ENGINEERING MANAGEMENT EDUCATION - TECHNOLOGY INTEGRATION, MANUFACTURING, OR THE MANAGEMENT OF ENGINEERS AND SCIENTISTS?

John V. Farr, Ph.D., Stevens Institute of Technology
Brian J. Sauser, Ph.D., Stevens Institute of Technology
Rashmi Jain, Ph.D., Stevens Institute of Technology
Dinesh Verma, Ph.D., Stevens Institute of Technology

Abstract

The content of Engineering Management (EM) educational programs has evolved significantly in the last five years. Many of the traditional EM departments have adopted systems engineering (SE) in their titles and have started systems engineering programs as part of their educational offerings. Subsequently, in many of the academic programs EM content has shifted from the combination of management of engineers and scientists within a traditional industrial engineering framework to one with a curriculum emphasizing the integration of management, human, and technology (i.e., systems) issues. The objective of all EM programs is to produce graduates who can work effectively at the interface between technology, management, and engineering. We believe that a systems engineering focus is a key component of the core curriculum for all EM programs. This paper attempts to present the market forces driving this change and presents an analysis of several large EM programs that have significant SE content. We hope that the ideas presented in this paper will be used in curriculum development for EM programs.

Introduction

Globalization, technology, and out sourcing are now the mantra for the U.S. economy. Even traditional professional services which have become the mainstay of the U.S. economy are being outsourced to developing countries or are being with replaced with technology in order to increase productivity/profits. Out sourcing is becoming a part of our everyday life where traditional services such as income tax preparation, legal research, the reading of medical x-rays, etc., are being shipped overseas. Even in the service industries, technological progress resulting in rising productivity is eliminating many white collar positions in the workforce. Technology has been the driver for this reduction and for many mid management and clerical positions. Technology has also lead to the elimination of many support jobs. For example, automated answering machines have eliminated receptionists, robots have eliminated factory workers, computers have eliminated typesetters, etc., positions in the workforce. Manufacturing jobs have decreased every year since 1952. Subsequently, the U.S. workforce is undergoing many of the same growing pains that were experienced between 1890 and 1920, when the U.S has moved from an agricultural economy to a manufacturing driven economy (Heritage Foundation, 2005).

Outsourcing, the shift in the U.S. to a services based economy, technology driven productivity gains, and the increased complexity of platform driven products have all contributed to different career paths for the traditional engineers (see Exhibit 1). Consequentially, the role of the practicing engineering manager is evolving to someone focusing more on all aspects of the product life cycle (see Exhibit 2) in lieu of manufacturing or the supervision of engineers and scientists. Engineers that practice in the services and manufacturing domains must be able to understand the tools and processes available in defining the fuzzy front end associated with generating conceptual ideas and developing the architectures of innovative and efficient product solutions and not solely function on the manufacturing or supportability of a product.

Exhibit 1. Traditional versus 21st century career paths for engineers

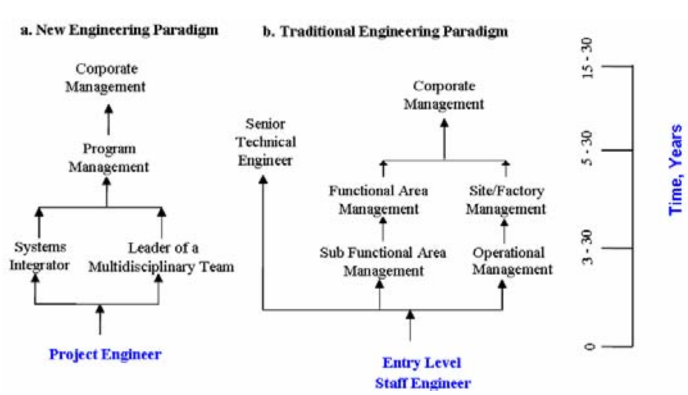
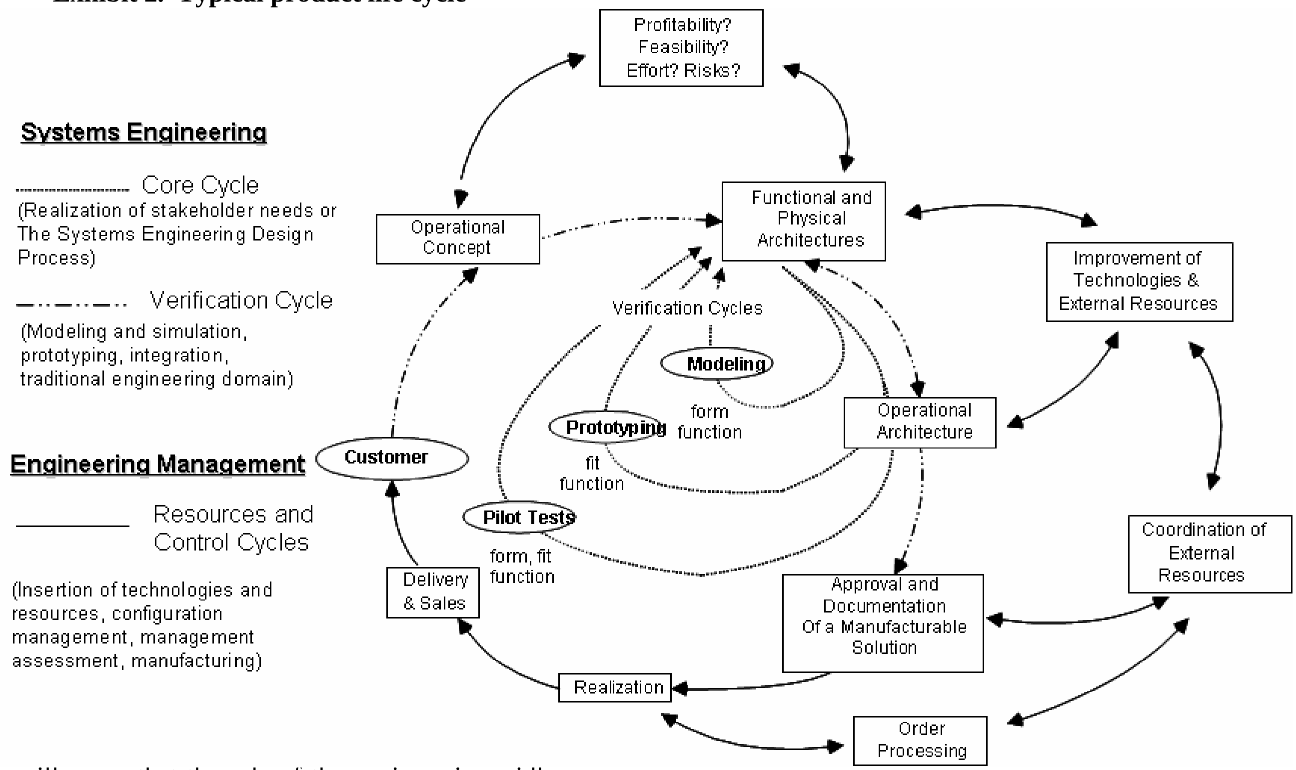


Exhibit 2. Typical product life cycle



Few will argue that the role of the engineer is rapidly changing. A recent Business Week (2005) article stated that not only manufacturing being outsourced overseas, engineering design is also being accomplished offshore. For example, the design of 70% of all personal digital assistants and 65% of notebook personal computers is being conducted in Taiwan. The same BuisnessWeek article states that "80% of engineers in product development do tasks that can easily be outsourced – like translating prototypes into workable designs, upgrading mature products, testing quality, writing user manuals, and qualifying parts vendors. What's more most of the core technologies in today's digital gadgets are available to anyone." While most companies in the U.S. have decreased research and development (R&D) investments (Hewlett Packard from 6% to 4.4% of sales, Cisco from 17% to 14.5%, etc), countries like India have seen a dramatic increase in funding. Also, companies like Nokia that in the past have done "everything in house" has outsourced many components of there phones because of complex supply chains and the complexity of modern technology. Many of there problems are becoming more of a systems integration issues instead of design and manufacturing. All of this will lead to a new role for an engineer that is vastly different that what is being taught in universities.

Few will argue that the next 20 years will produce economic upheaval for this country similar in many ways to the turn of the 20th century when we shifted from an agrarian based economy to a manufacturing based society. Similar consequences might include the creation of many new types of job types, products, and services. This also might lead to a more dispersed and international workforce. This much we do know that much of our future economic growth will be characterized by innovation and the business development aspects of large complex products. Relationships separated by only reprography and possibly cultures will be the norm among innovators/designers, retailers, and suppliers (i.e., the entire value of supply chain). Innovation and the ability to translate customer/market requirements into efficient new product is key to take advantage of the new economic realties. Low profit, mass produced items will be relegated to third world suppliers.

We believe that engineers will work in organizations that produce these complex products will have the following properties and attributes:

<u>Engineering/Technology</u>

- Constantly evolving technology and related international standards,
- Multitude of interfaces (hard and soft), distributed processing modes and platforms,
- security implications,

- utilization of extensive commercial off the self (COTS) systems and
- will be information and knowledge intensive.

<u>Business</u>

- constantly changing scope, business processes and partners, requirements, and expectations,
- global relevance, scope, and application,
- evolving marketplace and related vendors and suppliers.

<u>Organizational</u>

- numerous stakeholders (both economic and political), with conflicting preferences,
- dispersed international workforce, and a
- flexible organizational structures without the traditional constraints.

Unlike traditional engineering, which has been slow to accept the effect of these market realities on curriculum content, EM education in general has embraced this change at many universities by incorporating a systems engineering component and deemphasizing manufacturing. Exhibit 3 contains a list of departments that have systems engineering and engineering as the name of their departments. A review of the top 50 engineering schools showed that all had an EM component either explicitly as a degree, a stem within a traditional engineering degree, or as a major curriculum focus. Unfortunately, EM can take many forms as shown in Exhibit 4.

What SE Content is Appropriate for an EM Curriculum

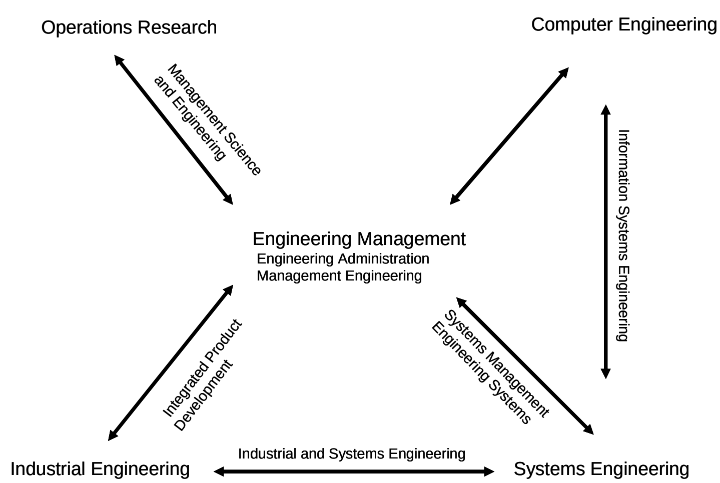
The basic principles of systems engineering are typically covered in a two course sequence in most graduate SE programs. The first course is typically an overview of systems concepts typically presented in some type of systems process or life cycle perspective. Detailed topics typically include

- Conceptual System Design Process and Models,
- Opportunity Identification/Stakeholder Need Definition,
- Requirements Analysis and Management, and
- System Concept Generation and Selection.
- Preliminary System Design Process and Models
  - ▪ Functional Analysis and Requirements Allocation,
  - ▪ System Architecture Development,
  - ▪ Functional, Physical, and Operational Perspectives (Reliability, Maintainability, Supportability, Availability, Durability, Manufacturability) and
  - ▪ Design Decision Making and Trade Study Analysis.

Exhibit 3. Departments with large Engineering Management and Systems Engineering programs in the same department

University	Department	EM Degree	SE Degree	Distance Learning
Stevens Institute of Technology	Systems Engineering and Engineering Management	BE, ME, PhD	BE, ME, PhD	Yes
University of Missouri - Rolla	Engineering Management and Systems Engineering	BS MS, PhD	MS	Yes
University of Alabama - Huntsville	Industrial and Systems Engineering and Engineering Management	MS, PhD	MS, PhD	Yes
George Washington University	Engineering Management and Systems Engineering	MS, DSc	BS, MS, DSc	No
Chinese University of Honk Kong	Systems Engineering and Engineering Management	MS, PhD	MS	No
Southern Methodist University	Engineering Management, Information, and Systems	MS, DEngr	MS, DEngr, PhD	Yes
Old Dominion University	Engineering Management and Systems Engineering	ME, MS, PhD	ME	Yes

Exhibit 4. The influence of related engineering and science on engineering management education



Advanced systems engineering topics might include architectural decisions which are driven by customer requirements and operational concepts. Obviously, given the multitude of competing requirements for a typical 10 course master's degree, two courses in SE is probably not feasible. However, one course covering the topics presented in the overview class is probably appropriate. Given the global nature of our economy, these topics are critical not only for engineering managers but for all engineers. A strong argument can be made that these topics should be presented at the undergraduate level – especially for traditional programs in mechanical, computer, and electrical engineering.

Exhibit 5. EM Programs with a formal minor/concentration in SE

University	Manufacturing	Systems	Project Management
University of Southern California	x	x	x
Stevens Institute of Technology	-	x	x
University of Missouri- Rolla	x	x	-

Note that Stevens Institute of Technology, Old Dominion University, and George Washington University all have required courses in systems engineering as part of there core requirements for their master's degree in EM.

A strong SE component to EM, combined with more innovation and business skills, is needed to be successful in the new global economic environment. Many traditional engineering services will be out sourced or replaced by technology. To retain our place in the global economic market, all engineers and especially those formally trained in EM must evolve to include skills that facilitate integration of complex systems and the ability to develop and translate requirements to innovative new products.

Summary and Conclusions

As shown in Exhibit 4, trying to quantify EM education is difficult because in terms of skills many universities all offer similar content but use different names for their program. One things that is certain that the role of the engineer is dramatically changing because of technology and globalization. Because of the outsourcing of both design and manufacturing the skill set of the 21st century engineer must involve more business, systems, and innovation. In general, EM programs have evolved to respond to the new economic realities. However, the question is the next evolution. Is manufacturing no longer relevant for engineering management education? As provider of degrees that are often advertised as "bridging the gap between engineering and management," we must evolve our programs to include more systems and business content and less traditional design and manufacturing. The argument can also be made that innovation along with order knowledge needed to define the "fuzzy front end" of product development should be come a major element of our course contents. The EM degree must lead engineering education because traditional engineering (to include Industrial Engineering) has been slow to respond.

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About the Authors

John V. Farr received his PhD from the University of Michigan in 1986. He currently serves as Professor and Department Director, Department of Systems Engineering and Engineering Management, SIT. Prior to Stevens, he served as the Program Director of Engineering Management at the U.S. Military Academy. His research interests are mainly in the area of modeling and simulation and risk analysis for complex systems.

Brian J. Sauser received his PhD in Technology Management from Stevens Institute of Technology in 2004. He currently serves as a Research Assistant Professor at Stevens. Prior to coming to Stevens he worked at the Robert C. Byrd National Technology Transfer Center – Kennedy Space Center, FL, in commercialization and marketing of technologies for NASA. His research interests are in project management and the commercialization of technology.

Rashmi Jain received her PhD in Technology Management from Stevens Institute of Technology, New Jersey in 2003. She currently serves as an Associate Professor at Stevens Institute of Technology. Before coming to Stevens she was employed as an Expert Consultant for Accenture (formerly Anderson Consulting) working on large and complex systems integration projects involving mainly information technology projects.

Dinesh Verma received his PhD from Virginia Tech in 1994. He currently serves as Professor and Associate Dean for Outreach, Department of Systems Engineering and Engineering Management, SIT. Prior to joining Stevens he served as a Senior Systems Engineer at Lockheed Martin Corporation. His research interests are mainly in the area of reliability and logistics.

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