Project Management Inside and Outside of the Curriculum at the Ohio State University

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Abstract
Students typically gain exposure to project management (PM) techniques through capstone senior design projects, however, many students would benefit from a greater depth of study. This has been indicated through student surveys and industry feedback. To support this, three departments within The Ohio State University (OSU) College of Engineering have developed complementary courses that cover topics in project management. In addition, students engaged in extra-curricular student projects, such as the EcoCAR 3 project, must practice project management techniques to manage multi-person teams on deliverable-oriented projects. This paper offers a review of these three courses within Electrical and Computer Engineering, Mechanical and Aerospace Engineering, and Integrated Systems Engineering. An overview of the techniques applied by the EcoCAR 3 project are also included as a proxy for the many student engineering projects that are on OSU's campus.

Keywords
Project Management, Systems Engineering, Education, Capstone, EcoCAR

Introduction
Students typically gain exposure to project management techniques through capstone senior design projects, however, many students would benefit from a greater depth of study. This has been indicated through student surveys and industry feedback. To support this, three departments within The Ohio State University (OSU) College or Engineering have developed complementary courses that cover topics in project management. In addition, students engaged in extra-curricular student projects, such as the EcoCAR 3 project, must practice project management techniques to manage multi-person teams on deliverable-oriented projects. This paper offers a review of the project management courses within Electrical and Computer Engineering (ECE), Mechanical and Aerospace Engineering (ME), and Integrated Systems Engineering (ISE). An overview of the techniques applied by the EcoCAR 3 project are also included as a proxy for the many student engineering projects that are on OSU's campus. The four experiences described in this paper are:

1. ECE 6070: Project Management in Electrical and Computer Engineering
2. ME 5194: Applied Project Management and System Engineering
3. ISE 3800: Engineering Project Management
4. The Ohio State University EcoCAR 3 Team

In the following sections, information pertaining to each course is provided, describing the motivation and key aspects of each course. In the appendix, simplified syllabi of each of the three courses can be found. In addition, the following summary table highlights the key differences and similarities between the three courses.

Course	ECE 6070	ME 5194	ISE 3800
Official Course Name	ECE 6070 - Project Management in ECE	ME 5194 - Applied Project Management and System Engineering	ISE 3800 - Engineering Project Management
Frequency Offered	Spring and Fall	Spring and Fall	Spring and Fall
Credit Hours	3	3	3
Textbook	An Introduction to Project Management, Fourth Edition (Kathy Schwalbe)	None	None
Enrollment Per Semester	50	30	75
Class Type	Requirement for ECE graduate students on non-thesis track	Elective	Requirement for undergraduate ISE students
Target Audience	Graduate	Juniors, Seniors, and Graduate	Juniors
Other Majors	Vast Majority are ECE	Yes	No
Instructor Name	Lisa Fiorentini	Shawn Midlam-Mohler	Jack Slavinski

Figure 1: Summary Table of PM Courses

Overview of ECE 6070: Project Management in Electrical and Computer Engineering
In this course, students learn general PM principles, processes, and tools, team culture and communication, risk and crisis management, and project documentation and reporting. All of these topics are taught in application to ECE projects. Several case studies are discussed to highlight the importance of minimizing risks to avoid project failure. Students conduct a real-world ECE project designed to strengthen skills in project management. Students are required to learn and use Microsoft Project for their project and deliver presentations about their project. This course features guest speakers who share their project management and industry experiences. This course is unique in that the target audience is exclusively graduate students. Because of the importance of project management skills in industry, this course is required for the ECE department's non-thesis Master's degree students. The learning objectives for this course are for students to:

1. Learn the principles of project management.
2. Apply project management tools and processes to solve Electrical and Computer
       Engineering problems as done in industry.
3. Emphasize and practice teamwork.
4. Practice organizational, communication, technical writing and presentation skills.

Overview of ME 5194: Applied Project Management and System Engineering
In this course, students learn a variety of applied systems engineering and project management topics. The course focuses on giving students a realistic experience in these topics through integration with real engineering projects and/or participation in "role-playing" case studies. Assignments will include tasks such as developing and maintaining timelines and developing and maintaining requirement tracking documents for the projects. To support these tasks, students learn various PM theories and tools (such as work breakdown structures). Students also gain experience using commercial software packages used in industry. In-class discussion of challenges experienced during projects is used to facilitate peer-to-peer learning between groups. This course was developed to fit into a newly created Professional Skills category in the Mechanical Engineering program. This course meets this requirement and is among the following list of options for ME students:

1. BUSMHR 2500: Entrepreneurship
2. ENGR 4194: Survey of Engineering Law
3. ENGR 5680: Leading in Engineering Organizations
4. ENGR 5050: Introduction to Humanitarian Engineering
5. MECHENG 4194: New Product Introduction, Development, Design, and Lean Six Sigma Manufacturing
6. MECHENG 4194: An Introduction to Six Sigma Concepts
7. MECHENG 5194: Applied Project Management
8. MECHENG 5194: Innovative Leadership for the Global Leader
9. PUBAFRS 3000: Introduction to Public Policy Analysis
10. PUBAFRS 5600: Science, Engineering, and Public Policy

This course integrates topics from systems engineering as well as project management into a single cohesive framework. This approach is driven in part by NASA's approach of dealing with these topics jointly to improve project and product performance. The learning objectives of this course are for a student to:

1. Apply project management techniques to facilitate an engineering project.
2. Apply systems integration techniques to facilitate development of complex products.
3. Use project management and systems integration software effectively.
4. Appreciate the importance of class topics to successful execution of complex projects.

Overview of ISE 3800: Engineering Project Management
The course is a diverse combination of weekly lectures, reading assignments, student presentations, team-driven group work, labs utilizing project management software, semester projects, and case study scenarios. This course features guest speakers who share their project management and industry experiences. Of the three courses discussed in this paper, this course is the only one that is a requirement for an undergraduate major. This is the case with many ISE programs because of the importance of these skills for graduating ISE students. The learning objectives for this course are for a student to:

1. Understand what effective project leadership, sponsorship and good communication means and why it makes a difference.
2. Conduct effective project planning from start to finish and measure progress.
3. Apply and scale various project management methodologies (agile versus waterfall).
4. Organize and structure projects.
5. Understand why projects often fail and how to potentially prevent that.
6. Define and manage scope and what "done" means.
7. Identify criteria for project success while resolving barriers to successful execution.
8. Develop project schedules, event driven plans, work breakdown structures and tasks.
9. Identify critical path roadmaps and phase gates.
10. Apply constraint modeling and analysis to schedules.
11. Depict project plan and dependency through visualization.
12. Effectively identify, assess and resolve project risks and issues.
13. Use various quality and defect management techniques.
14. Scale project processes to small, low risk projects as well as large, complex projects.
15. Understand how to appropriately leverage project management tools.
16. Handle projects in a state of chaos or damage control.
17. Managing project execution with the right level of discipline and rigor.
18. Understand effective leadership and team management.
19. Implement organizational change in the context of corporate culture.

Application of Project Management in EcoCAR 3

Sponsored by the U.S. Department of Energy and General Motors and managed by Argonne National Laboratory, EcoCAR 3 is a university-level competition to develop an energy-efficient and high-performance Chevrolet Camaro. The Ohio State University EcoCAR 3 Team is one of the 16 North American teams in the competition. Planning and executing a project of this complexity and magnitude requires strong project management. The tools and techniques utilized by the team include a balanced matrix organizational structure, a project charter, monthly status reports, bi-annual stakeholder status presentations, a project management plan, and earned value management.

The balanced matrix organizational structure of the team, in which team members report to both a project manager and a functional manager, allows for the proper balance between project management and technical oversight of project activities. This structure fosters the creation of cross-functional teams that blend students with different skill sets, backgrounds, and experiences. Each team member with project management responsibilities has taken one of the project management courses described in this paper or has been trained by the lead project manager.

At the beginning of the project, the team developed a project charter to serve as a rough schedule, scope, and cost baseline for the team. The charter has allowed the team to measure progress, avoid scope creep, and judge how tasks and activities relate to the overall project. The charter includes a background of the team, team mission and vision statements, assumptions and constraints for the project, project deliverables for the first year of the competition and beyond, and project authorization from the faculty advisor Dr. Shawn Midlam-Mohler.

Monthly status reports are provided to competition organizers and the team mentor at General Motors at the beginning of each month. The monthly status report includes key accomplishments from the previous month, key planned activities, major risks the team currently faces, and issues that are frustrating project performance. The team also uses stakeholder status presentations to convey the overall status of the project to competition stakeholders. These presentations are held twice per academic year. In the first year of EcoCAR 3, the first presentation was held in Austin, TX, and the second presentation was held in Seattle, WA. These events are judged by industry and government experts with experience in project management and stakeholder communication. In the stakeholder status presentation, the project manager must provide an overview of the team's organizational structure, the history of the team, overall project status, accomplishments of the team, planned activities, and important program risks. In addition, the project manager must discuss team knowledge transfer and lessons learned.

The team has developed a project management plan to guide the execution and control of the vehicle redesign project. It consists of a schedule management plan, a cost management plan, a human resource management plan, a stakeholder management plan, an internal communications management plan, a risk management plan, and a procurement management plan.

The schedule management plan includes the methodology and software for scheduling, rules for estimates, the schedule baseline, change control procedures, and reporting formats. The team utilizes a Gantt Chart and a cloud-based scheduling software known as Trello for schedule and task tracking. The Gantt Chart consists of major team activities, milestones, project deliverables, dependencies, and percent completion. Trello, developed by Fog Creek Software, consists of different "boards" for each of the sub-teams (e.g. mechanical, electrical, communications, innovation, etc.). Each board contains "to do," "doing," and "done" lists of tasks. Team members are allowed to view, edit, and move tasks. The transparency and usability of this system allows for enhanced project tracking and performance. The cost management plan is comprised of the cost baseline, methods for documenting costs, and roles and responsibilities. The team uses a project budget to manage income (from the university, company sponsors, etc.) and expenses (on vehicle components, marketing materials, etc.).

The human resource management plan defines roles and responsibilities of the team and the team's organizational structure. The team uses a RACI (Responsible, Accountable, Consult, and Inform) Chart for managing ownership of tasks. Included in the HR management plan is the recruiting strategy for the team. A strong recruiting strategy is essential for success in the competition because the team's roster, comprised of undergraduate and graduate students, is highly dynamic.

Competition stakeholders include government organizers, company sponsors, university backers, students, faculty, and local community members. The stakeholder management plan is used as tool for managing the expectations, influence, and engagement for all of these stakeholders.

The communications management plan documents the models, technology, and methods that are used for communicating with teammates and stakeholders. The team holds twice-weekly meetings for all team members. In addition, there is a weekly meeting of team leaders to discuss

project status, risks, and project issues. The team uses email and a cloud-based communication application called Slack to communicate quickly.

Proper risk management allows the team to pro-actively deal with risks—both threats and opportunities—as they arise. The team uses a risk register in which risks are ranked by severity, occurrence, and detection. In addition, risk triggers and potential responses are identified.

One of the major challenges in the EcoCAR competition is recruiting sponsors to provide the hundreds of components that will be included in the redesigned vehicle. Robust procurement management is critical to this effort. Each required component of the vehicle design is identified along with the respective costs, justification, and timeline for arrival.

The team uses earned value management to measure project performance against scope, schedule, and cost baselines. Communication of planned value, earned value, and variance with appropriate team members and relevant stakeholders generates better project results.

Conclusions
Three different departments at The Ohio State University have developed project management courses to address a different need in the curriculum. These courses share common roots in the fact that industry requires students with improved abilities to manage projects and function in organizations with formal project management processes. In addition to this curriculum, students involved in the more than thirty engineering student organizations practice project management to some degree. In projects like EcoCAR 3, the team has developed a very formal process for project management and is supported in this effort by the competition through training, project management milestones, and close collaboration with a mentor assigned to each team from General Motors.

ECE 6070 Syllabus: Project Management in Electrical and Computer Engineering

Credit Hours: 3 Hours

Course Description: General principles of Project Management; Project Management processes and tools; Case studies in Electrical and Computer Engineering.

Required Textbook:
Revised an Introduction to Project Management, Fourth Edition
Kathy Schwalbe, Schwalbe Publishing, 2013 ISBN--10: 1448607531

Suggested References:
A guide to the PROJECT MANAGEMENT BODY OF KNOWLEDGE (PMBOK GUIDE), Fifth Edition. Project Management Institute, 2013 ISBN: 978--1--935589--67--9

Learning Objectives:
Upon completion of this course, students will be able to:
1. Students will learn the principles of project management.
2. Students will apply project management tools and processes to solve Electrical and Computer Engineering problems as done in the Industry.
3. Students will emphasize and practice teamwork.
4. Students will practice organizational, communication, technical writing and presentation skills.

Course Topics:
- Introduction to project management (2)
- Project Selection (2)
- Project Management Process Groups:
    - Initiating (2)
    - Planning and Engineering Design (9)
    - Executing (2)
    - Monitoring and control (4)
    - Closing (1)
- Best Practices and Overview (1)
- Case Studies and Project Presentations (4)
- Guest Lectures (1)

Assignments:

Homework:	60%
Midterm:	5%
Final Project:	15%
Presentations & Participation:	10%
Final Exam:	10%

ISE 3800 Syllabus: Engineering Project Management

Credit Hours: 3 Hours

Course Description: This course is intended to provide foundational project management education. The course will focus on relevant project management topics and case studies that will prepare students to plan, organize, engineer, lead/manage and participate in the multi-faceted and complex conditions that arise during planning and execution of small to large projects and programs.

Course Narrative: The flow of the course material is designed to provide a broad perspective early in the semester and then get in to detail topics as we progress. The material will cover project management discipline, which is a true art and a science. We will also discuss how to achieve the right project management behaviors. Some might find project management to be common sense and we will discuss why the common sense theory does not always work in reality in the corporate world and what can go wrong. The lecture material will emphasize specific project management processes, conditions and best practice disciplines and techniques, inclusive of leveraging certain project management software tools. It will also seek to ground the project management lessons in realistic industry and business based examples.

Required Textbook: None.

Learning Objectives:
Upon completion of this course, students will be able to:
1. Understand what effective project leadership, sponsorship and good communication means and why it makes a difference
2. Conduct effective project planning from start to finish and measure progress
3. Apply and scale various project management methodologies (agile versus waterfall)
4. Organize and structure projects
5. Understand why projects often fail and how to potentially prevent that
6. Define and manage scope and what 'done" means
7. Identify criteria for project success while resolving barriers to successful execution
8. Develop project schedules, event driven plans, work breakdown structures and tasks
9. Identify critical path roadmaps and phase gates
10. Apply constraint modeling and analysis to schedules
11. Depict project plan and dependency through visualization
12. Effectively identify, assess and resolve project risks and issues
13. Use various quality and defect management techniques
14. Scale project processes to small, low risk projects as well as large, complex projects
15. Understand how to appropriately leverage project management tools
16. How to handle projects in a state of chaos or damage control
17. Managing project execution with the right level of discipline and rigor

Course Topics:
- Reasons for Project Failure
- Effective Project Leadership and Communication
- WBS
- Project Charter
- Team Organization
- Status Reporting
- Scope and Requirements Management
- Organizational Structure
- Critical Path Method
- Risk Management
- Schedule Acceleration
- Global and Virtual Teams
- Quality Management
- Cost Management
- Lessons Learned

Assignments:

Midterm:	20%
Final Exam:	20%
Quizzes:	20%
Projects:	20%
Lab work:	15%
Peer assessment:	5%

ME 5194 Syllabus: Applied Project Management and System Engineering

Credit Hours: 3 Hours

Course Description: Students will learn and apply concepts from the fields of system engineering and project management in product development team environments. Students will learn relevant theory as well as tools and techniques used in industry.

Course Narrative: In this course, students will learn a variety of applied systems engineering and project management topics. The course focuses on giving students a realistic experience in these topics through integration with real engineering projects and/or participation in "role-playing" case studies. Assignments will include tasks such as developing and maintaining timelines and developing and maintaining requirement tracking documents for the projects. To support these tasks, students will learn theory, be taught various tools (such as work breakdown schedules), as well as learn how to use commercial software packages that are used in industry. In class discussion will also be used to facilitate peer-to-peer learning between groups which will be encountering different challenges based on the particulars of the project they are working on.

Required Textbook: None.

Suggested References:
- *Project Mangers Portable Handbook*, David I. Cleland and Lewis R. Ireland, ISBN 0071741054.
- *NASA Systems Engineering Handbook*, NASA/SP-2007-6105.
- *NASA Space Flight Program and Project Management Handbook,* NASA NPR 7120.5
- *A Guide to the Project Management Body of Knowledge,* 5th Edition, Project Management Institute

Learning Objectives:
Upon completion of this course, students will be able to:
1. Apply project management techniques to facilitate a engineering project
2. Apply systems integration techniques to facilitate development of complex products
3. Use project management and systems integration software effectively
4. Appreciate the importance of class topics to successful execution of complex projects

Course Topics:
- Course Introduction and Team Formation
- Project Initiation
- Project Planning
- Project Planning Tools
- Project Execution
- Project Execution Tools
- Project Monitoring and Control
- Project Monitoring Tools

- Project Closeout
- Alternative Project Management Techniques
- Project Management Wrap-Up
- System Engineering Overview
- Systems Engineering Phases
- Top-Level Requirements, Concept of Operations & PBS
- Writing Good Requirements & Requirements Verification Matrices
- Functional Flow Diagrams & N2 Diagrams
- DFMEA and FTA Techniques

Assignments:

Student and Team Presentations:	20%
Homework Assignments and Quizzes:	50%
Final Report Written Submission:	30%