering education, contained in ABET 2000, as described in "Criteria for Accrediting Engineering Programs: Effective for Evaluations During the 2000-2001 Accreditation Cycle," Revised March, available at http://www.abet.org. The notations in (parentheses) above correlate topics to the ABET requirements section 3 a-k.
4. The deliberation for the Bernard M. Gordon - MIT Engineering Leadership Program on 18 December 2007, and subsequent development of summary documents by the group.