2006-1667: THE PROSPECT OF PROJECT MANAGEMENT INSTRUCTION IN UNDERGRADUATE ENGINEERING EDUCATION

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The Prospect of Project Management Instruction in Undergraduate Engineering Education

Abstract

This paper explores the need for engineers, especially young engineers, to graduate with demonstrable knowledge and performance competencies in the area of project management. Trends are explored and used to address the prospect for project management instruction in engineering undergraduate education. A Project Management Competency Development Model is proposed to provide a framework for structuring the knowledge areas and learning processes for undergraduate engineering students. This model responds to needs identified from major constituents, applicable references, and educational requirements from various engineering disciplines.

The Impetus for Change

Engineers in all stages of career and professional development want to be successful in this competitive world, where global outsourcing is just one the many challenges facing them. In response, ASEE President, Ron Barr, summarizes the opinions of many academic and industry professionals:

> "We have to produce American engineers who are not only obviously technically well-grounded but more talented at things like creativity, leadership, communication, and professionalism so that when a company hires an American engineer it expects him or her to lead that company or an international group of engineers." [1]

Market conditions, which drive the engineering industry, indicate a need for industry-ready engineering graduates. Current business drivers include the virtual teams, global projects, the internet, outsourcing, off-shoring, advanced technology, developing countries, restricted travel and immigration, and international teams. Walesh addresses the ramifications of current events in a very critical statement [2]:

> "Technical competency, although necessary, is not sufficient for young engineers or other technically educated professionals who wish to quickly realize their potential in the consulting business, industry, or government. They must supplement technical competency with basic management proficiencies and leadership understanding if they are to be productive. Unfortunately, management concepts, knowledge, and skills typically are not introduced in undergraduate engineering and related curricula, and virtually nothing is taught about leadership. As a result, young professionals must learn management and leadership skills by doing, often inefficiently and at high monetary cost to the employer, putting the young professional's career at risk."

Until recently, newly hired engineers were normally placed in training programs and encouraged to follow professional development programs associated with grade descriptions, experience, and

professional registration. A common and often used model for this career advancement is the ASCE Professional Grade Descriptions [3]. Each grade, from Engineer I to Engineer IX, is delineated by the general characteristics, directions received, typical duties and responsibilities, and typical position titles. Using the professional engineer (PE) registration as a discriminator between Grade III and IV, practicing engineers are not normally expected to "plan, schedule, conduct, or coordinate detailed phases of engineering work in part of a major project or in a total project of moderate scope" until becoming an Engineer IV as a registered professional engineer and the prerequisite five or six years of responsible work.

This timeline of early professional and technical development is changing. Out of necessity, employers are reacting to the general shortage of engineers by flattening their organizations and asking younger, less experienced engineers to perform non-technical aspects, or management, operations on a project. This action places junior engineers in situations where they are called upon to use basic project management knowledge and skills that in the past would have been developed through mentoring and possibly years of experience and career development. Earlier in their careers than has traditionally been the case, junior engineers are asked to assume responsible project roles; direct the actions of others; interact with clients; demonstrate their management knowledge, skills, and abilities; and to perform other related, but nontechnical, responsibilities. Failure in these early assignments by young engineers can result in any number of actions, including termination, while the consequences of success usually mean increased responsibility and demonstrated value to the organization.

As an example of a future-oriented approach to prepare engineers for practice and licensure at the professional level, the Civil Engineering Body of Knowledge for the 21st Century (BOK) provides a well-recognized response to the need for project management knowledge and skills among engineering programs. A publication of the American Society of Civil Engineers (ASCE), the BOK makes recommendations on "what should be taught to and learned by future civil engineering students." These recommendations are delineated in 15 outcomes. The first 11 outcomes reflect verbatim those currently used by the Accreditation Board for Engineering and Technology (ABET) [4]. Four new outcomes (Outcomes 12-15), "address technical specialization, project management, construction, asset management, business and public policy and administration, and leadership." Commentaries and descriptions of competencies explain each outcome. Outcome 12 "reflects the additional technical specialization[4]"and Outcomes 13-15 "reflect the additional professional and practice knowledge, skills, and attitudes" embodied in ASCE Policy Statement 465. Outcome 13 states, "The 21st century civil engineer must demonstrate an understanding of the elements of project management, construction, and asset management." This prompts the question, "How can engineering undergraduate programs respond to outcomes related to professional skills, like project management and business expertise?" This paper attempts to answer this question in a meaningful and actionable way.

What is Project Management?

Project management is the "application of knowledge, skills, tools, and techniques to project activities to meet the project requirements[5]". To help delineate this definition, the BOK uses its commentary[4] to offer a list of project management essentials. These essentials include "project manager responsibilities, defining and meeting client requirements, risk assessment and

management, stakeholder identification and involvement, contract negotiation, project work plans, scope and deliverables, budget and schedule preparation and monitoring, interaction among engineering and other disciplines, quality assurance and quality control, and dispute resolution processes."

These project management essentials are contained within and addressed in several authoritative publications. The most comprehensive and globally accepted publication is the *Guide to the Project Management Body of Knowledge* (PMBOK Guide) [5]. As an ANSI standard, the PMBOK Guide provides a system of processes, tools, and techniques for managing and leading a project. Around this standard, Project Management Institute (PMI) conducts a certification program; regional, national, and international conferences; and a global organization comprising 250,000 members with 140,000 certified project management professionals (PMP).

The PMBOK Guide organizes the elements of a project in terms of five process groups and nine knowledge areas. The five process groups are Initiating, Planning, Executing, Monitoring and Controlling, and Closing. The nine knowledge areas are Integration, Scope, Time, Cost, Quality, Human Resources, Communication, Risk, and Procurement management. The PMBOK Guide addresses the project management essentials identified in the BOK, plus it provides a comprehensive framework for understanding, applying, and teaching project management concepts, tools, and techniques. In doing so, the PMBOK Guide provides an authoritative resource for both imminent and experienced professionals.

Relevance of Project Management

The professional work environment for newly graduated engineers portends a need to manage and operate within a product/project delivery system of multidisciplinary teams of technical experts. The need for scientists, chemists, physicists, engineers and other technical disciplines to work collaboratively will demand well developed people skills, in addition to their ability to perform ethically, efficiently, and effectively within a project environment[11].

In describing the relevance of project management to engineering undergraduate education, Walesh[2] explains that an entry-level technical professional will not be managing a project during his or her first year of employment, but may be responsible for designing a component of a much larger project. Walesh offers the following scenario:

> "Manage your project effectively, considering the ideas and information presented in this chapter. As a result, you will increase the likelihood that your part of the overall project will be completed on time, within budget, and in accordance with functional and service expectations. Besides short-term, project-specific benefits, your commitment to smart management will establish you as someone who makes good things happen. That desirable reputation will lead to more challenging project management and other growth opportunities. Colleagues who notice your success will inquire about and want to emulate your approach to project management. As a result, your efforts will have a positive ripple effect on the organization. The ability to change the behavior of others by example is one mark of a leader[2]."

Providing students with an industry ready education is not an easy task in an environment undergoing rapid and accelerating change. Globalization impacts us all, including academia. Hira[6] addresses the current situation when he observes:

> "Engineering educators in the United States are considering changes to the curricula to ensure that their graduates are employable. Their ideas include adding courses that emphasize teamwork, including so-called soft skills such as management and leadership, and teaching technical skills that cannot be easily compartmentalized and outsourced."

The drivers motivating market changes within the engineering industry emphasize the need for more formalized project management related education and training, which is bolstered by the fact that for years engineering firms have been looking to hire "industry-ready" graduates[7].

Competency in Project Management

To use an example, the BOK in delineating the minimum competency required for each outcome directly addresses the requirements for Outcome 13 in the following statement, "Outcome 13 (includes "understanding the elements of project management") should be taken to Level 1 (recognition) in the B and/or M/30." The "B and/or M/30" refers to a Bachelors degree and/or a Master's degree or 30 credits, and represents to the total post-secondary education expected to fulfill the requirements for professional licensing and practice in civil engineering[4].

Level 1 or recognition is associated with the lower two levels of Blooms Taxonomy - Knowledge (memorization and recall) and comprehension. Knowledge "consists of facts, conventions, definitions, jargon, technical terms, classifications, categories, and criteria. Knowledge is necessary but not sufficient for solving problems[8]." In the instructional environment, knowledge is associated with a student's memorization skills and not their problem solving skills. Level 2 or comprehension is "the ability to understand or grasp the meaning of the material, but not necessarily to solve problems or relate it to other material[8]. Knowledge is required for comprehension, but comprehension requires the learner to interpret "experimental data, trends and tendencies" while being able to demonstrate an understanding of ideas, principles, and theories.

Using Bloom's Taxonomy as the taxonomy for educational objectives, a graduating engineer should be able to demonstrate an understanding of project management in the form of deliverables reflecting basic project management knowledge and skills. These are the performance competencies to be developed by engineering students in order to be considered "industry-ready."

Development of a learner's knowledge, skills, and abilities to the comprehension level implies an equitable and proportionate attention be provided within an engineering program and suggests the need to formalize the educational aspects associated with the "elements of project management." This formality may be necessary in order to identify and assess the required level of knowledge.

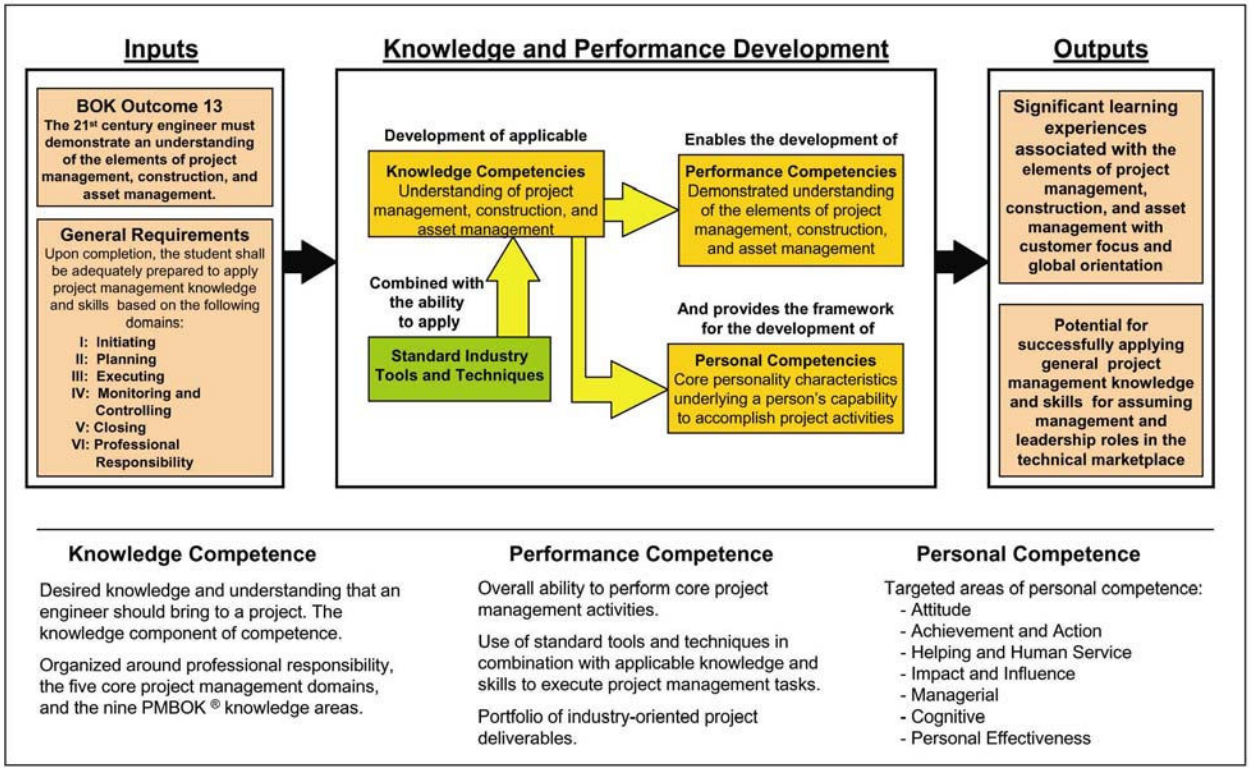
Applying the Project Management Competency Development (PMCD) Framework

In 1998, PMI sponsored a project to develop a Project Management Competency Development (PMCD) Framework[9]. This project resulted in a framework that "defines the key dimensions of project manager competence and the competencies that are most likely to impact project manager performance." This framework offered competency in terms of three separate dimensions: knowledge, performance, and personal competence, and looked "solely at the competencies needed to help project managers be successful in their role.

As discussed earlier, the project management role of newly-hired engineers begins within the first year or two with their first responsible work assignment. This infers that the PMCD dimensions could also be used as an educational development model. The use of this model should provide (1) an overall view of the knowledge, skills, and behaviors associated with a competent, "industry-ready" engineering graduate; (2) a structure for developing the prerequisite knowledge, skills, and behaviors in a way that is transferable across industries; and (3) a framework for the engineer to use to relate and understand the elements of project management, and possibly, construction, and asset management in their undergraduate, graduate studies, and career and professional development.

As shown in Figure 1, the PMCD Framework is adapted to provide a learning model for project management knowledge and performance for educators, students, and working engineers.

Figure 1. Project Management Knowledge and Performance Learning Model



This model structures the development of knowledge and performance in a way that is consistent with a major tenet of W. Edwards Deming, which articulates, "Without theory experience teaches nothing." This tenet emphasizes the importance of providing the knowledge or "theory" that enables the young engineer to learn from his or her experiences[10]. Also, Deming asserts that, "To copy examples without understanding the theory and process behind them is to invite disaster." Therefore, providing an inexperienced engineer with files of schedules and budgets from a previous project is not a prelude to success. In fact, it may be disastrous.

Looking Ahead

Many factors impact what should be taught and learned by engineering students. In addressing the spectrum of knowledge that a graduating engineer should possess, professional skills, commonly associated with project management and multidisciplinary activities, are receiving considerable attention within the academic community[11], and in one instance has become an expected outcome[4]. Given the current market conditions and expectations of rapid product/project delivery, engineers at all levels increase their potential for success in their chosen careers by recognizing the need for project management knowledge, skills, abilities, and the corresponding competencies. The realization of their future success comes from developing and implementing a learning plan associated with their anticipated professional and career development.

Post-secondary institutions can decide whether or not to respond to constituent needs and provide engineering graduates who are industry-ready. Those institutions that respond with the necessary program changes will reap the rewards of prestige and growth. Those institutions that do not respond effectively run the risk of becoming obsolete, garnering the reputation of being "out of sync" with the current market demands, and possibly worst of all, finding themselves ill-prepared for what is obviously a potential addition to their ABET criteria.

With the rapid and global growth of PMI membership and PMP certification, the PMBOK is becoming the de facto standard for delineating the processes, inputs, tools, and techniques of project delivery. Therefore, it is recommended that the PMBOK be used in combination with discipline specific course materials in preparing engineering students for future work assignments.

Given the current trends and industry demands, it would be wise and prudent for undergraduate engineering programs to review their course content in relation to project management and professional skills. This would require that they consider the broader implications of developing and implementing applicable project management courses and coursework. Moreover, given the challenges facing engineering graduates, increased enrollment should follow those institutions that prepare their graduates to perform and excel in their chosen careers.

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