AC 2011-1532: A MODULAR PROJECT MANAGEMENT APPROACH TO UNDERGRADUATE SENIOR DESIGN PROJECTS

Teodora Rutar, Seattle University

Teodora Rutar Shuman is a Paccar Associate Professor at Seattle University, Department of Mechanical Engineering. She received a B.S. in Mechanical Engineering from Belgrade University, Yugoslavia, and an M.S. and a Ph.D. in Mechanical Engineering from the University of Washington. She pursues research in electro-mechanical systems for sustainable processing of microalgae. email: teodora@seattleu.edu

Brandon Shuman, MS

Brandon Shuman is a graduate of the UW Mechanical Engineering Baccalaureate and Masters programs. Since then he has been a medical device engineer for 15 years at Boston Scientific and Spiration. His projects have included cardiac and pulmonary catheters and implants. He is also an adjunct faculty member at Seattle University.

A Module Oriented Project Management Approach to Undergraduate Design Projects

Abstract

This paper describes implementation of Module Oriented Project Management (MOPM) in capstone design projects. MOPM is a method used in industry to break down projects into modules for which one individual is responsible. This provides opportunity for ownership and responsibility while maintaining a framework for collaboration and milestones, and as such could fill the gap usually encountered in capstone design projects. In the 23-year history of year-long industry-sponsored capstone design team-projects at Seattle University, projects often suffered from the following shortcomings: failures to meet deadlines, poor contribution from some team-members, and incomplete use of available resources. Furthermore, advice from our program's industry advisors indicates that engineering graduates should have some project management skills and understand the importance and challenges of managing projects. In response, we adopted MOPM to our senior design projects.

The paper describes implementation of MOPM in our senior design projects in school year 2009-2010. It also shows qualitative assessment data that support following conclusions: 1) students took more ownership of their duties on the project through involvement in planning and modules; 2) students implemented project scheduling and monitoring to their capstone projects, effectively beginning to develop related skills; and 3) faculty advisors were for most part focusing only on the technical parts of the project, effectively leaving the management to students and a few in-class workshops. The paper also offers suggestions on how to motivate and train the students and faculty for future years.

Introduction

At Seattle University all engineering seniors are required to participate in a three quarter capstone senior design project. All projects, which satisfy ABET's design-related criteria for accrediting engineering programs[1], are sponsored by either government or industry. They commence at the beginning of fall quarter (commonly last week of September) and end at the end of spring quarter (commonly second week in June.) Students work in teams of three to five, are supervised by a faculty advisor, and are encouraged to work closely with the liaison engineer from the sponsoring company.

Typically, the senior design course requirements include working on the assigned project, reporting on progress in oral and written format, writing final project report, learning and assessment of basic design process, learning engineering ethics, building knowledge of contemporary issues through seminars, etc. Hence, we developed sixteen outcomes for these courses that we map to ABET's a-k criteria and mechanical engineering-specific criteria. These outcomes are: students work in teams to solve an open-ended engineering problem, use engineering judgment, consider economic factors, implement project planning and management, create written documents, give oral presentations, communicate with people of various technical

backgrounds, incorporate environmental, economic and social constraints into the project solution, integrate knowledge obtained in mechanical engineering and core classes, apply various mechanical engineering courses into creating a solution, learn methods to integrate knowledge obtained in college with future careers, provide service to personal and public life, demonstrate knowledge of contemporary issues, demonstrate knowledge of engineering ethics, demonstrate a need for lifelong learning, and grasp the impact of engineering in society. The students generally perform at or above our expectations on those outcomes.

However, senior design projects have been known at our university and at other universities to have project management problems. In the 23-year history of projects at our university, projects have suffered unless an experienced student or advisor fills the role of project manager. While some students overcome, others falter under misguidance or misunderstanding of the benefits of properly managing a project. Additionally, student teams have had problems completing projects when they become bogged down with prototyping to ever changing product requirements. Some projects fall so far behind schedule that the original objectives are not met. Student discussion groups commonly blame this result on underperforming teammates or low team motivation. Low team motivation has been observed in other studies to be caused by undesirable project assignments[2]. A solution to these problems may be formal project management training[3], which our students do not receive in our curriculum. Our industrial advisory board members and other outside constituents began alluding to this deficiency in the past several years. This advice is consistent with "The Engineer of 2020: Visions of Engineering in the New Century"[4], and if successfully implemented, should improve the employability and careers of our graduates. When one of our constituents, a practicing engineer, offered to help us implement basic project management into our senior design courses, the faculty accepted the offer. The faculty's expectations were to create an easily implementable method that would allow students to develop basic knowledge and small experience in project management. Our goal was not to create project management experts, but to broaden perspectives of our graduating engineers by having them develop basic understanding of challenges and importance of managing projects. Senior design courses and projects are a logical place to implement project management instruction and implementation.

Furthermore, our university has a smaller sized engineering department. Last year, we graduated twenty mechanical engineers. Hence, we only had five projects with four students on each. The smaller project teams present additional project management challenges because classical project management methods, such as Gantt charting, critical chain and critical path, function better in larger projects where more technically diverse resources can be leveraged. However, Module Oriented Project Management (MOPM), which focuses on modules and individual ownership of each, seems applicable and valuable.

This paper first briefly describes goals of the five senior design projects; then, it describes the MOPM method and how it was implemented; finally, we show our assessment results and provide discussion.

Senior design project goals

In school year 2009-2010, we had five very diverse senior design projects in the Mechanical Engineering Department. And, MOPM was implemented on all five projects. We list here project goals for each.

1. Autonomous Material Sorter

In the Autonomous Material Sorter project, students had to design, build, and test an autonomous system capable of accurately sorting common recyclable materials, namely ferrous and nonferrous metals, plastics and glass into distinct waste containers. The system had to be capable of both material identification and waste handling. The prototype was entered into a student competition where points were awarded for material processing accuracy and speed, and for device weight. The competition was held in early spring 2010.

2. Computer Cabinet Heat Recovery

In the computer cabinet heat recovery project, students had to research, design, analyze and test a system that will recover some of the heat generated within computer cabinets and convert it to useful power.

3. Fuel From Algae Project

In the fuel from algae project, students had to research, design and test an inexpensive, low-energy and low-water consumption device for the continuous extraction of lipids from algae.

4. National Park Building Efficiency

In the National Park building project, students were tasked to perform energy audits of two buildings, analyze alternatives and recommend insulation for the building envelopes, and design heating and ventilation system for both buildings. The goal was to achieve very high energy efficiency using 20 kWh/m^2 of heating annually.

5. Bicycled Cell Phone Charger and Brake Retrofit

In the bicycle cell phone charger project, the goals were to develop a cell phone charger run by a bicycle that could be used in harsh and remote environments and for costs near one dollar. They also had to develop an easy to use parking brake so tired travelers pushing their bikes up hills could take breaks without having to hold their bikes from rolling back down the hill.

Method of implementation

Module Oriented Project Management (MOPM) is a method of project management used in the design and development phases of a project. In MOPM a project is broken down into different milestones or phases that are each broken into smaller modules for which one individual is responsible. All of the modules are rolled up to the phase level when completed to advance the project to the next phase. One major advantage to this method is that it fosters ownership and responsibility in individuals while maintaining a framework for collaboration and milestones. When adapted for student projects, each student feels responsible and accountable for some portion of a project. This invokes competition as well as teamwork within student teams.

Healthy competition is fostered within teams when one student strives to complete his or her module before others and teamwork is fostered when students help each other for the sake of team success. Accountability is fostered as teammates know who is responsible for each portion of the project, forcing their teammates to be accountable for assigned tasks. If implemented correctly, MOPM should alleviate problems related to the lack of a trained project manager and alleviate teamwork issues related to lack of individual contribution.

MOPM was adapted in 2009 to supplement the formal engineering design methods in use on senior design projects in the Mechanical Engineering Department at Seattle University. Projects were divided into four phases. Phase zero is the initiation of the project when the faculty advisor sets objectives and phase-end deliverables for the students on his/her teams. Phase 1 is the project concept phase where the students lay out the project requirements based on the project goals set in Phase 0. Phase 2 and 3 are the prototype and project reporting phases, respectively. The final three phases roughly coincide with the fall, winter and spring quarters. In each phase the phase goals and deliverables were broken up into modules and assigned to individuals. This is depicted in Figure 1 in the Appendix.

In Phase 0 faculty meet with project sponsors and they agree to project goals, scope, and deliverables. The faculty writes up the Phase 0 document and it is presented to students on the first day of the quarter. An example of the Phase 0 document is shown in Figure 2 in the Appendix.

Phase 1 begins with instruction on MOPM, what it is and what are the benefits. Students are prepared for "what's coming this year" through an overview which includes the flow chart shown in Figure 1. Next, a couple of one-hour workshops are administered. The students work with their teams to break the project up into discrete components or modules. This step is similar to a classical work breakdown exercise. The module owner is responsible for completing or overseeing the work on their module and completing associated phase deliverables in each phase. Examples of Phase 1 modules might be "fill out the Phase 1 form and turn it in to the advisor", "research centrifugal algae lipid separation method and determine its operation costs", or "research Rankine cycle methods of heat recovery and applicability to the project," or "gather data for and calculate life-cycle cost of heating a building with propane". Depending on the relative scope of each module, many students took on more than one module. An example of Phase 1 form is included in the Appendix.

The module owner is responsible for overseeing the work on their module and completing associated phase deliverables in each phase. Two in-class workshops per quarter are conducted to guide students in revising and updating the modules and the schedule. A student group was not permitted to advance to the next phase until the preceding phase was approved by the project advisor. The relative success of a project group to meet the phase deliverables helped the faculty assign grades. When a group did not meet the deliverables, and thus was graded accordingly, the advisor could personally advance or coach the project team into the next phase by providing the required information for a successful start of the next phase. The principal exercise that defined the start of the subsequent phase, after the prior phase modules were complete, was the assignment of new modules originating from the new phase deliverables or goals.

Assessment

Assessment of effectiveness of implementing MOPM was achieved by meeting with the students and with a survey given at the end of the year. Effectiveness was measured by how well the students completed their projects and how much MOPM assisted with the management of the project. All projects were considered successful both in terms of the deliverables and because 19 out of 20 students actively participated. The reminder of this section shows results of a survey administered at the end of the school year, along with comments students made during informal in-class discussion.

Survey results

The survey results are broken down into the 5 questions asked, including sub-questions on questions 1 and 4. Table 1 below shows results of question 1 and its five sub-questions we posed to students at the end of the school year.

Table 1. Question 1 regarding how well MOPM helped the project

1. How well did MOPM help ...[a]				
	Not at all	*Minimally*	*Moderately*	*Significantly*
...organize your project time?	0%	39%	**50%**	11%
...organize your group's time?	5%	39%	**56%**	0%
...divide responsibility for different parts of the project?	0%	29%	**41%**	29%
...you communicate with your advisor regarding project schedule?	17%	**39%**	33%	11%
...align your advisor's with yours views of the project?	16%	22%	**61%**	0%

[a]18 respondents

The intent of these first questions was to determine how well MOPM helped the students in key areas. The first 3 had to do with organization and communication between team members, while the last 2 were related to the role of the advisor. The results in this table clearly show that MOPM had a positive effect on the division of responsibility in the project. There was some positive effect on the organization of time, probably due to the division of responsibility. It is less clear that MOPM helped communicate with the advisor, but students' perception is that it did align students' and advisers' views.

Question 2 was designed to assess the invasive nature of MOPM and how it was used this school year, (see Table 2).

Table 2. Question 2 regarding how often MOPM was discussed

2. Throughout the whole project, how often did you think about or discuss MOPM?			
Not at all	*A bit*	*Often*	*Very often*
17%	**56%**	17%	11%

While two students took advantage of this very often, most only discussed it a bit. Nevertheless, this is a good result because it means that MOPM was part of conversation during projects, which has never been the case before. MOPM may be easy to understand and isn't burdensome.

In the next question, we attempted to assess teamwork directly (Table 3).

Table 3. Question 3 regarding working together with teammates

3. Because of MOPM I noticed my team mates worked better with me compared to my other group projects.	
	Response Percent
True	44.4%
False	**55.6%**

The results showed that a small majority of students didn't believe that MOPM helped them get along or work any better with each other than if it weren't there. This result initially seems in contrast to question 1b and 1c, however, it is probable that project time division and getting along with team mates are not as related.

Question 4 repeated some of the same themes addressed in question 1 but added the teamwork detail (in Table 4).

Table 4. Question 4, regarding the MOPM methods in general

4.Other MOPM questions	*Very little*	*A bit*	*A lot*	*Significantly*
How well did the team members divide up project responsibility?	6%	33%	**39%**	22%
How well did the team members understand their responsibilities?	5%	33%	**44%**	17%
How much did MOPM help you meet your personal course objectives?	23%	**35%**	29%	12%
How much did MOPM help you meet your project goals?	6%	**56%**	19%	19%

The results shown in Table 4 indicate that responsibilities among team members were shared well, but that could be improved. MOPM was not as successful in helping students meet personal course objectives and project goals.

Question 5 was intended to understand how satisfied the students were with the course (Table 5).

Table 5. Question 5, regarding course satisfaction

5. Overall, how satisfied are you with the year long course in its entirety?			
Not satisfied	*somewhat satisfied*	*satisfied*	*very satisfied*
0	11%	72%	17%

A low score on this question could have meant that the responses to the other questions were influenced by another factor. However, the results of question 5 showed that most were satisfied with the course.

Student comments

Meetings with the students to specifically discuss how MOPM was working and what they should be focused on, occurred at least once per quarter. Many students commented that they thought MOPM helped them organize their project. They also felt that their tasks were better defined and could link task accountability to the project goals. One of the common complaints from the students was that the project advisor was not helping enough.

While this coaching was supposed to occur at the beginning of winter quarter, sometimes advisors would wait until the middle of winter quarter not realizing there was a problem or hoping the problem would self resolve. These projects suffered time crunches or goal reductions at the end of school year.

In general each phase took about three months, or one quarter, however, the prototyping phase, where most of the hands on work is done, typically was the longest. Teams that completed the project definition in Phase 1 the earliest and started Phase 2 earlier were more successful.

Discussion

The results of the assessment and student meetings show that MOPM helped the student teams break up projects into appropriately sized pieces that were individually manageable. These methods also apparently helped students divide and understand their responsibilities.

In prior years, students complained of disagreements regarding relevant and non relevant tasks, and often these disagreements occurred later in the project life. Students also had trouble understanding how long a task would take to complete. This led to frequent changes to the project scope as students were attempting to downsize the project to fit the timeline. Both of these problems led to lack of teamwork and motivation and students branching out on their own.

Conversely results shown here show that students were satisfied with the course and they were able to organize their time more effectively. Regarding length of tasks, students were encouraged to leverage their advisor's experience throughout the quarter, and especially at the end of phases, to keep projects on time.

However, there was also less positive feedback regarding communication with the advisors. This result, from question 1, aligns with student discussions that complained of lack of advisor interaction. We interpreted these results and comments as a referendum on the lack of proper advisor training in MOPM . If the advisors had been better trained they could have better focused their assistance early in the project and at the key phase changes.

Because we were encouraged by our first tryout, we are continuing the MOPM in school year 2010-2011.

Conclusions

This study set out to apply MOPM to five student groups with the intent of helping students feel more responsibility and camaraderie during the year. The survey given at the end of the year showed that the students felt that MOPM helped them with project breakdown and responsibility. In this study project success was more important than a diverse education in project management. Students could then concentrate on the use of their engineering fundamentals to finish a project rather than test and apply different types of project management. While more work needs to be done to refine and adapt this project management method, this study showed that its adaptation benefited students, solved some common senior design project problems and showed potential for providing a better education experience for students and faculty during senior design courses.

Recommendations

Advisor training is important because the advisor often must step in to guide the students regarding project timeline. In this regard, advisors need to be trained to fill out a detailed Phase 0 document which clearly defines the scope and goals of the projects. Advisors also need to set standards for what students will have to accomplish each quarter to achieve a desirable grade. Finally, advisors should also be adequately trained to temper students' ambitions and assist with task length estimation as underestimation of project length can lead to low motivation.

Students should be trained during phase 1 to identify tasks (modules) and deliverables, identify deadlines for each module so that the module doesn't hold up a phase deliverable, monitor module and phase progress throughout the project process on at least a monthly (and for many student groups a bi-weekly basis) and leverage the expertise of faculty in different disciplines.

References

1. ABET, http://www.abet.org/, accessed on January 17, 2011.
2. L Lopes et al., Optimization Support for Senior Design Project Assignments, Interfaces, Vol. 38, No. 6, November–December 2008, pp. 448–464
3. J M Conrad; Y Sireli, Learning Project Management Skills in Senior Design Courses, Proceedings - Frontiers in Education Conference, 35th Annual Conference, 2005: F4D-1
4. The Engineer of 2020: Visions of Engineering in the New Century, National Academy of Engineering, 2005 (http://www.nae.edu/nae/naepcms.nsf/weblinks/MKEZ-5Z5PKL?OpenDocument), accessed on January 18, 2011

Appendix

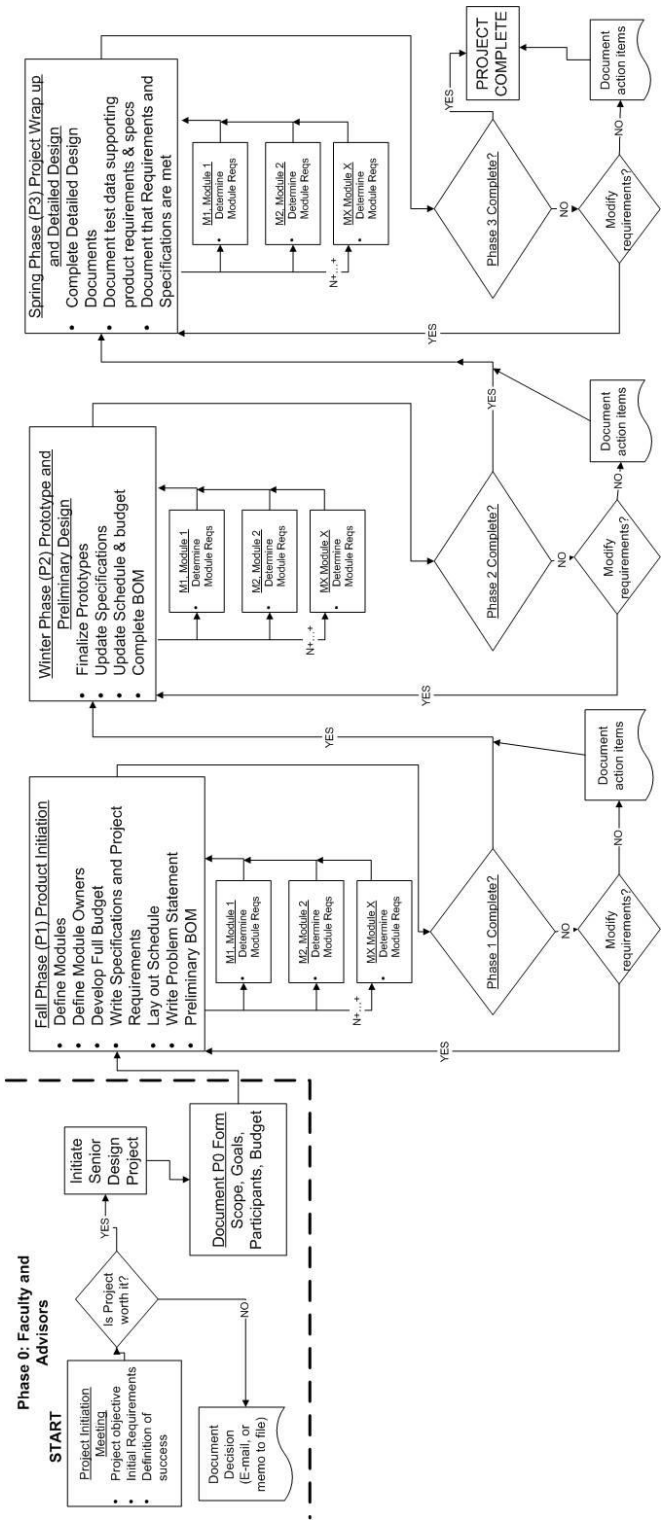

Figure 1: Flow chart of a task oriented project management structure

Project Phase 0	**Project Initiation Form**	
Project name		
Sponsoring Organization		
Sponsoring Liaison		
Faculty advisor		
Team members		
Maximum Project Budget		

Project scope:

Project resources required:

Phase 1 (Fall) Deliverables:

Phase 2 (Winter) Deliverables:

Phase 3 (Spring) Deliverables:

Figure 2. Project Phase 0 Document

Project Breakdown Form
Project Phase 1

Project Name:_____

Module name (if using systems, include system level)	Assigned to

Figure 3. Project Phase 1 Document