Project Management Education as a Component of University Research

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Abstract **- In a graduate student's time at a university, they are exposed to many technological topics and concepts. When they graduate and start employment in industry, they will quickly find that they need more than technical skills to be successful. In today's competitive business environment, engineers cannot afford to be pure engineers. They need to have project management (PM) skills to manage various aspects of a project-driven technological organization to work in a cross-functional team either as a manager or as a member of the team. Many companies are expecting new graduates to be productive on their first day of work, and a solid understanding of PM concepts helps these new employees to be more productive team members. However, graduate students are rarely exposed to any PM concepts in their classes or studies. This paper discusses experiences with introducing PM concepts like work breakdown structures, scheduling, and risk assessment in research grants, contracts, and projects. Detailed steps for introducing these processes and mentoring students are also discussed.**

Index Terms - Grants, project management, research, risk assessment, scope, work breakdown structure.

INTRODUCTION

Many engineers are now either faced with management responsibilities at their current positions, or promoted to higher positions [1]. Therefore, they need to have project management (PM) skills to manage various aspects of a project-driven technological organization combining engineering problems, human factors, and financial issues and to work in a cross-functional team either as a manager or as a member of the team. Consequently, to be successful in this work environment, it is crucial for engineers to have some level of PM knowledge and experience BEFORE they join the workforce. Similarly, it is critical for companies to consider their employees' PM skills as they are hired, to be competitive.

The Project Management Institute, the professional organization for project mangers, has identified a "Body of Knowledge" [2,3] useful for managing small and large projects. Those who have served as a project manager and have displayed a mastery of this body of knowledge can earn the "Project Management Professional" (PMP) certification. Although this body of knowledge and certification is valuable in industry, it is too extensive to cover completely in a university curriculum centered on technical skills. It is, however, an excellent basis that educators can draw from and incorporate into existing courses and research programs.

Although many universities include a few very basic PM concepts within their engineering curricula, most universities do not provide detailed PM instruction [4,5]. The problem lies in the competing goals of a university, a discipline prerequisite knowledge, and the national engineering accreditation organizations. There are only so many credit hours in a typical Bachelors of Science curriculum. Further, university faculty are historically not known for their PM skills and knowledge, so the faculty will typically not introduce PM concepts into classes or use PM skills in their research [5-7].

This paper describes one way to introduce project management skills to students - teaching by example. In this method, the faculty member will need to learn a basic level of PM skills and use these skills to conduct research. The research should include these basic PM skills during the planning and execution of the projects. This paper also provides three case studies that illustrate the techniques described below.

RESEARCH CHARACTERISTICS AND PM OPPORTUNITIES

Classifications of Research

In order to identify the opportunities of PM instruction in research, one needs to identify the environment in which the work will be conducted and identify any promised deliverables. Our definition of research categories is identified by the following characteristics:

- Grant, required deliverables; complete a specific task or develop a specific product as mandated by the sponsor. Effort bounded by time and money; deliverables are product, reports. Residual deliverables include conference papers, journal articles, and thesis/ dissertations. Subcategory is the service agreement, where intellectual property (IP) remains with the sponsor.
- Grant, open ended (no required deliverables); work wherever it looks interesting; deliverables are IP, conference papers, journal articles, and thesis/ dissertations. Effort bounded by money, but not necessarily time.
- Unfunded research, directed by faculty, work wherever it looks interesting. Effort not bounded by time or money. Deliverables are IP, conference papers, journal articles,

thesis/dissertations, and results necessary for future grant proposals.

Of note is that each of these three categories has different bounds of time and money. Obviously, the "grant, required deliverable" category will have the most stringent requirement for good planning, but all could benefit from the application of sound PM methodologies.

PM Skills Useful in University Research

In the Project Management Body of Knowledge, there are nine knowledge areas that contain processes that are used in project planning and execution. These knowledge areas are [2]:

- **Project Integration Management**
- **Project Scope Management**
- Project Time Management
- Project Cost Management
- Project Quality Management
- Project Human Resource Management
- **Project Communications Management**
- **Project Risk Management**
- Project Procurement Management

While all of these knowledge areas are important, we have identified the four bolded above as the most important. If taught correctly, these four knowledge areas could have the greatest impact on project success and PM education [5]. This knowledge can be grouped into three distinct pedagogical "modules" or study areas. These modules can be demonstrated to research students, after which the students could apply the knowledge to their own projects. These modules are:

Project Scope and Work Breakdown Structure Identification Skills: Often a research project has an industry or academic sponsor. With these skills the students will learn how to identify the scope (expected deliverables and functionality) of their project and develop a scope statement that satisfies their sponsor. Students will also learn how to verify and control changes of the scope. Another important concept is creating a work breakdown structure (WBS). A WBS is a deliverable-oriented grouping of project components that organizes and defines the total scope of the project [2,3]. A WBS is considered one of the most important documents of project planning - it is used in most of the other project processes. Students working on research projects should create a WBS all the way down to the work package level (individual tasks).

Project Time and Integration Management Skills: Once the project scope and WBS is developed, project activities are planned. In this set of skills students can learn how to convert their WBS to specific identifiable tasks, and then sequence these task to create a project plan that can be followed during project execution. The faculty researcher can also include an introduction to PM tools like GANNT charts and the application Microsoft (MS) Project.

Project Risk Management and Reporting: Risk management is a concept that receives little attention in the academic world, but is an important component of corporate project implementations. Students are not prepared to address problems that arise in their project work or research, and thus are rarely able to respond to risks in their first employment position. This important topic includes planning, identifying, controlling, and mitigating risks in a project. Students will also learn risk assessment and progress reporting during project execution.

Teaching PM by Example in University Research

As suggested above, PM skills can be taught in a class-like environment, as an iterative mentoring process, or as demonstrated by the faculty researcher. The adage "I hear and I forget, I see and I remember, I do and I understand” is applicable to PM as well. Students will not truly understand the PM processes and knowledge unless they are active participants in its use in research. The steps to best involve students are:

1. Involve them in the creation (or at least the modification) of the final statement of work. If this is not possible, at least ensure that the student has a copy of the statement of work - this is the document that drives all of the work of the project.
2. Involve them in the creation of the WBS. This includes the many tasks that are associated with a project.
3. Involve them in the scheduling of the tasks. They will be better motivated to work on the project if they had a part in the plan’s creation.
4. Have them record the time they spend on each task so they understand the effort they are spending on the project.
5. Have them write status reports of accomplishment weekly or bi-weekly. They will learn the importance of accountability for their efforts.
6. Have them participate, and possible monitor, the risks of the projects. The simplest is a risk assessment, as shown in Figure 1.

CASE STUDIES – EXAMPLES OF PM IN RESEARCH

I. Case Study 1 – Grant, Required Deliverable – Team

The first case study involves a grant with deliverables between UNC Charlotte and a small software/hardware products company. The relationship was developed because the faculty researcher purchased tools from the company and asked if the company would be interested in any collaborative efforts. After some discussion, an initial need was identified. The effort involved having student researchers learn a communications protocol decoding application and the decoding scripting used by this application. They then wrote new decoding scripts for several proprietary industrial communications protocols.

The effort was initially scoped with the assistance of the company’s subject matter expert. The expert and the university researcher then developed the work breakdown structure and project plan (GAANT chart). The hours of effort for each project task was estimated based on unwritten past

Risk Analysis and Mitigation Plan - Project: Optical

Probability: 3 = likely, 2=possible, 1=unlikely

Impact: 3=show-stopper, 2=medium, 1=low

Ease of Mitigation: 3=costly, 2=medium, 1=low or none

Risk	Prob	Impact	Rank	Mitigation	Ease of mitigation	Cost
Not enough UART devices on Atmel ATmega 128	3	2	6	Use Atmel ATmega256; Add jumpers if using Atmel ATmega128	2	12
IrDA circuit is too noisy	2	2	4	Use an off-the-shelf board	2	8
Cost of development may be too high	2	2	4	Get part donations	2	8
New optical transceiver is unknown - may be difficult to implement	2	2	4	Revert to older separate transmitter/receive pair	2	8
Atmel ATmega256 chip may have problems - not in production	3	2	6	Use Atmel ATmega128 to debug	1	6
			0			0
			0			0

FIGURE 1. SAMPLE OF A RISK ASSESSMENT

experience and adjusted for the expected experience of the student researchers. The statement of work included the general objectives of the work and the detail of the project plan with expected hours of effort. An example of the WBS and GAANT chart is shown in Figure 2.

The work included learning each proprietary protocol by a team of two students. There were two student teams as well as the faculty researcher "supervisors". Members of the teams helped each other learn and understand the protocol. After this education, one member worked writing the protocol script, and the other worked writing a test plan, test cases, and sample data to validate the script. Although the team members talked to each other frequently on the protocol, they did not share details after the education phase of each protocol effort. After each team member completed their tasks, they tested the scripts using the test cases and existing sample data.

Weekly status meetings were held between the company and the university team. During meetings, progress was assessed and larger problems that could change the scope of the work were discussed. The university team also recorded the number of hours actually spent on each task. These hours were compared to the initial estimate for the possible future use of more accurate estimating.

The effort was considered a success – the new scripts were completed on time and within budget. One part of the effort was cancelled when specifications to complete the work could not be provided to the university team. Some of the major observations and accomplishments were:

- Students, though not a part of the plan development, felt in control of their efforts and an integral part of the team, since they saw the complete project plan and where they fit into the plan. In fact, conversations with the participants after the work included comments like, "It was valuable to know what I needed to do and when – it allowed me to stay focused, and "I want to plan my MS thesis just like this".
- The company sponsor did not allow adequate time to support this activity (subcontractor project management). The items delivered to the company were not reviewed thoroughly or timely. Often weeks would pass before the materials were reviewed and a change requested – sometimes after the students had moved on to work on another protocol script.
- The company sponsor was switched off of supporting the effort near the end. This meant that the faculty researcher needed to "re-educate" a new sponsor on the objectives of the work and past and current progress.

II. Case Study 2 – Grant, Required Deliverable - Individual

The second case study involves a grant with deliverables between UNC Charlotte and the same small software/ hardware products company from Case Study 1. The effort again involved having student researchers write new decoding scripts for several proprietary industrial communications protocols.

This time the amount of work was smaller – it only needed one or two student workers. The company also determined that there was no need to create test cases to validate all of the functionality of the decoder scripts. They believed that the existing trace data of the protocol's normal communications was ample coverage of the proposed scripts. They also indicated that they would generate additional test case data using a company tool; this data would be provided to us when needed. Though the faculty researcher tried to convince them otherwise, the company would not support the effort of more than one student for the effort.

The statement of work (SOW) was developed with the assistance of the sponsor, faculty PM, and the student team

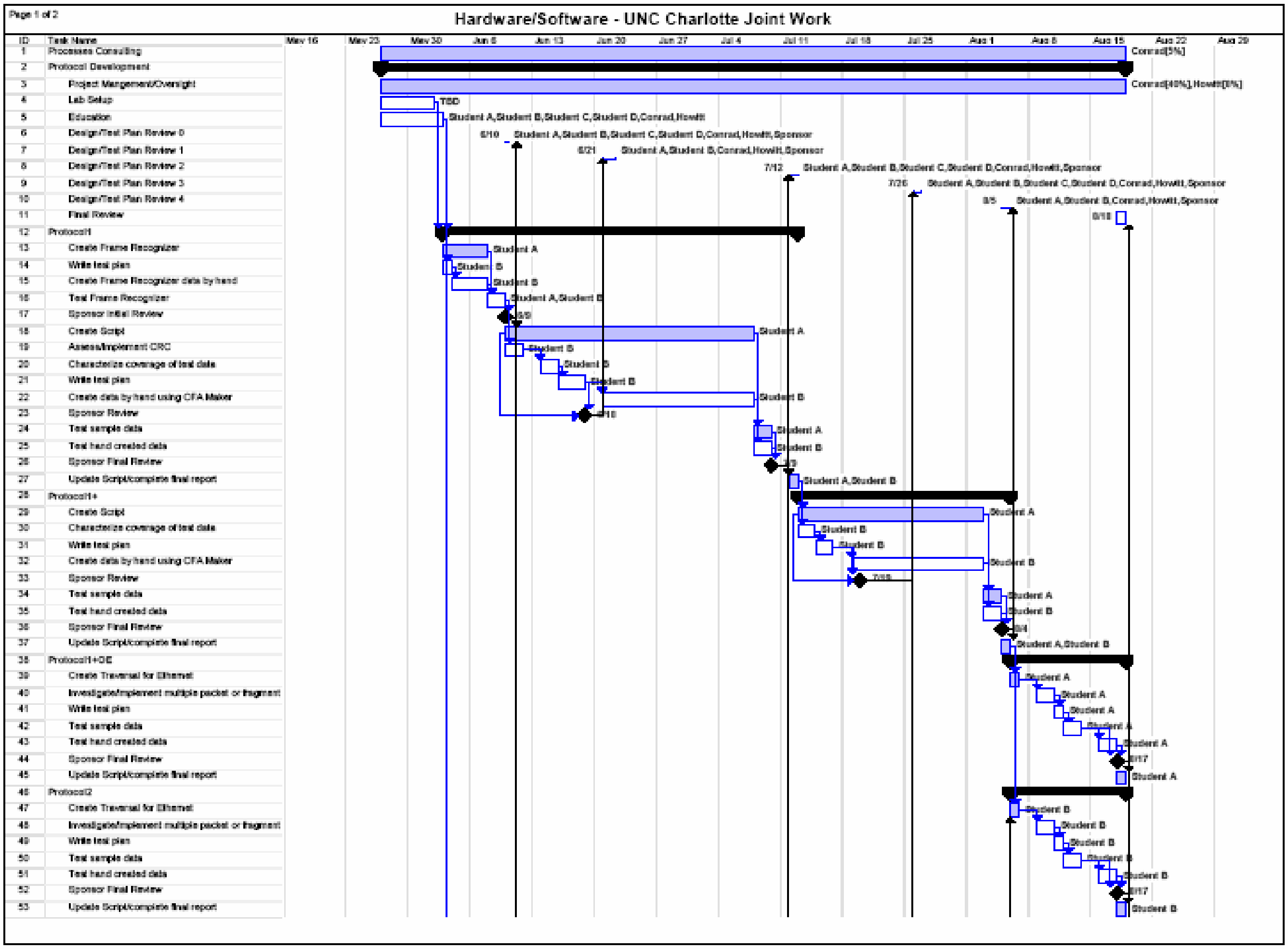

FIGURE 2. WORK BREAKDOWN STRUCTURE AND GAANT CHART FOR CASE STUDY 1.

member. This included the WBS and GANNT chart. Estimates on the hours of effort were made using the data recorded from effort described in Case Study 1.

The effort started a bit late due to delays in the contract paperwork – therefore, work was accelerated from the scheduled plan. Work progressed on schedule, but problems soon arose because it was a lone-person effort – the student worker did not have any one else familiar with the protocols to discuss concepts and ideas. The worker also found that the test data provided covered only a small portion of the protocols; especially since the promised "extensive test case data" was not provided due to time constraints. This resulted in a delivery of one script that worked fine with the provided test data, but upon inspection by the sponsor did not meet the intent of the effort. Rework was completed, but the sponsor lost confidence in the student.

Although the final work was delivered on budget and slightly behind schedule, it was not as successful as Case Study 1 for several reasons:

- Complex software development tasks should include several participants so that they can work collaboratively.
- Testing was reduced to minimize cost – this is an age-old problem that should not have been allowed by the PM (and will not happen again).
- The sponsor's effort was not included in the overall project plan, so their effort was not tracked or discussed during weekly project meetings.
- The additionally "extensive" test case data was never provided, and thus the testing was not performed to the level that should have been done.
- The effort could be summed up by the comment of the student worker: "they seemed interested in the work at the beginning, but lost interest in the end and seemed to just want the delivery of anything."

III. Case Study 3 – Grant, Open Ended -Individual

The third case study involves an open-ended grant awarded to a faculty researcher for work on an optical communications board to be used for education and research test beds. The work included the requirements, specification, and design of a PCB and associated software to allow a one-microcontroller evaluation board to communicate to another board via optical fiber, IrDA, USB, or RS-232 technologies (with the option of attaching an IEEE 802.15.4 wireless transceiver as well). This work has been reported in several papers [8-10]. The work was to be funded for seven months, with the deliverables to be a completed board, educational materials (i.e. lab exercises), and several publications.

The student and faculty researcher together wrote the SOW. Once the grant was awarded, the student and faculty researcher created the WBS and plan. An early risk assessment was created but further assessments and mitigation updates were not done, though they should have been completed. The progress of the work was not closely tracked to the project plan, so valuable information related to the effort required for each task was lost.

The sponsor did not require a specific deliverable at a specific time, but we have made presentations to the sponsor's community to demonstrate the project's functionality. For example, the work was presented at a poster session of the North Carolina Optics Symposium in the Fall of 2005. The work is nearly complete but has extended beyond the seven-month plan.

CONCLUSIONS AND FUTURE WORK

Integrating the fundamentals of project management skills into the graduate student's research experience can provide them with a competitive advantage when entering the job market, whether academic or industrial. The experience provides the student with essential tools and first hand experience in using these tools. Three case studies were presented in which PM concepts such as work breakdown structures, scheduling, and risk assessment were introduced to graduate students during the course of carrying out the technical requirements for research grants, contracts, and projects. Observations and lessons learned from these case studies were presented.

Our future plans are to continue to use these PM skills for our research. We will also develop and publish PM materials that encompass the three modules described. Visit http://www.coe.uncc.edu/~jmconrad for more information.

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