Gaps in engineering education, perception of career tracks, and demographics associated with cyclical hiring practices have insufficiently educated the engineering workforce, most critically in training technical leaders capable of competently bringing a product to market. The traditional leadership path using apprenticeships, mentoring, and gradually increasing responsibility in running progressively larger teams, is heavily dependent upon opportunity. The perfect alignment of these opportunities to lead, and availability of talented engineers who are ready to lead rarely occurs in today’s lean corporate environment. Hence in many cases, high potential employees are put in positions to lead, beyond what their level of genuine experience has prepared them for. Engineering executives have estimated that when relatively unseasoned engineers are tasked to run their first team or project, nearly 80% fail in satisfying all of the project’s critical requirements, either missing on functionality, performance, quality, time-to-market, cost or other key objectives.

The Gordon Engineering Leadership Program at Northeastern University targets the key soft skills, organizational awareness, and technical agility to accelerate the development of leadership skills in an engineering environment. Started with a grant bestowed by Dr. Bernard Gordon the program actively works with over 20 industry partners in honing the key knowledge, skills and attitudes essential in accelerating the building of a new generation of game-changing engineering leaders. The program consists of class work in scientific foundations and in engineering leadership – to establish solid background of technical tools for general appreciation of engineering solution approaches, and to provide project management tools for leading teams and effectively attaining goals – and the Challenge Project, which is a master’s thesis-equivalent tightly-scheduled, deliverable-oriented demonstration of human and material resource management and engineering problem solving.

A growing consortium with programs at other major universities is working to advance and share research, curricula and best practices in this area.
Introduction

The mission of the Gordon Engineering Leadership Program (GEL) at Northeastern University is to create an elite cadre of engineering leaders with an exceptional ability to lead engineering teams by providing purpose, direction and motivation to influence others to achieve a collective goal, realizing the successful completion of engineering projects from concept to market success. This is achieved via an intensive, one-year graduate curriculum consisting of several complimentary elements, leading to either a masters in engineering or, for those already with an advanced degree, a certificate.

In concert with Northeastern’s history and reputation as a leader in global experiential learning, most notably via the undergraduate co-op program, GEL works hand-in-hand with industry partners in developing leadership and growing the proficiency, effectiveness and dexterity of selected high-potential, future leaders.

The purpose of this paper is to introduce the unique structure, process and techniques used in achieving these objectives.

What is the problem and why is it hard?

The accelerating increase in discipline specific knowledge, deepening silos even within a single field of study, and the lack of consensus on the skills, knowledge and attitudes necessary to be immediately effective in an engineering environment widen an already significant gap between the needs of industry and society and the output of engineering education. Critically at risk is the potential impact on the inexperienced engineer’s confidence and ability to lead, initiate, innovate, invent and implement products that fully capture, address and meet all of the key requirements of the customers, markets and stakeholders that their companies serve.

The consequences of this gap have been identified as impacting competitiveness, profitability and success at all levels within an industry:

- At the corporate level, resulting in missed business, opportunities, deficient products and financial stress.
- At the department level, the absence and inability to reliability and dependably deliver products on time, to spec and within target cost.
- At the team and individual level, the lack of time to understand the context of their role within the organization and opportunity to develop and master personal competencies in the interpersonal skills and team dynamics that lead to sustained high performance.

Many companies attempt to address this disparity with internal training, mentorship and other methods to acquaint and nurture the engineer’s awareness of their way of doing things. Others invest in ongoing continuing education, both degree and other. But, in a large number of firms, the cyclical hiring practices over the past decades that have left voids in the workforce. Increasingly, experienced engineers are thrown into positions with substantial leadership
responsibility without the benefit of having learned in practice through progressively leading small teams, medium teams and larger teams. Secondly, because there are fewer mid-level employees, less-experienced engineers are frequently stretched into leadership roles beyond what would typically be given them.

Interviews with several technology executives estimate that nearly 80% of projects led by these well motivated, but raw, chiefs fail in achieving many of the key objectives of the project, at best creating a non-optimal product; at worst something unworthy of taking to market.

Adding to the difficulty of developing engineering leadership is distilling the difference between management and leadership. Developing engineers perceive career growth in the technical space as capped or limited and that eventually they need to move into management to maintain professional momentum. Both this bias and the tendency of many graduate programs addressing this space to evolve into engineering management or technical MBA tracks, underscore the urgency to provide a clear blueprint and direction that enable the aspiring leader to stay in, not leave, the role of engineering leader.

Finally, the pace of technology advances continues unabated, bringing new capabilities into the market at faster rates. The increasing sophistication and complexity of many systems and products through the integration of elements spanning multiple areas of expertise requires that an engineer remains current in many domains and intellectually curious, flexible, agile and nimble, capable of grasping and learning new areas of knowledge confidently, competently and continuously throughout their careers.

Left unattended, this skill deficit will continue to limit and impair the capacity of many companies to attain and maintain an enduring competitive edge.

**What is the GEL approach?**

Dr. Bernard Gordon, an engineering innovator and visionary, founder and chairman of Analogic, co-founder and CEO of NeuroLogica, holder of over 200 patents and recipient of the Presidential National Medal of Technology is most renowned as the father of analog-to-digital data conversion. Beginning with his treatise on the dilution of engineering education, “What is an Engineer?” delivered as the keynote address at the European Society for Engineering Education’s annual conference in 1984, Dr. Gordon has started and nurtured several independent and university aligned programs in his mission to instill a pragmatic and holistic approach in developing engineering talent.

The Gordon Engineering Leadership Program, established in 2006, is designed as a successor of prior programs and contemporary of others to continue to build upon the concern, interest and passion of Dr. Gordon in continuously improving the competency of engineers to make a meaningful impact in their businesses and in society. A graduate of the program earns the distinction of being named a Gordon Fellow.
**GEL Cohort**

The program has enlisted over 20 industry partners who provide a core group of students, referred to as candidates and typically engineers early in their careers, vetted by company-specific talent review processes to participate. The diversity of companies, engineering disciplines and experience represented by the members of this cohort add cross-cultural richness, facilitating opportunities for peer learning. In addition, the tight integration with companies, accentuated via the Challenge Project (covered later), ensures that both the program and faculty stay attuned to current industry concerns, practices, trends and needs.

The cohort meets regularly as a group, in classroom and laboratory scenarios, share a joint study area, participate in multiple team projects and, through these interactions, grow and learn together as a unit.

**GEL Structure**

The structure of the program (Figure 1) is built upon Northeastern’s philosophy of, and over 100 years of practice in, experiential learning. Pillars represent five key elements, coordinated and integrated to enhance the delivery, practice and mastery of the concepts, methods, tools and behavior essential to lead in an engineering context.
GEL caps the structure in making a clear distinction between researchers, scientists, technologists and engineers, emphasizing that the objective of the engineering leader is to develop products that serve to satisfy the collective needs of a market, customers and their firm’s associated stakeholders.

**Leadership Capabilities**

The 14 leadership capabilities taught in the program emerge from a synthesis of the timeless characteristics articulated by Dr. Gordon, the Sloan-MIT Leadership model as adapted for engineering leadership in partnership with GEL’s sister program at MIT (Led by Ed Crawley and Joel Schindall), the surprisingly (to non-military folks) personal and proven methods of leadership found in the Army’s officer training program, other models, as situationally appropriate, and the cumulative experience of over 100 years of industry knowledge represented in the core faculty teaching in the program.

They are:

1. **Initiative**: Assess risk and take the initiative, to create a vision and course of action.
2. **Decision Making**: Make decisions with information at hand factoring in risk; maintain and take alternative action when necessary.
3. **Responsibility and Urgency to Deliver**: Determination to accomplish mission in the face of constraints or obstacles; commitment to absolute responsibility to deliver on time, pursuing necessary follow-up.
4. **Resourcefulness – Get it Done**: Focus on the tasks at hand, with passion, discipline, intensity, and flexibility.
5. **Ethical Actions and Integrity**: Adherence to ethical standards and principles, and the courage to act ethically and with integrity.
6. **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.
7. **Courage**: Face difficult/high-risk actions head-on.
8. **Vision**: Creating compelling images of the future, identifying what could and should be for new products, systems and enterprises.
9. **Realizing the Vision**: Designing processes and approaches to move from abstraction to invention, innovation and implementation. Lead an organization to plan and deliver a project exercising solution judgment and critical reasoning.
10. **Inquiry**: Listen to others with intention of genuinely understanding their thoughts and feelings; recognize their ideas may be better than yours.
11. **Interpersonal Skills**: Respect needs of individuals and the group; recognition of others’ strengths; coaching, gracious professionalism.
12. **Communicating and Advocacy**: Clearly able to explain point of view, approach to those with differing backgrounds and cultures; assess extent to which you are understood.
13. **Connect – Across Disciplines, Skills and Cultures**: Appreciate, engage, and connect with those who have different perspectives.
14. Negotiating and Compromise: Appreciating the need to identify potential disagreement or conflict, negotiate to find mutually acceptable solutions.

GEL begins by creating self-awareness within the cohort. Through reflection and self-assessment, the candidates go through a series of exercises, including Myers-Briggs, the Thomas-Kidman conflict style instrument and others to help them learn their natural style, personality and tendencies. Always revealing, the candidates rate themselves on a scale of 1-10, 10 being mastery, on each of the leadership capabilities as a starting point and identify specific areas to develop (Figure 2). This diagnostic is repeated at the end of the course in the form of a 360-degree feedback survey to measure growth overall and in the targeted capabilities.

![Figure 2, Engineering Leadership Capabilities](image)

Each capability is introduced in theory and historical context in an Engineering Leadership class enhanced by stories culled from the collective experience of the teaching cadre.

Leadership Laboratories

A Leadership Laboratory supplements each Engineering Leadership class enhancing the candidates’ experience and mastery of topics introduced in lectures. By engaging in continued self-assessment, interactive role-playing exercises, and case studies, students explore topics through practical experience.
Leadership Labs play a key role in adapting the language of the concept to the demographic profile and experience level of the cohort. Different cultures and generations start from different reference points and view the desirability of, need for and approach to leadership in teams through very different lenses. These labs typically unearth the most surprising, entertaining and unanticipated insights gained in the program.

The first leadership lab reveals a Leadership Framework covering values, engineering leadership knowledge, capabilities and attitudes. In this lab, the candidates learn the distinction between leadership and management. Leadership deals with people and behavior; management, the science of organizing and planning programs, budgets and systems. As a group, a definition of leadership is developed and embraced.

Leadership starts by clearly knowing ones core values, behavior, beliefs, feelings and personality. Candidates write a personal mission statement and learn the power that comes from living a life with purpose, integrity, and courage. They begin to hone their view of the world by understanding how judgment, prejudice, and perspective can be biased by their own feelings and experiences.

Building upon these developing leadership attitudes, the labs next acquaint the candidates with the tools essential to leading people and teams. Among them are creating a common vision, planning a project, organizing and inspiring a team, developing goals, assigning roles, setting expectations, providing feedback, negotiation, decision-making, and conflict resolution. Communication and presentation skills are practiced in simulated workplace scenarios, developing the expertise necessary to influence a team in the successful completion of a project.

Finally, the impacts of the business, cultural, and societal environment in which candidates will lead are explored. The ability to stay situationally aware in complex and dynamic organizational and business domains, account for cultural differences, maintain sound ethics, manage up and down, and successfully maneuver throughout the extended enterprise enable candidates to create the perspective and context in which they will lead.

Labs are performance based and candidates receive direct feedback at the end of each session. Labs are held both inside and outside the classroom, including a full-day Field Leadership Reaction Course (FLRC) exercise at nearby Camp Edwards.

**Product Development Process**

As a key component to leading engineering teams in the implementation of products to the marketplace, GEL begins by introducing engineering specific leadership in the context of product development. Candidates are asked to bring in copies of their companies org chart, team structure, and product design flow. This helps to establish a context for how they fit within the structure of their organization.
The framework used to drive this portion of the program, adopted from a leading text, *Product Design and Development*, by Karl Ulrich and Steven Eppinger, leads the candidates step-by-step through a structured, generic product development process. In each phase, candidates are tasked to look within their organization for representative procedures analogous to those covered in class, such as interviewing a customer, requirements management, deriving specifications, concept development, system and detailed product design, user interfaces, design for manufacturing, supply chain management and project management.

Exercises aligned with the topics serve to make the candidates familiar with the detailed flow of product development and that most companies are very similar in their approach. They learn that product development is not cleanly done through a sterile sequence of separate events. Rather, it encompasses a collection of overlapping activities and interdependent series of people-centered processes where authority, decision-making and boundary conditions are fluid and dynamic.

Finally, the techniques are tailored to equip the candidate with tools that can be immediately applied in the formation, planning, implementation and completion of their Challenge Project.

![Figure 3, Product Development Process](image)

Interspersed through the product development portion of the program are deep dives into qualitative and quantitative methods that improve group problem solving. Application and practice of Quality Function Deployment (QFD), Deming’s “Plan, Do, Check, Adjust”, failure mode and effects analysis, design of experiments, change management and other standard tools supply the candidates with techniques that add rigor and discipline and increase confidence when called to tackle difficult challenges.

The final portion of the product development lecture covers broader topics, including systems engineering, systems thinking, finance for engineers and politics, creating perspective on how
complexity and context, the corporation, industry, society and world all play an influential role in how products evolve.

All material in the product development portion of the program is presented within an envelope of the overall product lifecycle, continuously reinforcing the key leadership skill that thinking about things at the front-end and choices made early in the life of product have the most leverage and greatest impact on the outcome and success of the project.

**Scientific Foundations**

In order to be a good engineering leader one must first be a good engineer. An element of the program that breaks away from more traditional treatments of leadership and management is the Scientific Foundations course. Scientific Foundations refreshes candidates on the first principles of the main engineering disciplines they are likely to face when leading teams; to enable the ability to perform back-of-the-envelope calculations in solving problems that bridge multiple technical areas.

GEL connects the breadth and depth of these engineering topics by focusing on fundamental science as applied to everyday and routine objects and situations. This deepens the candidates understanding of the broad scientific principles underlying the apparent phenomena in product and system behaviors. Among the material covered are Maxwell’s equations / constitutive relations; wave phenomena: propagation, diffraction, and interference; quantum mechanics; thermodynamics /statistical mechanics; fluid dynamics; biology; chemistry; and others as possible.

A second benefit of the Scientific Foundations course is that, by pushing the students from introduction to understanding to mastery of a field in a short period of time, they gain confidence in their ability to tackle and learn a new field of science without being intimidated. The faculty pulls examples from their own careers in which a discontinuity in how things behaved in their domain routinely required them to learn a new area of science.

For those in the master’s degree track, additional technical courses are selected to meet their specific needs. By combining these with Scientific Foundations, a candidate increases their own competency in the broad domain of engineering.

**The Challenge Project**

The Challenge Project is the analog of the thesis experience in a conventional academic master’s program but concentrates on technology development and delivery in a customer and stakeholder focused project, rather than research. Done well, it enables the candidate to get graduate level credit while working on a project that contributes to and has a quantifiable benefit to their industry sponsor. For the industrial sponsor, the project is the mechanism in which a product of commercial value and impact is developed on behalf of the company. For the candidate, it is the opportunity to apply knowledge, develop self-confidence and expertise under real-world time, business, performance, and quality pressure.
The candidates write a proposal as part of the admissions process where they outline how their project enables them to demonstrate growth as viewed from three complementary perspectives:

1) **Market Value** – Specific value to the sponsor in developing breakthrough new technology or market opportunity, same or better performance at a lower cost structure, or better performance at the same or acceptable cost.

2) **Technology/Scientific/Engineering depth** – Targeted depth in the candidate’s engineering discipline or novel, innovative and unique application of technology sufficient to meet the standard for credit towards an engineering masters degree.

3) **Leadership** – Specific leadership capabilities the candidate intends to exercise and master in the process of running the project, including techniques and skills in initiating, executing and delivering on a plan to solve a complex problem and honing leadership acumen through leading a team in completing a project on time, within budget and to specification.

During the course of the program, the candidate expands the proposal into a complete project specification, including schedule, cost estimates, description of the technology and anticipated value to the sponsoring company. Upon completion, the candidate writes a formal, thesis length report that describes the project, results and final status. This report is archived and in some cases published. They prepare and present a 45-minute defense of the project for final approval by a faculty review board.

**Mentorship**

The program supports the candidate during the program via a team of mentors to guide their engineering leadership development in the delivery of the challenge project: an Industry
Sponsor/Advocate from the candidate’s sponsoring organization, a Gordon Mentor from GEL, and a Faculty Advisor from the University department most closely associated with their discipline and technology area of interest. This support team works as a unit to guide the candidate through the three major phases of the project (Figure 4).

**Summary**

The mapping of how each element of the program serves to bridge specific gaps between industry needs and engineering education is shown in Figure 5.

![Figure 5, Mapping of Program Elements to Objectives](image)

**Conclusion**

The Gordon Engineering Leadership Program Mission is:

“To create an elite cadre of engineering leaders who stand out from their peers in their ability to innovate, invent, and implement engineering projects from concept to market success. These leaders will demonstrate an exceptional ability to lead engineering teams by providing purpose, direction and motivation to influence others to achieve their collective goals.”

The program couples best practices in leadership with in-depth training in both the pragmatic methods to bring a product to market and the underlying scientific principles and is designed to significantly accelerate the immediate and future contributions of graduating Gordon Fellows to their organizations and industries.

Future work includes partnering with similar programs at other major universities to share approaches, perspectives and research as a first step in creating a nation-wide standard for teaching engineering leadership.

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