Creating a "Learning Lab" in Undergraduate Engineering Management Lecture Courses

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Abstract

Junior and Senior Engineering students take a 3-hour course designed to develop career enhancing professional skills in technical project management. Historically the content was delivered through lecture and discussion. To encourage active discussion and teamwork, exercises in project decision making spreadsheet simulation exercises were developed and introduced. Key course concepts are covered in lectures, then demonstrated by the professor using scenarios and exercises incorporating the spreadsheet simulations followed by guided practical application during an in-class "Learning Lab." The Learning Lab provides an opportunity for students to work in teams and apply key concepts to gain a better understanding of engineering and project management fundamentals. Students receive pre-class preparation assignments that free up class time to engage in the simulation, team discussions, decision-making exercises and presentations. Several real benefits of this approach include helping students develop leadership and team working skills through practical application.

Keywords

Lecture innovation, Project Management, Spreadsheet Simulation, In-class Learning Labs

Introduction

Within the School of Engineering Junior and Senior Mechanical Engineering students have the option of taking a 3-hour elective course, PMGT 401 (Project Management Career Skills). Civil Engineering students have the option of taking a 3-hour elective course, CIVL 411(Engineering Management). Both courses are designed to develop career enhancing professional skills by introducing key concepts in technical project management. Specific areas of focus include Project Integration, Planning, Scheduling, Budgeting, Quality, Risk, and Stakeholder Management. Developing project leadership and teamwork are emphasized throughout the course. Historically the content was delivered through lecture and discussion with no lab component, and therefore was missing out on the learning benefits a laboratory offers, such as:

1. Providing an experimental foundation for the theoretical concepts introduced in the lectures.

2. Familiarizing students with the scientific method.

3. Applying data analysis to make careful experimental observations and draw conclusions.

4. Working in teams and learning how to write a report and communicate technical information in a clear and concise manner.

5. Providing an opportunity to gain knowledge through practice and observation.

Practical application is important for learning any new discipline and is essential for making the connection between theory and experience. A good lecture may be very helpful but not fully useful without actual practice[1]. In order to strengthen the learning experience and create the types of insight gained through experimentation and teamwork associated with labs, several spreadsheet simulations were developed and introduced to reinforce lecture content and create a simulated “Learning Lab” providing students an opportunity to work in teams and gain experience developing, monitoring and controlling a project. The simulations are designed to exercise lecture concepts provide content for the course capstone project.

Course Design

Incremental delivery approaches are used to teach key management principles and allow the student project teams to develop familiarity and confidence with the spreadsheet simulation. Lectures are followed by the professor demonstrating concepts using the simulation. Demonstrations are followed by a period of guided practical application during a Learning Lab period in which student teams work with the simulation. In the Learning Lab students explore the principles and applications of; analyzing a project Statement of Work (SOW) and creating a task list to develop a work breakdown structure (WBS). They develop an initial project schedule and Gantt Chart; develop a project budget and monitor and report costs using an Earned Value Management (EVM) tool in the spreadsheet simulation; develop and manage a Risk Matrix tied to the project schedule; and develop and practice making schedule decisions based on instructor generated input. Student teams analyze the impact of their decisions on project cost, schedule and performance. Managing a project is a complex task that requires technical project managers be prepared to address both predictable and unforeseen problems that arise during project execution and make sound decisions[2,3]. The simulation activities and resultant team management decisions become learning experiences that strengthen decision-making. Students learn that project managers are expected to play a key role in planning, developing and managing projects according to a schedule, within a budget, and while meeting required performance and profit goals. Student teams learn that projects rarely go as planned and when problems occur, management must be able to respond[4].

This simulation exercise provides students with an opportunity to work in teams and create a project plan for a capstone project of their choice. Through this process students develop an understanding of the complexities involved in decision making. The learning lab provides opportunities for student teams to make project management decisions centered on changes to the schedule. When it appears that schedule performance will not meet objectives, students must collect and evaluate information, identify and assess potential courses of actions, and then make decisions to bring the project back on schedule. While there are a number of factors that can contribute to poor project cost and performance, inconsistent and unreliable schedule estimates introduce unstable assumptions and constraints into the planning process that affect future project performance[5]. Projects with overly ambitious deadlines and too few resources can result in increasing error rates, overworked employees, and declining performance[6]. Researchers describe how complex projects add uncertainty and require greater effort, information and knowledge sharing for effective problem solving. Positive benefits can be achieved by employing decision support tools to help managers address the complexities of project planning and decision-making. There is demonstrated value in applying a formal and structured approach to project management that can be achieved through proactive management[7,8,9]. Using simulation and modelling in project management training and education demonstrates how investigation of projects can improve managerial understanding, decision-making, and performance. [10]

Inverting the Classroom to Support the Simulation

The Learning Lab provide an opportunity for students to apply key concepts presented in lectures and to gain a fuller understanding of technical project management fundamentals. Students are expected to prepare for class by completing the assigned chapter readings, reviewing the lecture slides which are posted on the school's Learning Management System (Blackboard), and participate in discussion of the assigned readings prior to coming to class. With the prior preparation class time can be freed up to help students engage in the practical application provided by the simulation and Learning Lab, team discussions, and presentations. Several real benefits come from providing time for students to work in project teams during the class and the simulation to develop their Team Capstone Project Plan. First, students gain valuable insight from working in teams. Second, students gain experience and practice in preparing concise status briefs, which are presented to the class and critiqued. Third, student teams are required to respond to changes that will affect the status of their project. They must collect and analyze data, make decisions and assess the impact of their decisions on the project. The following table shows the linkage between the lectures, simulation exercise, and Team Capstone Projects.

Table 1. Linkage between the lectures, simulation exercise, and Team Capstone Projects.

Course Chapter	Simulation Activity/Learning Lab	Capstone Project Deliverable
Chapters 1, 2, 3, 4, 5	Analyze SOW and identify Specified and Implied Tasks, develop Assumptions and Constraints	Develop Project SOW
Chapters 5, 6	Create Activity Lists and identify precedence relations	
Chapters 5, 6	Create WBS	Develop Project WBS
Chapters 5, 6	Develop Project Schedule using a network diagram and a Gantt chart	
Chapters 5, 6	Develop Project Resource List	Develop Project Organization and Resources
Chapters 5, 6	Identify the Critical Path	Develop Project Schedule Using a Gantt Chart
Chapters 6, 7, (Project Planning, Budgeting and Risk Management)	Develop a Project Risk Matrix	Develop a Project Risk Matrix
(Project Planning, Budgeting and Risk Management)	Develop a work budget estimate	Develop Project Work Budget Estimate
Chapters 10, (Project Planning, Budgeting and Risk Management), (Monitoring, Controlling and Reporting Cost)	Develop an EVM Report	
(Stakeholder Management and Communications)	Conduct Risk Planning and Analysis	Report Project Status
(Stakeholder Management and Communications)	Stakeholder Analysis	Stakeholder Matrix, Communications Matrix

Team Based Learning

In the Learning Lab student teams work the same assigned activities using the simulation to develop deliverables. These application activities require the teams to make specific choices based on team analysis of the data, work on the associated problems and report their decisions. Upon completion, each team presents their deliverable to the class in a five-minute power point presentation. Peer evaluation is an important part of team-based learning and teams must answer questions stemming from their presentation to the class. These "out briefs" require teams to articulate their thinking, and evaluate their own reasoning. We allot time for questions and answers after each out brief, allowing teams to discuss the different decisions made by teams. The flexibility in applying the simulation results in the potential for each student team to arrive at a slightly different baseline project schedule. Gantt charts are developed by the student teams and the critical path is identified and monitored and reported on. Figure 1 shows a representative example of the Gantt chart output from the simulation. Team performance is monitored and evaluated based on their EVM report. Student teams assess each of the potential risk events and based on team discussions assign a project delay impact in days, cost to the project and probability of occurrence. The risk matrix ratings input by the student teams will feed into the project budget estimate and EVM tools shown in Figure 2 and 3.

Figure 1. Project Gantt Chart

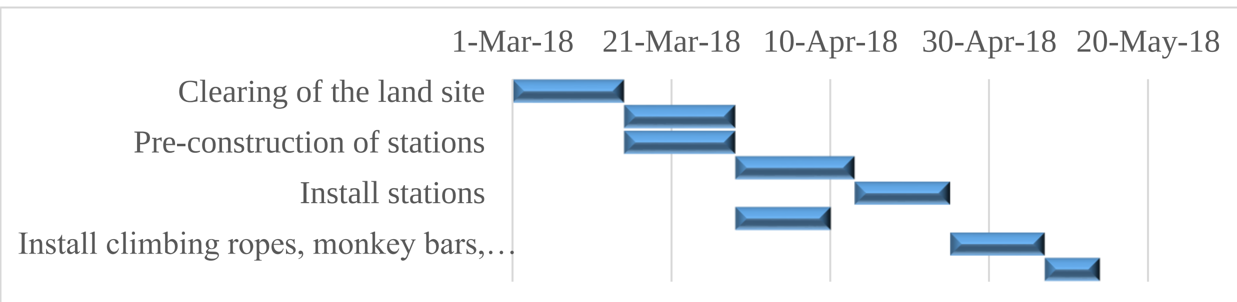
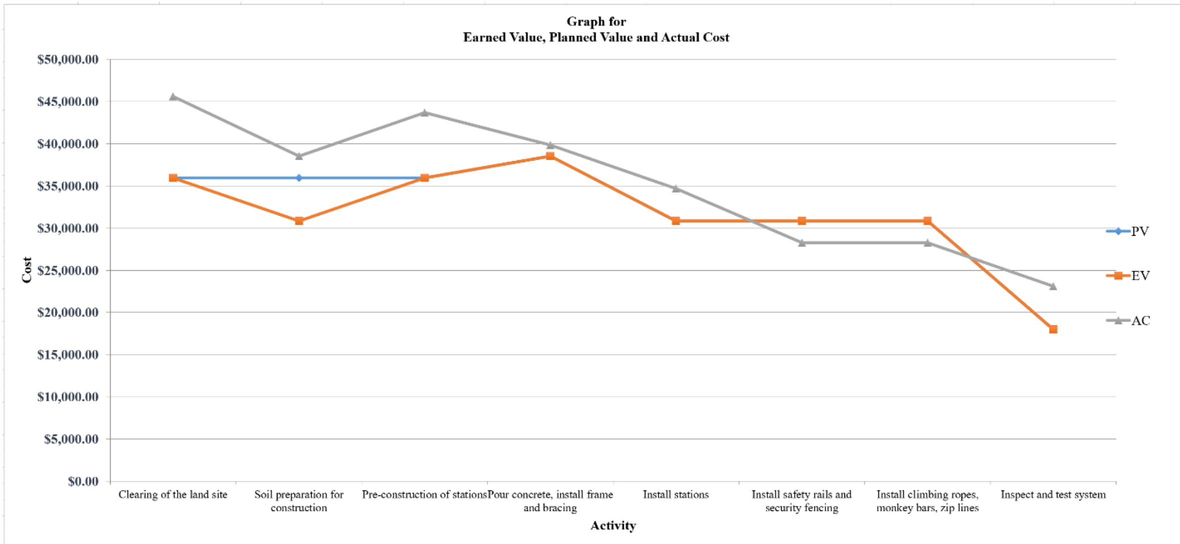


Figure 2. Project EVM Report

Total budget (BAC)	257000
Rate/Day:	2570
Total Hours:	800
Total Days:	100
Cost per day if work	2570

		Manual Input (For cells in Yellow)																
	Days Allocated per activity	Days of Work Completed	Days Used	PV	EV	AC	CV	SV	CPI	SPI	EAC (Atypical)	EAC (Typical)	EAC (Cumulative)	ETC	VAC	TCPI	Over or Under Budget?
Clearing of the land site	14	14	16	$35,980	$35,980	$45,620	-9640	0	0.79	1.00	$266,640	$325,857	$325,857	$221,020	-$9,640	104.56%	Over Budget
Soil preparation for construction	14	12	15	$35,980	$30,840	$38,550	-7710	-5140	0.80	0.86	$264,710	$321,250	$368,367	$226,160	-$7,710	103.53%	Over Budget
Pre-construction of stations	14	14	17	$35,980	$35,980	$43,690	-7710	0	0.82	1.00	$264,710	$312,071	$312,071	$221,020	-$7,710	103.61%	Over Budget
Pour concrete, install frame and bracing	15	15	15.5	$38,550	$38,550	$39,835	-1285	0	0.97	1.00	$258,285	$265,567	$265,567	$218,450	-$1,285	100.59%	Over Budget
Install stations	12	12	13.5	$30,840	$30,840	$34,695	-3855	0	0.89	1.00	$260,855	$289,125	$289,125	$226,160	-$3,855	101.73%	Over Budget
Install safety rails and security fencing	12	12	11	$30,840	$30,840	$28,270	2570	0	1.09	1.00	$254,430	$235,583	$235,583	$226,160	$2,570	98.88%	Under Budget
Install climbing ropes, monkey bars, zip lines	12	12	11	$30,840	$30,840	$28,270	2570	0	1.09	1.00	$254,430	$235,583	$235,583	$226,160	$2,570	98.88%	Under Budget
Inspect and test system	7	7	9	$17,990	$17,990	$23,130	-5140	0	0.78	1.00	$262,140	$330,429	$330,429	$239,010	-$5,140	102.20%	Over Budget
Total:	**100**	**98**	**108**	$257,000	$251,860	$282,060											

Figure 3. Project EVM Chart



Incorporating Risk Events to Stimulate Decision Making

Examining simulation outcomes causes the student teams to consider the relationship between cause and effect and to identify problems that could undermine project objectives. The use of risk-based decision making requires that the student teams collect and organize empirical and objective data to implement a scientific decision-making process.

Figure 3. Project Risk Event Matrix

Activity	Task	Predecessors	Risk	Delay in crew days	Impact /Response	Event Cost	P (x)	Risk Reserve P(x)*$ Cost	Event Occurrence Y=1/N=0	Event Cost
A	Clearing of the land site	0	Weather delays start or completion	3	Idle Crew	$7,500	0.2	$4,500	1	$4,500
A	Clearing of the land site	0	Equipment failure delays start or completion	2	Repair/Replace Equipt	$5,000	0.2	$2,000	0	$0
B	Soil preparation for construction	A	Weather delays start or completion	3	Idle Crew	$7,500	0.2	$4,500	1	$4,500
B	Soil preparation for construction	A	Equipment failure delays start or completion	2	Repair/Replace Equipt	$5,000	0.2	$2,000	1	$2,000
C	Pre-construction of stations	A	Material availability delays	4	Idle Crew, Expedite material from secondary source	$12,000	0.2	$9,600	1	$9,600
D	Pour concrete, install frame and bracing	B	Weather delays start or completion	4	Idle Crew	$8,000	0.2	$6,400	1	$6,400
D	Pour concrete, install frame and bracing	B	Material availability delays	3	Idle Crew, Expedite material from secondary source	$6,000	0.2	$3,600	1	$3,600
E	Install stations	C, D	Weather delays start or completion	3	Idle Crew	$7,500	0.2	$4,500	1	$4,500
F	Install safety rails and security fencing	C	Weather delays start or completion	3	Idle Crew	$9,000	0.2	$5,400	1	$5,400
G	Install climbing ropes, monkey bars, zip lines	D, E	Weather delays start or completion	3	Idle Crew	$6,000	0.2	$3,600	1	$3,600
G	Install climbing ropes, monkey bars, zip lines	D, E	Material availability delays	4	Idle Crew, Expedite material from secondary source	$8,000	0.2	$6,400	1	$6,400
H	Inspect and test system	F, G	Weather delays start or completion	2	Conduct Failure Analysis, develop CCOA, Implement Fix, Retest	$5,000	0.1	$1,000	1	$1,000
H	Inspect and test system	F, G	Weather delays start or completion	5	Conduct Failure Analysis, develop CCOA, Implement Fix, Retest	$12,500	0.1	$6,250	1	$6,250
					Total Risk Reserve			$59,750		$57,750

The risk analysis can demonstrate how risks might impact a project's results, and requires student's teams to plan for "*what if something happens?"* and assess "*how likely is it to happen*?" Development of the risk matrix, shown in Figure 3, encourages the student teams to identify and consider key project risk so resources can be more efficiently allocated. By identifying the key risks, student teams can evaluate the available risk mitigation strategies or measure how much they would be willing to pay to mitigate a given risk.

Results

Student perceptions of the effectivity of using the learning lab approach encompassing the spreadsheet simulations in class was measured with a survey, given to two sections totaling 48 students, at the end of the class. A five point Likert survey was used and the ten survey questions and average results are shown below.

1. I prefer to work on individual projects rather than on team projects and assignments. Average score of responses = 2.48
2. I have experience using spreadsheet simulations to apply key concepts and to gain a fuller understanding of class fundamentals. Average score of responses = 3.88
3. I enjoy working on team projects in class. Average score of responses = 4.15
4. The use of Laboratory exercises helps me to better understand the course material. Average score of responses = 4.06
5. Developing a detailed statement of work is important in order to run a successful project. Average score of responses = 4.83
6. Developing a project schedule is an important component of a project. Average score of responses = 4.94
7. It is important for Project Managers to monitor and control a project schedule. Average score of responses = 4.81
8. Good Project Managers don't need to plan for Risk as much as poor Project Managers do. Average score of responses = 1.19
9. I have a good understanding of how to use financial metrics to assess project performance. Average score of responses = 3.15
10. I am confident in my ability to create clear and concise technical reports. Average score of responses = 3.96

Summary and Conclusions

The survey results reveal some interesting insight into student perceptions of the learning lab. For Question 1, Question 2 indicates that the students have some moderate experience with incorporating spreadsheets to reinforce learning concepts. Responses to Questions three and four indicate that the students saw a positive value in the learning lab exercises. Responses to Questions five through ten indicate that the students have a good understanding of the key concepts emphasized in the learning lab exercises. The instructors feel that the survey results show the learning lab concept did achieve one of the main goals of the course, to provide students with the opportunity to work in teams, and to introduce in-class applications in a traditional lecture only class, that engage the students and drive home key course concepts. Students were also given the opportunity to provide written comments and several students stated they had a new appreciation for the importance of teamwork, and communications in project management. Several students also reported using the spreadsheet simulation or modifying portions of it to support their capstone projects. The instructor received a number of suggestions by students for improving the learning lab and those will be incorporated in future classes. We plan to continue using the learning labs with the intent of expanding them into additional courses.

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