AC 2012-4640: ”WHAT COUNTS FACTORS”: PREPARING ENGINEERING STUDENTS TO INNOVATE THROUGH LEADERSHIP OF MULTIFUNCTIONAL TEAMS

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"What Counts Factors": Preparing Engineering Students to Innovate Through Leadership of Multi-Functional Teams

Abstract

The role of Product Manager within industry is a driving force of innovation. Product Managers are trained as individual contributor engineers, yet evolve into multi-functional managers who lead the business, often through on-the-job training. Drawing on 17 in-depth interviews with Product Management practitioners and recruiters across a range of businesses, a collection of "what counts factors" emerged for success in this position. These characteristics, in turn, are used to define a workshop intervention that prepares engineering graduate students to face the challenges of multi-functional team leadership in the Product Manager role.

1. Introduction

> *"Leadership in innovation is essential to U.S. prosperity and security. In a global, knowledge-driven economy, technological innovation, the transformation of new knowledge into products, processes, and services, is critical to competitiveness, long-term productivity growth, and the generation of wealth."*
>
> **Engineering Research and America's Future**
> Committee to Assess the Capacity of the U.S. Engineering Research Enterprise
> National Academy of Engineering[1]

In the academic year 2008-2009, a total of 69,133 Bachelor of Engineering (BSE) degrees were conferred in the US, an impressive 4.3% increase over the previous 5-year average.[2] In the same year, 165,375 Master of Business Administration (MBA) degrees were conferred, 96,242 more than BSE degrees and an astounding 14.7% increase over the previous 5-year average. This is quite a different picture than in 1970-71, where 45,034 BSE degrees were conferred compared to only 26,490 MBA degrees.

This trend toward academic training for business careers has also impacted the number of engineers who gravitate to business after graduation. A 2008 report tracking the 10-year career progress of 1993 graduates shows that only 7% of engineering graduates reported having business occupations and this rises to nearly one-quarter of graduates 10 years later.[3] In the same report, of engineering undergraduates who returned to school for additional education, almost one-third enrolled as MBA's making engineering one of the largest streams of students into growing MBA programs.

Why are so many engineers seeking business training post-graduation? It may be that the larger task of innovation extends beyond what is typically taught in engineering programs. Perhaps there is a component of value creation, in tandem with invention and problem solving that defines innovation and may be lacking in current engineering education.

We define *innovation* simply as *invention that sells.* The tension in this definition is the juxtaposition of the certain genius associated inventing with the value generated through commercialization. The commercialization aspect of engineering is often ignored in today's

engineering curriculum, leaving the young engineer at a disadvantage in multi-function product development teams.

In many companies, the challenge of leading the innovation process typically falls to someone referred to as a "product manager." This person is typically a classically trained engineer who has transitioned into this role over time by exhibiting an aptitude for the work of innovation.

Dave Packard and Bill Hewlett are perhaps the first and best examples of Product Managers. They were both trained as engineers, brilliant (but by their own admission, not *the* most brilliant) inventors and founded a company in 1939 that became the $120B revenue technology giant, Hewlett-Packard. Packard and Hewlett spent a combined 31 years in the roles of President, CEO and Chairman of the company.[4]

In 1957, Packard and Hewlett set forth a list of "shared values" that define the company operations today. These values (in part) include: *Passion for Customers, Trust and Respect for Individuals, We Effectively Collaborate, Meaningful Innovation, Uncompromising Integrity*. [5] This broad ranging description of success reflects an understanding of the process of innovation that extends well beyond the initial work of invention. Additional examples of engineers turned "product managers" are plentiful, including Bob Galvin of Motorola, Bill Gates of Microsoft and most recently Sergey Brin and Larry Page of Google.

However, workplace success for the "engineer-and-business manager" is far from assured. The work of product management involves many skills not always taught within a standard engineering curriculum. Learning beyond post-secondary education is often a "sink or swim" proposition filled with uncertainty and lost productivity.

2. Role of Product Manager

For the purposes of this research, a "Product Manager" is described as a classically trained engineer who works in a for-profit business, in a role that:

> *"… sits at the nexus of technology development and business management. They deliver the product offering by leading activity that interprets customer needs, shapes technology development and generates bottom-line business results."*

This is a commonly understood role in virtually all technology-oriented businesses, from established start-ups to major, multi-national corporations. This role may be referred to as *Product Leader, Project Leader, Project Manager* or *Technical Product Manager* but the skill requirements remain largely consistent.

Product Managers are the driving force for the commercialization of innovation. They often work in tandem with inventor engineers and translate customer requirements (or needs) into product and service opportunities.

3. Research Method

The research is descriptive, involving 17 in-depth interviews with a cross section of managers who are familiar with the Product Manager role. The subjects were actual Product Managers or they hired Product Managers and a few worked side-by-side with Product Managers in related roles. Subjects were recruited through professional contacts and had a mean 18.2 years of work experience. The list of companies interviewed is shown in Table 1.

Table 1 – Companies Interviewed.

Autodesk	Hewlett-Packard	Nokia
Bosch	Intuit (2)	Procter & Gamble (2)
CNH Case New Holland	Logitech	SAP (2)
Google	Microsoft	VW of America
Grumman/Butkus	Motorola	

Numbers in parenthesis represent multiple interviews at the same company.

An initial set of job-based skill criteria was collected from engineering-directed career-counseling books that described generic engineering roles. [6] [7] This resulted in an 8-criteria "what counts factor" list, with 37 descriptive characteristics. This list was used as a guide for the interviews and was revised as more information was gathered from participants in the interviews.

The literature search and interviews identified eight skill areas that defined the role of Product Manager. The managers interviewed were asked to rank these criteria from 1- most important to 8 least important. Results are shown in **Figure 1**.

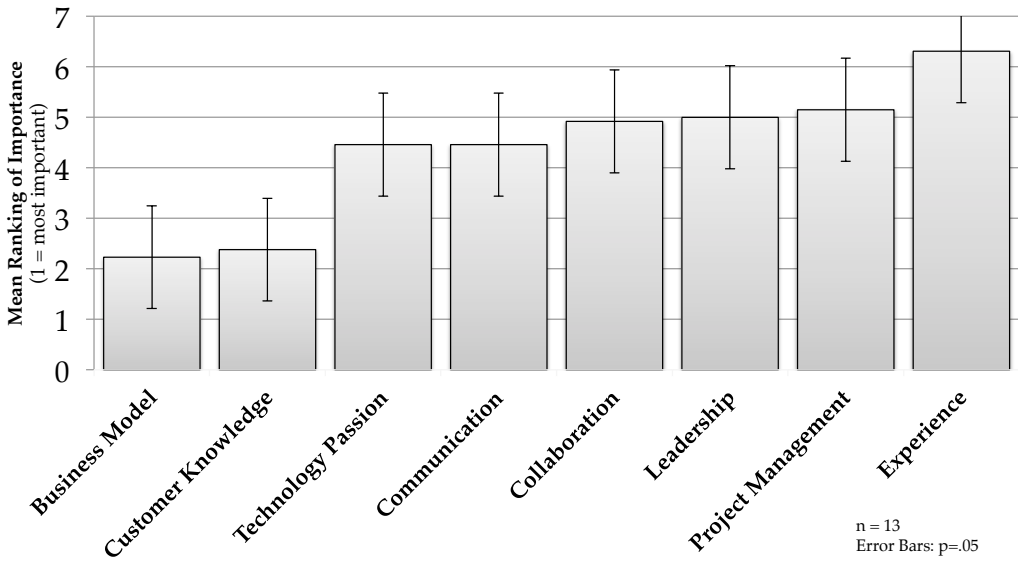

Figure 1 - Mean Ranking of Product Manager Criteria

Two distinctly non-technical criteria, Understands the Business and Knows the Customer, were rated "most important" and significant over all other factors. Two additional criteria,

Passion for Technology and Clearly Communicates, also rated as relevant and important. Four criteria, Inspires Collaboration and Leadership Project Management Skills and Experience, were lower rated.

4. ME310 Student Profile

ME310 is a capstone course that has been taught at Stanford University since 1967. The year-long course is a mechanical engineering master's-level sequence in which student teams work on complex engineering projects sponsored by industry partners. Student teams complete the design process from defining design requirements to constructing functional prototypes that are ready for consumer testing and technical evaluation.[8]

Students come to the course having earned undergraduate engineering degrees, mostly all in mechanical engineering. They gravitate to ME310 because they are interested in learning more about design and developing products. An annual survey of students asking where they "hope to work after graduation" shows that Apple, IDEO or a Car Company are the top choices. These are companies that practice product management and have Product Managers who run major development projects.

ME310 students often participate in design research studies and over time a psychometric profile of the typical students has emerged. The Herrmann Brain Dominance Indicator (HBDI) is a cognitive assessment tool that has been judged to be both valid and reliable [9] and maintains a significant database of industry and functional subject norms. The HBDI can provide data on cognitive profiles for "engineers," "designers," "marketing," and "sales" professional roles.

The HBDI provides, on the basis of 120 items, a four-factor classification of mental preferences or cognitive styles.[10] The HBDI-A factor (A) reflects a preference for solving analytical and factual problems using logical and reason, while the HBDI-B (B) factor shows a preference for temporal and sequential reasoning, sequencing content and the application of rules. The HBDI-C (C) factor reflects a problem solving preference for interaction with others, sensing and reacting to input from others, while the HBDI-D (D) factor shows a preference for imaginative or conceptual problem solving, synthesizing input and viewing problems in a holistic manner.

ME310 students have an HBDI profile that differs from that of a typical "engineer" score as defined in the HBDI occupational database, as shown in Table 2.

Table 2 – HBDI scores for ME310 students (n = 93) over three academic years (2008-2011).

	Factor Score	"Engineer" Score	Difference
HBDI - A	.61	.80	**-.19**
HBDI - B	.45	.51	-.06
HBDI - C	.42	.39	+.03
HBDI - D	.55	.30	**+.25**

HBDI raw scores have been norm-referenced to the instrument mean (.50) for each factor.[11] Differences in bold are significant at p<.05.

While ME310 students showed an expected preference for analytical and factual problem solving (HBDI-A) it was significantly lower than preferences for working engineers. The distinguishing factor is the ME310 student preference for imaginative and conceptual problem solving where they show a significant advantage relative to the working engineer.

Students exhibited similar preferences as measured by the Clifton Strength Finder (CSF) instrument.[12] The CSF is a preference 140-item instrument that identifies personal preferences among 34 "themes" of work-related activity.[13] These preferences are described in detail, with business language that helps students prepare work-seeking materials like resumes and interview skills.

ME310 student results show a meaningful percentage of the student population values "Empathy," as shown in Table 3. Clifton describes "Empathy" as the ability to "sense the emotions of those around you." This is encouraging because empathy is a key skill in the design thinking tool set. There were also meaningful preferences for themes such as "Achiever" ("helps explain your drive") and "Developer" (seeing "the potential in others"). We are only beginning to explore the value CSF instrument in helping prepare ME310 students for leadership in the workplace.

Table 3 – Clifton Strength Finder "themes" for ME310 students. Number in parentheses is the percentage of students (n=20) who reported this as one of their top-5 "themes."

Empathy (45%)	Input (25%)	Focus (15%)	Maximizer (10%)
Achiever (35%)	Futuristic (20%)	Responsibility (15%)	Woo (10%)
Developer (35%)	Ideation (20%)	Restorative (15%)	Activator (5%
Individualization (30%)	Positivity (20%)	Analytical (10%)	Command (5%)
Learner (30%)	Adaptability (15%)	Competition (10%)	Communication (5%)
Relator (30%)	Arranger (15%)	Connectedness (10%)	Intellection (5%)
Strategic (30%)	Discipline (15%)	Includer (10%)	Self-Assurance (5%)
			Significance (5%)

5. ME310X - Teaching Multi-Functional Team Leadership

Building on this taxonomy for the role of Product Manager, a series of workshop interventions (offered as a 1-unit/quarter ME310X: Product Management) were held for a cohort of ME310 students to help them explore, define and succeed in a product management role as a career path. In year one, six 3-hour evening sessions over three academic quarters were held. In year two, nine sessions were scheduled.

The metaphor for organization of the workshops is the multi-functional new product development team. Students are introduced to the group dynamics of the multi-functional teams. Key members are the Finance Manager, Marketing Manager, Sales Manager, Manufacturing Manager and the Product Manager, likely to be the ME310 student after graduation. Sitting around this "table" are multi-functional representatives of the organization, who will bring unique strengths, viewpoints and political agendas to the new product development conversation.

The Product Manager leader must be able to understand these differences and bring together competing perspectives to successfully design, develop and launch new products.

The topics for workshops were designed to accommodate the students' engagement in the parent design and innovation course and to match their schedule for looking for gainful employment after graduating their master's program, as shown in Table 4.

Table 4 - ME310X: Product Management course Curriculum Overview

Session	Topic	Learning Activity
1	What is Product Management?	"What Counts" Factors [14] Case Study: KLUTZ [15]
2	Getting a Product Management Job	Resume Writing, Note on Interviewing [16] Job Finding Skills
3	Leadership and New Product Development Team Dynamics	Why Teams Don't Work [17] Simulation: Everest Simulation [18]
4	The Finance Mindset	Yahoo Finance Exercise Case Study: Culinarian Cookware [19]
5	The Marketing Mindset	Case Studies: Global Brand Face-Off [20] Bryant Pharmaceuticals [21]
6	The Sales Mindset	Persuasive Selling, Distribution Channels Case Study: Arck Systems[22]
7	The Human Resources Mindset	Employee Motivation Case Study: Starling Systems [23]
8	New Product Development Strategy	New Products Management: Chapter 3 [24] Case Study: Crafting Winning Strategies in a Mature Market [25]
9	Personal Leadership and Winning Ethically	Opposable Mind: Chapter 4 [26] Case Study: Levi Strauss & Co. [27]

The first session served as an introduction to Product Management and a case study concerning a toy company business decision about choosing a product to bring to market. This relates directly to understanding the business model that drives a product or company, which is the highest rated characteristic of the "What Counts" Factors. A vice president from the company was invited to discuss the session topic with the students.

Session 2's topic was on networking, interviewing and finding a product management job. Students engaged in a resume critique and active learning interview practice. The guest was a product engineer from a local technology company recounting her job search and hiring experience. The topic of Session 3 focused on leadership and team management skills. The main

activity was a computer simulation team experience climbing Mount Everest [18], followed by a debriefing and discussion with a guest speaker who had actually done the climb.

Sessions 4, 5, 6 and 7 covers specific non-technical functions within the scope of a Product Manger. Session 4's topic was about project finance and business models that drive the major corporations and aligns with the top-rated criteria required for a successful product manager. This class also included a case study experience (Culinarian Cookware) and a guest discussion with an engineer-turned-finance-manager for a major software company. Session 5's topic was on marketing and the customer experience, featuring two Harvard Business School case studies (Global Brand Face-Off and Bryant Pharmaceuticals) and a guest discussion with a senior vice president of marketing with a senior vice president of marketing at a major aerospace company. This experience helps reinforce the need for effective communication and understanding the customer, both important "What Counts" Factors.

Session 6 deals with Sales and the pressure of creating revenues and working with customers. This includes and interactive business model that generates revenue estimates based on several sales-related activities (Arck Systems) and a guest discussion by a senior sales manager from a major manufacturing company, trained as an engineer, who views selling as a greater challenge than engineering. Session 7 covers human resources and the issues with sourcing and retaining talent and features four role-play segments where students practice communication and collaboration skills through tough personnel conversations. This session features a guest discussion with a senior vice president human resources manager of a global technology company to reinforce the message.

Finally, Sessions 8 and 9 topic deal with business strategy and personal selling behaviors, again referencing top-rated "what counts" criteria and includes both case studies and discussions with a relevant industry professional. In Session 8, there is an in-depth discussion of the new product development process within large companies. This includes a discussion of the advantages and disadvantages of the Stage-Gate Process and concluded with a guest discussion by a senior vice president of a major consumer goods company. Session 9 concludes the class series by returning to the subject of leadership, leadership behaviors and the challenge of ethical conduct of business. The guest discussion is lead by the CEO of a start-up company who shared experiences that involve ethical decisions and conduct.

6. Discussion and Impact

This classroom experience addresses two difficult issues for graduate level educators. The first challenge is helping graduate level students who aspire to a career in industry achieve this goal and successfully transition into the workplace. Master's-level graduate students often come to this program with little or no meaningful business experience, and they are on campus for just 12-24 months that are busy with coursework. The objective is to help these students gain the necessary business perspective and prepare to successfully enter the workplace, while continuing to build their engineering skills. Accomplishing this within existing coursework is challenging but necessary.

The second challenge is the blend of topics within a limited amount of course time. The new product development team metaphor is helpful because it provides a structure for the topics to be covered and it reflects a business environment likely encountered by the engineer just entering the work place. The students often struggled with the verbal nature of the case study process but enjoyed situations where there was no clear answer.

Students engaged in this workshop intervention seemed to have gain more confidence in taking their technical skill out into the workforce. Initial assessments of the student cohort and their attitudes are still just preliminary. Feedback from a small number of alumni who participated in a first-year pilot of this workshop series and entered the workforce as product managers indicate the applicability of the workshop content:

> *My first rotation has been as the product manager of one of [company]'s smaller product lines. It's very challenging but it's also been a great learning experience. One of your last presentations that I attended was when you discussed the challenges of being a product manager, especially after coming from an engineering background. I definitely understand what you were referring to.*

We intend to conduct additional analyses based on pre- and post-experience survey measuring student satisfaction as well as a comprehensive tracking of post-graduation employment with and without engagement in the product manger workshop.

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