Teaching Project Management for a Manufacturing Environment

Mark Angolia[1], Charles Lesko[2]

Abstract – Project management tools are a critical skill set to be acquired in an undergraduate engineering or technology education. Through extensive field work in providing customized industrial project management training classes for manufacturing engineering staff members, a core set of project management competencies has been defined to address the needs typically requested by engineering managers for manufacturing operations, who can be considered to be a primary consumer of bachelor degreed engineering students. This research develops an undergraduate course syllabus designed to meet these needs by mapping the Project Management Institute's Body of Knowledge (PMBOK) to the industrial training course syllabi and popular academic project management textbooks. The mapped PMBOK knowledge areas provides instructors with a framework to design a comprehensive pedagogy by supplementing "core competencies" with topics suitable to their specific course objectives and overall engineering discipline needs.

Keywords: Project Management, Manufacturing, Engineering Education

INTRODUCTION

A great deal of news media and trade journals point to a significant amount of re-shoring of manufacturing operations, reversing the off-shoring trends started in the 1980s. [1] In a 2013 survey of over 275 chief executives, Grant Thornton LLP found companies were either "likely" or "very likely" to bring back previously off-shored work to the United States including: IT services (42%), components/products (37%), and materials (34%). [2] This revitalization of US manufacturing will be managed by many companies that have gone "lean" during the interim, and these manufacturing organizations will rely on project teams to replace a flattened middle management. [3] This paper focuses on projects executed at the production floor level within the manufacturing industry, and is derived from a review of literature, analyzing multiple years of teaching undergraduate project management courses, and extensive field work conducting industrial training of engineers from various manufacturing companies. The field work provided anecdotal evidence that engineering managers were well versed in the project management requirements for success, but that their support staffs did not have a level of capability to execute effective project management.

The typical types of projects that engineering managers have staff oversee include planned maintenance shut-downs, manufacturing process improvements projects, and capital acquisition / installation projects. Engineering managers look for a core set of competencies that are primarily involved with planning, scheduling, and communication. The goal of this paper is to map the Project Management Institute's Body of Knowledge (PMBOK) to the wants and needs of managers that will recruit engineering graduates, and present a syllabus to meet their immediate needs while simultaneously providing a foundation allowing graduates to take companies to the next level on the Capability Maturity Model - Integrated (CMMI) for project management.

[1] East Carolina University, 405 Science & Technology Bldg., Greenville, NC 27858, angoliam@ecu.edu

[2] East Carolina University, 215 Science & Technology Bldg., Greenville, NC 27858, leskoc@ecu.edu

PROJECT MANAGEMENT INSTITUTE BODY OF KNOWLEDGE

PMBOK, fifth edition, contains 47 project management processes grouped into ten separate knowledge areas [1] that provide a framework of "generally recognized" best practices for managing projects. It is intended to provide practices, techniques, and tools for managing projects, but is not intended to be a "how to" manual, nor can it define a uniform methodology since each organization/project can be considered unique. [4] A key tenant of PMBOK is that the practices presented do not need to be applied uniformly to all projects, and organizations are responsible to implement a subset of processes, and establish the degree of application robustness required. [4]

The Project Management Institute (PMI) defines a project as a "temporary endeavor undertaken to create a unique product, service or result." [4] To be considered a project, the endeavor must have a defined start and end point, along with a specific set of measurable objectives which are generally termed a "project scope". The cause for most project failures is almost universally pegged to unclear goals, i.e. a poorly defined scope, or lack of leadership. [5] The end point of a project is reached when the project's objectives are met, or when the project team determines the objectives cannot be met, or the need for the project is no longer viable. [4]

PMI goes on to define project management as "the application of knowledge, skills, tools and techniques to manage activities" required to meet objectives within a project scope. [4] The role of a project manager is to lead a team and balance competing constraints of scope, cost (including budget and resources), and time (schedule and deadlines). [5] The balance of these constraints is impacted by the risks of the project and the desired quality of the outcomes.

CAPABILITY MATURITY MODEL INTEGRATION

The original Capability Maturity Model [6] and the project management related interpretation crafted by Kerzner and the International Institute for Learning, Inc., (ILL) [7] are depicted in Figure 1. These are used to characterize the current state of implementation of project management methods at the manufacturing shop floor level and the reason engineering managers seek training for their staff. It is also the reason to consider the focus and structure for undergraduate project management courses geared for manufacturing related engineering disciplines.

Of interest from the review of literature were two studies, conducted ten years apart, that both assessed the capability of project management within a manufacturing environment. [8, 9] A 1997 paper by Ekmark, et al., placed the project management maturity at level 1, meaning that that project planning and execution was mainly ad hoc. [8] In addition, since projects were generally focused on immediate crisis and problems, scheduled times and budgets were often exceeded and quality was compromised to meet deadlines. [8] Approximately ten years later, a 2006 survey by Grant and Pennypacker revealed little movement for capabilities exhibited by manufacturing operations. [9] Table 1 breaks out the data from the 2006 research and summarizes only the manufacturing operations. Based on current field work, it can be inferred that companies contracting project management training are still at either at level 1 or in the processes of trying to establish themselves at level 2 of the IIL CMM.

Once engineering staffs demonstrate an understanding of the fundamental requirements and concepts involved in managing projects, the IIL considers an advancement to level 2 by having trained personnel develop a company specific set of processes for planning, scheduling, cost control, etc. Table 1 shows a majority of operations fall in the level 1 column and a decreasing percentage as we go up the maturity levels. The goal of engineering managers and higher education instruction should be to prepare our students to switch the percentages in columns one and two, and create an essentially normal distribution for the first three levels of capability maturity. Also, the IIL also recommends that a company have a PMI certified project management professional (PMP) on staff, to facilitate the implementation of the principles and techniques in the PMBOK.

Table 1. Capability Maturity Level Percentages for Manufacturing Operations

Knowledge Area	Level 1	Level 2	Level 3	Level 4	Level 5
Schedule Development	70.6	11.8	11.8	5.9	0
Resource Planning	70.6	23.5	5.9	0	0
Cost Control	58.8	17.6	23.5	0	0
Scope Change Control	41.2	41.2	17.6	0	0
Organization Planning	41.2	47.1	5.9	5.9	0

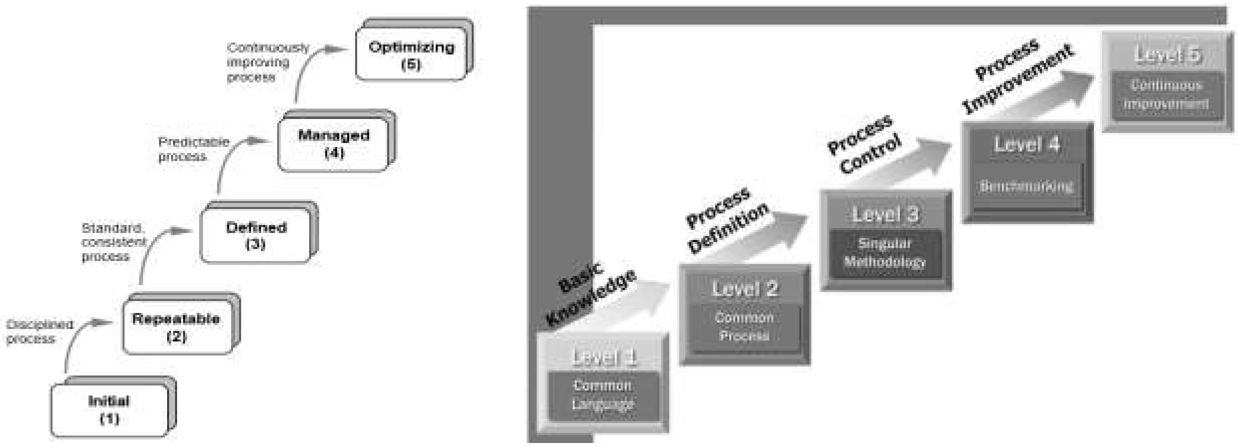

Figure 1. Capability Maturity Model Translated by the IIL to Five Levels of Project Management Maturity

MANUFACTURING OPERATIONS: ENGINEERING MANAGER EXPECTATIONS

Work that falls into the definition of a project requires a different set of managerial processes from work that is considered repetitive or ongoing. Newly hired college graduate engineers are often required to be project managers, leading multiple small projects within a functional or matrix organization. As such, the expectation is that degreed engineers will be capable of utilizing the proper tools, at the proper time, and at the proper degree of rigor.

Table 2 lists the "knowledge areas" that are used to organize the PMBOK, and maps the engineering manager expectations, i.e. core competencies desired. Additionally, for each knowledge area, Table 2 maps the PMBOK processes and tools that are typically found in college level textbooks, but not routinely requested by manufacturing manager practitioners. The table shows that the core competencies requested are focused in four of the ten PMBOK knowledge areas: scope management, time management, human resource management, and communications. The proposed syllabus that follows is intended to meet these needs by providing an industry driven set of core competencies along with a proposed project simulation methodology, and alternatives for instructors to add other related topics based upon their textbook and area of interest.

Interestingly, there is no practical demand for training in PMBOK knowledge areas for cost management, quality, risk management, procurement, and stakeholder management. This does not imply that these areas are of no interest, but that engineering managers see their primary need in short term goals and trying to move from level 1 to level 2 in the CMM. Hence, demonstrated core competencies including project scope, work breakdown structure (WBS), schedule, and communication, including task management, meetings, and reporting, must be part of the outcomes of a project management course. Of some consideration was the importance of risk management, but topic interest was more at the engineering manager level rather than the engineer as project manager. A caveat here is that Kerzner cautions against failing to consider risk management in scope development and project planning. [10]

Another critical area for syllabus development and textbook selection is the decision whether or not to include project management software, specifically Microsoft Project (MSP). Initially, project software was thought to be the panacea for project results that often were overdue and over budget. Properly employed, project management software can be an effective planning, communication, tracking, and reporting tool, but it cannot substitute for project management knowledge. Field experience showed that few "MSP practitioners" understood the nuances of Microsoft Project and what was required to make the software work properly. Since MSP is more often than not misused in industry, engineering managers hope to see college graduates bring a level of proficiency currently lacking. Note, of all the manufacturing companies requesting project management software, Microsoft Project was the unanimous selection, although the release version varied from 2003, 2007, and 2010.

Table 2. Industrial Training and Textbook Topics Mapped to PMBOK

PMBOK Knowledge Area*	PMBOK Process Requested for Training	PMBOK Related Training Tools	Instructor Discretionary PMBOK Related Textbook Topics	
(4) Integration	• None	• None	• Stakeholder Register • Statement of Work • Business Case	• Project Charter • Change Request Logs • Forecasts
(5) Scope Management	• Define Scope • Create Work Breakdown Structure (WBS) • Validate (Approve) Scope	• Mind Mapping • Affinity Diagram • Scope Statement • WBS by Deliverable	• WBS Dictionary	• Scope Change Control
(6) Time Management	• Define and Sequence Activities • Developing Milestones • Create Network Diagram • Develop Schedule • Schedule Network Analysis	• Activity Lists • Gantt Charts • Precedence Diagram Method (PDM) • Critical Path Method • Project Calendars • Microsoft Project	• Bottom Up and/or Top Down Estimating of Resources and Durations • Earned Value Rules • 3 Point Estimating (PERT) • Reserve Analysis (Time Buffers)	• Resource Breakdown Structure (RBS) • Critical Chain Method • Resource Leveling • Crashing and Fast Tracking • Leads and Lags • What If Analysis • Simulation
(7) Cost Management (Resources)	• None	• None	• Estimating topics from “Time” are repeated here • Earned Value Management (EVM) • EVM Forecasting	• Human Resource Management Plan • Vendor Bid Analysis • Budgets and Management Reserves
(8) Quality	• None	• None	• Cost of Quality • 7 Basic Quality Tools • Quality Assurance Tools	• Statistical Sampling • Design of Experiments • Benchmarking
(9) Human Resource Management	• Development of Team	• RACI (Responsibility) Matrix • Meeting Structure	• Organizational Theory • Negotiating • Virtual Teams • Training • Building Trust	• Interpersonal Skills • Performance Appraisal • Conflict Management
(10) Communication	• Communication Plan	• Performance Reporting • Meeting Management	• Information System Management	• Communication Model
(11) Risk	• None	• None	• SWOT Analysis • Risk Categories • Risk Assessment • Risk Probability and Impact Matrix	• Quantitative Risk Analysis • Strategies and Contingencies
(12) Procurement	• None	• None	• Types of Contracts • Statement of Work • RFI, RFP, RFQ, IVB	• Negotiations • Purchase Agreements
(13) Stakeholder	• None	• None	• Stakeholder Analysis • Interpersonal Skills	• Management Skills

* PMBOK Chapters are shown in parentheses ( )

SYLLABUS

In the competitive world of collegiate publishing, textbooks are produced that are useful at both the undergraduate and graduate level. As such, these textbooks typically have more chapters than there are weeks in a semester. As individual instructors have their own favorite authors and textbooks, this paper does not intend to define a "best" textbook, but rather outlines a course structure to prepare undergraduate engineers to meet the expectations of engineering managers in a manufacturing environment.

The challenge in teaching project management in higher education is that there is an extremely diverse content selection and no uniform definition of an "ideal" project structure [4], just as there is no "typical" project. Therefore, there is no standard curriculum for a project management class at the undergraduate level. A well-designed undergraduate project management class must introduce students to a wide range of practices and tools that will allow them to develop their capacity to understand which are required in the industrial world, yet provide enough rigor to ensure that core competencies are developed to the extent they can be applied immediately.

The proposed course syllabus, outline, and content are intended to deliver the core competencies derived from the aforementioned literature review and field work. These competencies are taught concurrently within a framework of three project simulations for the three types of projects typically encountered at the manufacturing floor level: plant maintenance shut downs, continuous improvement projects, and capital projects. Table 3 details a fifteen week course outline, breaking the semester into three unequal modules. The table also shows proposed project simulations to be run sequentially, thus requiring utilization of core competencies in a repetitive manner for reinforcement of learning.

The following subsections detail the syllabus, course structure, modules and their related core competencies, and the project simulations in more detail. It should be noted that the syllabus only addresses internal company projects. While many of the competencies apply for externally oriented projects, material and methods related to external projects would be considered an instructor determined content area.

Table 3. Suggested Weekly Course Outline

Topic/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Module	PM Overview and Communication		Planning and Scheduling							Monitoring and Control					
Project Simulation			Plant Maintenance			Continuous Improvement				Capital Procurement and/or Installation					
Tools			Manual (Excel and Word)							Microsoft Project Software					

Course Objectives

The objective is to introduce project management techniques from the standpoint of developing and executing internal projects at the manufacturing floor / operations level within an industrial organization. Specific objectives include students gaining competence in:

- Leading industrial project teams
- Communication and inter-personal skills
- Development and control of project scopes
- Planning and scheduling a project
- Risk management techniques for project management
- Execution and control of a project
- Communication planning and status reporting
- Status reporting and business / technical correspondence
- Project management software (Microsoft Project recommended)

Course Structure

Table 4 breaks the course materials into three sequential modules mapped to the PMBOK: Overview and Communication, Planning and Scheduling, and Monitoring and Control. A fourth module, Project Simulations, is run concurrently with students executing project management simulations, employing more and more involved processes as the semester progresses. Additional content may be added at the instructor's discretion; this table serves as a threshold level of required content.

Table 4. Syllabus Modules: Core Competencies Only

Module	PMBOK	Core Competencies	Tools and Templates
Project Management Overview and Communication	(9) Human Resources (10) Communication (12) Procurement (13) Stakeholder	• Leadership Skills • Interpersonal and Conflict Management • Meeting Management • Stakeholder Management	• Written Communication • Kick Off Meeting • Meeting Agendas
Planning and Scheduling	(4) Integration (5) Scope (6) Time (11) Risk	• Stakeholder Analysis • Scope • Work Breakdown Structure • Activity Sequencing/Scheduling • Resource Analysis • Communication Planning	• Progressive Scope Elaboration • Mind Mapping • Yellow Sticky Approach / Network Diagram • Responsibility Matrix • Communication Plan • WBS / OBS / RBS
Monitoring and Control	(7) Cost (8) Quality	• Progress Tracking / Reporting • Scope Control • Closing and Lessons Learned	• Gantt Charts • Scope Management
Project Simulations		• Short Term Plant Maintenance Shutdown • Continuous Improvement Project Team • Capital Project	• Team Organization • Scope Development • Milestones • WBS • Project Plan • Communication Plan • Kick Off Meeting Agenda • Progress Report Template

Module 1: Project Management Overview and Communication

Larson and Gray define communication as the main job responsibility of a project manager, and therefore it needs to be a core competency in a project management course. [5] Project management is also very much about the need to plan and control the work being completed, and communication is a vital aspect of this.

PMBOK differentiates communication into three styles: pull, push, and, interactive. [11] Pull information is the easiest to establish. It is defined as large volumes of information set and maintained by the project team in a repository manner such as a SharePoint site that stakeholders can access at will. Thus, SharePoint or other "cloud type" training is useful for students. Push information is specific information sent to specific users, and as such is the most challenging because it involves teaching stakeholder analysis and the art of written communication. Kerzner points out that sponsor related information is different than project team related information, a difficult concept to teach for those un-indoctrinated to corporate organization and politics, and of course vastly different depending on company culture. [10] Additionally, while many colleges have core writing programs, they are primarily academic styles, rather than technical or business writing. Perhaps the coming generation of engineers faces a steeper learning curve with interactive communication, which is defined as an exchange of information in meetings, phone calls, video conferences, etc. In an age of text messages and Twitter, face to face communication is an increasingly rare form of communication. Creative exercises to simulate project kick off meetings and use of in-class project reporting role play meetings are useful here.

PMI provides a communication management template plan that includes a matrix of stakeholders, information required, method of distribution, timing or frequency of distribution, and person responsible to send the information. [4] The template also includes a list of assumptions and constraints on which the plan itself is based, and room for a glossary of terms. Business writing guides can be found in the Purdue Online Writing Lab (Purdue OWL). [12]

Module 2: Planning and Scheduling

This module is focused on internal projects and begins by imparting on students that the "why" of a project must come before the "what are we going to do." [3] Once a "why" is established for a project, the project manager can start to define what needs to be done. Subsequently, a formalized scope statement can be approved (validated) by an internal company official, usually the project sponsor. PMBOK establishes six primary requirements for a project scope along with a template which includes the items in Table 5. [11] The concept students have a difficult time grasping is that the scope is developed iteratively, referred to as "progressive elaboration" [11] along with a work breakdown structure (WBS), and potentially with a network diagram produced via the precedence diagram method (PDM). Therefore, scope assignments should include a preliminary and final assignment structure.

Kerzner states that most practitioners need to focus on the early steps of project management, but cannot neglect risk management as a major component in planning failure. [10] Projects for external customers will generally always employ a degree of risk management, but field work provided anecdotal evidence that engineering manager expectations generally skip both risk management and a formal scope process for internal projects.

Table 5. PMBOK Project Scope Requirements

Scope Requirement	Description
Project Description and Objectives	• Developed by progressive elaboration • Characterizes the result of the project by defining the "what and when" • Project milestones (not in PMBOK, but recommended)
Acceptance Criteria	• A set of conditions required for acceptance of deliverables
Deliverables	• Any unique and verifiable product, result, or capability to perform a service • Ancillary reports and documentation
Project Limits and Exclusions	• Identifies project boundaries • Specifies what is excluded from the project in order to manage stakeholder expectations
Constraints	• Internal and external limiting factors affecting the project execution or processes • May include budget, imposed dates (deadlines), schedule milestones • Contractual agreements for external projects (if applicable)
Assumptions	• A factor assumed to be real that impacts planning • Explains the impact if an assumed factor proves to be false (not real) • Must be identified, documented, and validated during scope development

The processes required to create a scope, produce a comprehensive WBS, and then sequencing activities is a core competency. A review of PMBOK and textbooks determined that "mind mapping" was a best practice and should become a standard tool for engineer training for WBS development. [3, 13]

Another key aspect of a WBS is the importance of verbs to begin an activity/task definition. [3] One of the interesting revisions of PMBOK in going from fourth to fifth edition was a change to rename project management processes in "verb-noun" format. This provided a degree of anecdotal evidence of the need to impart clarity on an activity by starting with an action word, i.e. a verb, and then having a noun describe the content required.

Once a WBS is generated, a communication tool is required for project coordination and management. If project management software tools are not used or desired, manual methods of scheduling include the responsibility matrix, organization breakdown structures (OBS), resource breakdown structures (RBS), or a Responsibility, Approval, Consult, Inform (RACI) chart. These methods will list activities needed, i.e. document the work breakdown structure, and provide a communication tool for resources and dates. [4] Other communication tools that may be used to provide a WBS and timing include the six sigma DMAIC process or the "story board" approach used with the popular A3 format. Both of these reporting methods are driven by some sort of responsibility matrix, which is one of the fundamental organization methods in the PMBOK chapter 9 on human resource tools and techniques. [11] It should be noted that a key shortcoming of the PMI RACI and textbook responsibility matrix templates is the omission of task deadlines. For short term projects, milestones may serve as deadlines for all intermediate tasks if a network diagram is not required. For longer terms project, project software is the preferred method, but again, without a properly constructed project network, timing may not be valid. These methods of communicating a WBS have primary use in short term projects with defined deadlines that generally do not require close scheduling coordination, hence dates can be management deadline driven rather than calculated with the PDM.

If more precise scheduling is required, the sequencing of activities to develop a network diagram is required, but existing capability for this is at level 1 for manufacturing operations, per Table 1 and confirmed through field work. Construction of a network diagram is facilitated by project management software, which also allows students to ascertain technical aspects such as individual task start and finish times, the project critical path, and overall duration. However, a tool is needed to determine the predecessors for the tasks in the software file. The recommendation is to teach the "yellow sticky approach" to provide a structured approach. [3, 5] Additionally, experience has shown that working the "yellow sticky approach" will generate a good deal of collaboration, buy-in, discovery of new activities, and updates to project scopes. As a caveat when using Microsoft Project instruction, a critical teaching point is to include the interaction effects between "resources" and "activities" since once the resource function is used, the timing aspects of the software will change with each modification of resources. In addition, calendar functions must be explained, including calendars for resources, tasks, and the project calendar, to preclude misuse of the software. Field work showed that Microsoft Project practitioners rarely understand these interactions and impacts.

Module 3: Monitoring and Control

Communication of task and milestone progress in inherent in project management, and as such, standard reporting methods are a core competency for this module. While PMI does provide a reporting template, it is much too basic for industrial use and needs to be adapted for individual course requirements. A key aspect in the upcoming Module 4 simulation will be for project teams to develop standard reporting forms, along with stakeholder analysis and a communication matrix to document distribution. The Gantt chart is the predominant reporting tool, and it should be taught in both manual (Excel) format and as a standard output from project management software, if utilized.

Other core competencies in this module include scope control to prevent scope creep, and a formalized process for project closure and lessons learned. These competencies should be reinforced by student teams developing standard forms and operation procedures to implement, and be reinforced in the project simulation module. Finally, project management texts and PMBOK spend time and effort on the earned value method of reporting project performance, but it is rarely used in manufacturing operations and may be more of a graduate level topic. Therefore, it is not considered a core competency but it is a recommended inclusion for familiarity of the practice.

Module 4: Project Simulations

Three project simulations, as shown in Table 3, are recommended. The recommendation is to create project teams of three students, with rotating managerial, planning, and communication duties. Team should self-select members based on common degree disciplines/interests, and be tasked to select a real world company to develop simulated projects. The teams will execute the three projects sequentially, adopting core competencies and modifying methods as the course progresses. The first two projects are run manually (Excel and Word) and the last project utilizes project management software if desired in the course structure. If software is not used, then Excel and Word methodologies would be enhanced. The strategy is to provide experiential learning though repetition and an increasing rigor of the core project management competencies.

Project management tools should be used in a "project within a project" concept format. Student project managers would be expected to develop a project scope, WBS, and RACI chart to complete the assignment, i.e. what will team members do to complete the instructor's grading requirements. Then, the students would embark on developing the simulated project requirements, including common requirements for all three projects: 1) submission of a preliminary project scope, and subsequent progressive elaboration, 2) creating a WBS, 3) creation of project milestones and/or schedule, 4) initial Gantt chart. At this point, each project would employ a different communication and management tool. The first project, plant maintenance shutdown, should be coordinated using a RACI chart or a responsibility matrix. The second project, for continuous improvement, would utilize either the A3 storyboard format or excel based Gantt charts. The third project, for capital, would utilize project management software if desired, or an enhanced version from the continuous improvement project. Students would also be expected to produce forms and templates of other core competencies including communication plans, meeting agendas, progress reports, close out / lesson learned, etc.

SUMMARY

This paper proposes a "core competency" approach for undergraduate project management courses based on PMBOK related techniques and tools needed by engineering managers of manufacturing operations in Eastern North Carolina. While a core competency approach is directly applicable for industrial training needs, it is not sufficient for a well-rounded undergraduate higher education project management class. Therefore, to provide a richer project management education experience within an engineering curriculum, core competencies must be supplemented with other content. Table 2 documents the core competencies from PMBOK and also describes PMBOK related content currently available from popular project management textbooks. This allows for discipline specific concepts to be included and meet any ABET related requirements. Ideally, this course would be delivered in the first semester of a student's junior year and then the content / techniques utilized for semester projects in all subsequent courses.

Outcomes

The proposed syllabus and course outline provide a roadmap to develop an undergraduate project management course structured around the PMI PMBOK. The material presented establishes a core set of PMBOK competencies sought by engineering managers within manufacturing companies, and provides an outline of PMBOK related textbook topics that are to be included based on an instructors preference and course objectives. The research provides the tools that will allow engineering graduates the ability to make an immediate impact on a manufacturing operation to improve from a CMM level 1 to a CMM level 2 or 3 maturity. In addition, as the provided course syllabus is primarily based on the PMBOK, the proposed course structure would provide engineering graduates a competitive advantage in pursuing the Certified Associate in Project Management (CAPM) from PMI and establish a professional credential early in his/her career.

Future Research

This pedagogy for the core competency approach in an undergraduate technology related degree program will be implemented in a technology project management course in 2014 at East Carolina University's Department of Technology Systems.

Additionally, the pedagogy put forth by this paper will be tested to evaluate how project management core competencies can be integrated into class work not specifically designed / titled to teach project management. If successful, this will provide an enhancement of learning that will aid engineering students inasmuch as they will be provided with a comprehensive project management course, and then able to reinforce core competencies by application in other classes.

The future study will be completed with two semester projects in a collaborative, inter-disciplinary teaching venture during the 2014 calendar year. In this study with an academic colleague, the core competency framework will be implemented as part of a two course sequence of industrial engineering technology courses: Introduction to Computer Integrated Manufacturing (spring 2014) and Electromechanical Systems Integration (fall 2014). These courses currently take student project teams through the academic rigor to design and build a functioning robot for an inter-collegiate competition. The instructor of this two course sequence has historically had students manage the project using ad hoc project management tools, but this year will introduce the proposed core competency tools as stand-alone course module and part of the rubric for semester project work.

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Mark Angolia
Dr. Mark Angolia is an Assistant Professor at East Carolina University in the College of Technology & Computer Science. Prior to entering academia, he held industrial positions in engineering, manufacturing, quality, materials, and operations management for manufacturing companies within the automotive supply chain. In addition to teaching in ECU's Department of Technology Systems, Dr. Angolia conducts approximately 200 hours per year of industrial training and consulting for topics including forecasting, inventory management, production planning, project management, and supply chain management. His research interests are in improving supply chain efficiency through the application of technology and best practices for warehousing, logistics, and inventory management. He holds a B.S. and Master of Engineering degree from Rensselaer Polytechnic Institute, and a Ph.D. in Technology Management from Indiana State University. He also holds professional certifications of CPIM and CSCP from APICS, The Association for Operations Management, and a PMP from the Project Management Institute.

Charles Lesko
Dr. Charles Lesko is currently serving as Assistant Professor in the College of Technology & Computer Science at East Carolina University. His career focus is on managing and leading technological innovation in the workplace; his past experiences bring to the table a heavy technical background with a strong management and technical leadership base. Dr. Lesko has over (20) years of experience in the systems integration and project management fields; his experience base also includes military service and (9) years in academia. He holds a B.S. from the US Naval Academy, a M.S. in Forensic Science from National University, a M.S. in Computer Information Systems from Boston University and a Ph.D. in Applied Management and Decision Science from Walden University. He is also a certified Project Management Professional (PMP).