A Design Project Management Course at RIT

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Abstract

Rochester Institute of Technology is currently implementing a college-wide initiative to incorporate multi-disciplinary design as a central theme for all students in the capstone design sequence. For several years, the Kate Gleason College of Engineering has supported a number of multi-disciplinary design teams. Each year, a limited number of multi-disciplinary teams would be formed, typically under the leadership of a strong faculty proponent.

During the current academic year, RIT is incorporating lessons learned to institutionalize a multi-disciplinary capstone design experience for ***all*** students in the college. This paper will focus on educating the project managers and its content. A primary observation, based on the personal experiences of faculty members teaching design projects, and reflections of other faculty in the literature, indicates that most engineering students do not understand how to work collaboratively on multi-disciplinary teams. Many engineering students have no formal training in technical project management.

During the Fall quarter of 2002, RIT introduced an advanced undergraduate course entitled "Design Project Management." During this course, students from mechanical engineering, industrial and systems engineering, and electrical engineering participated in a series of learning exercises specifically directed towards helping each student become a more effective team leader, when they assume responsibility for leading a design project team. Each student in the class will become a team leader of a multi-disciplinary team that will convene in the winter quarter, and work through the spring quarter to deliver a design project for a client.

In this article, we will review the course learning objectives, daily topical coverage, and provide an in-depth review of weekly team-training exercises that the student engaged in. Within the design project management class, the student leaders formed sub-groups to apply formal techniques of product development and design to a classroom example. Every student in the class, except one, had completed a freshman "hammer building" exercise in the college machine shop. We used that common baseline of experience as a touchstone throughout the quarter. Students could then use a familiar project, and a challenge of "designing a better hammer" to learn about the contributions of each discipline, apply the fundamental principles of product development, and practice the management skills that they were learning.

The article will conclude with an assessment of the course outcomes, and provide feedback gained from the students via an in-depth survey conducted at the end of the project management course. In addition, while the design teams themselves will proceed past the paper

submission deadline for the conference, we will provide a subsequent assessment of the management course by conducting a survey of all students in all design teams at the end of the spring quarter.

Course Learning Objectives

Rochester Institute of Technology (RIT) is institutionalizing a multi-disciplinary capstone design experience for ***all*** students in the Kate Gleason College of Engineering. Based on the personal experiences of faculty members teaching design projects, and reflections of other faculty in the literature, it is clear that most engineering students do not understand how to work collaboratively on multi-disciplinary teams. Many engineering students have no formal training in technical project management.

During the Fall quarter of 2002, RIT introduced an advanced undergraduate course entitled "Design Project Management." During this course, students from mechanical engineering, industrial and systems engineering, and electrical engineering participated in a series of learning exercises specifically directed towards helping each student become a more effective team leader. Each student in the class became a team leader of a multi-disciplinary team that convened in the winter quarter, and worked through the spring quarter to deliver a design project for a client.

The Design Project Management (DPM) class was comprised of 17 students, 8 from mechanical engineering, 8 from industrial and systems engineering, and 1 from electrical engineering. Due to scheduling constraints, the electrical engineering student audited the course, and was able to attend approximately 40% of the class sessions. Most of the students enrolled in DPM are dual degree students, working towards concurrent completion of a Bachelors and Masters degree in their disciplines. Many of the students had a general idea of the project team they would be leading prior to enrollment in the DPM class, due to a relationship already developed with their major professor. The learning objectives for the course are categorized as follows:

Level 1: Knowledge
- 1.1. Learn about various Engineering Design Methods and Processes.
- 1.2. Understand the influence of Team Dynamics and interpersonal interaction in a working environment.
- 1.3. Have a basic understanding of the concepts and tools of engineering design project management
- 1.4. Understand the various forms of intellectual property, various forms of protection available for such intellectual property, and the roles and responsibilities of the engineering relating thereto.

Level 2: Comprehension
- 2.1. Demonstrate comprehension not only of knowledge learned in this course, but also demonstrate comprehension of knowledge gained in previous courses and during past co-op work experiences.

Level 3: Application

3.1. Apply a formal Engineering Design Method to the solution of a multi-disciplinary design problem.
3.2. Have experience functioning as a (mechanical, electrical, or industrial) engineer within an engineering design and development group.
3.3. Complete a ``real-life" design task - transform a client's needs into a tangible, tractable project definition, and see the project through to completion.
3.4. Understand and use a formal engineering design method, with emphasis on building concurrent engineering procedures into the basic design method
3.5. Be proficient in the preparation of Oral and Written Reports and Technical Data Packages

Level 4: Analysis

4.1. Become proficient in preparing and reviewing formal technical data packages related to an engineering design.
4.2. Apply the broad range of technical tools and engineering sciences learned during the previous formal education

Level 5: Synthesis

5.1. Be ready to begin a career as an engineer.
5.2. Synthesize the learning achieved from not only the formal classroom experiences, but also co-op work experiences, to form a solid foundation for subsequent professional development.
5.3. Be able to function in a multi-disciplinary environment.
5.4. Understand the importance of life-ling education.

The learning objectives of the DPM class may be mapped against the ABET EC2000 educational outcomes as indicated in Table 1. Each department in the college has developed their own set of program outcomes, specific to the needs of their constituencies. However, Table 1 provides a basis for initiating a discussion across departments, and identifying topics which may be of lesser or greater relevance in the DPM class.

Table 1. Mapping between the learning objectives for the Design Project Management Course and the ABET EC2000 Outcomes a-k.

RIT Design Project Management Course Map	**ABET EC2000 Outcomes**										
	ability to apply knowledge of math, science, & engineering	ability to design & conduct experiments / analyze and interpret data	ability to design a system, component, or process	ability to function on multi-disciplinary teams	ability to identify, formulate, and solve engineering problems	understanding of professional & ethical responsibility	ability to communicate effectively	broad education needed to understand impact in a global and societal context	recognition of the need for, and ability to engage in life-long learning	knowledge of contemporary issues	ability to use the techniques, skills and modern engineering tools for engineering practice
Course Learning Objectives	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Level 1: Knowledge											
1.1 Design Methods & Processes	X	X	X	X	X					X	
1.2 Team Dynamics			X	X				X		X	
1.3 Design Project Management			X	X							
1.4 Intellectual Property				X			X				
Level 2: Comprehension											
2.1 Past Classes & co-op	X			X	X	X		X			

Level 3: Application											
3.1 Apply Design Method to M-D			X	X	X						X
3.2 Function as an Engineer			X	X							X
3.3 Design to Completion			X	X							X
3.4 Concurrent Engineering		X	X	X	X						X
3.5 Oral and Written Reports			X	X		X	X				X
Level 4: Analysis											
4.1 Prepare & Review T.D.P.			X	X	X	X	X				
4.2 Engineering Science Tools	X	X	X	X	X						
Level 5: Synthesis											
5.1 Entry Level Engineer				X		X			X	X	
5.2 Foundation for Prof. Devel.				X		X		X	X	X	
5.3 Function in Multi-Disc Enviro.				X							
5.4 Foundation Life-long learning				X		X		X	X	X	

Freshman Widget Case Study Project

With the exception of a single electrical engineering student, every student in the DPM class had participated in a freshman "Materials Processing" class during their first year on campus, five years earlier. The materials processing class that these students each took consisted of three lectures, and one two hour lab session per week. During the sequence of 10 laboratory sessions, each student manufactured a hammer, and learned about basic machines shop operations such as measurement, drilling, milling, and turning. The students reviewed their own experiences in the materials processing class, and were presented with the results from student evaluations and other curriculum assessments. The basic theme common to the materials processing class evolution has been reported elsewhere (DeBartolo, 2002), but can be summarized as "Love the Lab – Lose the Lecture." Students in the DPM calls were challenged to "design a better hammer" that would include electro-mechanical components, and better topical coverage of modern material processing technology that would be of interest to a range of freshman engineering students. A photograph of the RIT Hammer, considered the baseline against which the alternative DPM student concepts would be compared, is shown in Figure 1.

Figure 1. The "RIT Hammer", manufactured by each first year student in mechanical and industrial and systems engineering.

Students in the DPM class used the process of designing a better hammer as a touchstone case study throughout the academic term. This project was referred to in class, and by the students, as the "widget project." The widget project gave students and faculty members a common background for discussion, an opportunity to immediately apply new knowledge learned in the class, and a vehicle for peer to peer education.

Daily Topical Coverage

The Design Project Management class was conducted in the System Dynamics Laboratory, a studio laboratory with 12 two-student workstations, a dual-headed projection system useful for supporting impromptu design sharing and small group reporting. The DPM class met two days per week, from 10:00 a.m. to 11:50 a.m. on Tuesdays and Thursdays. Typically, each two hour session was conducted as a series of two 50-minute, or four 25-minute periods. A typical day would consist of a 25-minute lecture, followed by a 25-minute active learning exercise. The active learning exercises ranged from individual tasks, to partner tasks (typically one M.E. working with one I.E. student), three design teams of 5-6 students each, a half-class (8 students), or the full class (16-17 students). The class sessions were intentionally designed to be used in a variety of academic formats, and are readily adaptable to a semester of 45 (15 weeks, 3 days per week) 50-minute class periods, 22 (15 weeks, 2 days per week) 75 minute class periods, or a quarter of 20 (10 weeks, 2 days per week) 100-minute class periods, or 40 (10 weeks, 4 days per week) 50-minute class periods. The active learning exercises were developed to be implemented with class sizes of up to 48 students. In a larger class, the students would be clustered as 24 groups of 2 for computer tasks, 6 groups of 8 for role-plays, and 8 groups of six for design teams. The specific sequence of topics "as delivered" is presented in Table 2, using a ten week quarter format at RIT.

Table 2. Daily topical coverage of the Fall quarter pilot offering of the "Design Project Management" class. Each class session consisted of two 50 minute segments, for a nominal 40 class periods during the quarter.

Session	Topic	Classroom Topical Coverage and Activities	Homework / Active Learning Activities
1	Introduction	Introduce the range of projects available, through 2 minute presentations by faculty guests from all disciplines. Introduce the role of the leaders on each project. Build excitement for the DPM class.	
2	Overview of Design Process & Design Planner	Introduce multi-faceted design process and design planner toolkit. Start with the generic problem solving process: need recognition, problem definition, data gathering, problem solving, validation & verification. This progression goes from generic to specific and should cover a wide range of projects we will encounter. Move into a generic product development (waterfall) format. Close with DesignPlanner™.	
3	An Introduction to Project Management	Defining objectives, goals, tasks, work breakdown structure. Introduce PERT and Gannt for planning projects, discuss estimating completion times, slack, and critical path. Use Plan Do Check Act as a theme for each facet. Team Exercise: Apply skills to begin planning the tasks involved in making the hammer.	Professors post the student developed list, from the team exercise, to the web site. Each student downloads a copy of the task list for individual use.

4	Intellectual Property	Patents, Trademarks, Copyrights, Briefing, maintaining intellectual property hygiene, Use a contrived hammer disclosure as an example.	Conduct a patent search on an area of interest to each individual.
5	Intro. to Project Planning.	Project planning fundamentals. Use MS Project in a studio lab to prepare a plan for building the existing hammer.	Submit project plans and process instruction sheets for the current RIT hammer.
6	Team Dynamics and Team Interactions	(a) Establishing Team Values and Norms (b) Integrated Product / Process Teams (c) Role Play personality Types (d) Difficult people and situations	Review on-line learning materials, come prepared for questions and activities about them.
7	Detailed Project Descriptions and Consensus Techniques Used to Assign each project manager to a project.		
8	Facet 1: - Plan	Facet 1: Recognize and Quantify the Need; Distribute Design Planners for each team. Customer statement of work.	
9	Facet 1: - Do, Check, Act	Developing a market plan, and project business case, justification for the project at hand. Peer review presentations to the class.	Learning Activity: "Needs Assessment for the WIDGET."
10	Facet 2: Concept Development (PDCA)	Facet 1: Act: Developing a project mission statement Facet 2: Concept Development, PLAN-DO-CHECK-ACT Brainstorming methods for concept identification.	Learning Activity: "Concept Development for the WIDGET."
11	Concept Development Continued	A: Group Drawing exercise on two concepts in parallel, empathy method on one concept. B: Literature Review	Student teams prepare a mini-technical data package (with drawings and BOM) for their top two widget concepts.
12	Facet 3. Feasibility Assessment (PDCA)	Review technical, schedule, performance, and economic issues influencing the concept selection process.	Learning Activity: "Feasibility Assessment for the WIDGET."
13	Facet 4: Objectives & Specs (PDCA)	Prepare learning objectives, design specifications, implementation constraints, etc. for the WIDGET. Begin discussion of technical writing techniques.	Students work on Draft 1 (Brain Drain) of their project Needs Assessment.
14	Facet 5: Preliminary Design (PDCA)	Discuss a preliminary design review process; introduce expected elements of a technical data package.	Students work on Draft 2 (Sloppy Copy) of their project Needs Assessment.
15	Facet 6: Analysis & Synthesis (PDCA)	Introduce tools such as Design Structure Matrix, Systems Approach to Design Projects, and Quality Function Deployment	Students work on Draft 3 (Neat Sheet) of their project Needs Assessment.
16	Facet 7: Engineering Models (Plan)	Prior project sample experiences and lessons learned for prototype development. Cautions and suggestions for software & hardware prototyping projects. Turning ideas into reality	Students work on Draft 4 (Final Form) of their project Needs Assessment.
17	Project Planning	Red Line review of three week project plan by faculty and peers	Students complete a red line review of peer project plans
18	Need Statement Done	Red Line of needs statements prepared by students & mentors	Students complete a red line review of peer needs assessments
19	Practice Project Presentations	Each team manager presents a 2 minute project overview. Faculty and peers provide suggestions for improvement.	Students present their draft two minute slide show to recruit others to work on their project.
20	Practice Project Presentations Continued		
21	Exam week	Each team manager submits a (1) 90% complete needs assessment (2) a 3 week project plan (3) a one page flyer (4) a table top poster board.	

Brief lectures were used to introduce new concepts and various facets of the design process to the class. Each lecture would set a global view of each topic to motivate the material being presented (knowledge), and then present a perspective specific to the students' current level of professional development (comprehension). A combination of visual and verbal learning aides was used in each mini-lecture wherever possible. Each learning activity focused on asking the students to apply their knowledge to a classroom case study (application). The student teams shared their results with the rest of the DPM class, and were subject to friendly, but thorough, peer review on a regular basis (analysis). Finally, the homework activities near the end of the academic term focused on asking the students to extend their experiences in the classroom, and from the group active learning activities, to the preparation of a plan for their own design project (synthesis). Students were exposed to engineering design as a multi-faceted process (REF), with each facet being composed of four basic steps: Plan, Do, Check, and Act.

As we moved through the academic quarter, we found that ***all*** of the students had prior to exposure of ***some*** topics covered in the lectures, while ***none*** of the students had prior exposure to ***all*** of the topics. This observation provided both a challenge and an opportunity. The instructors were constantly challenged to present information in a manner that was a clear introduction to neophytes, while not being viewed as boring to the more experienced students. For example, the industrial engineering students were quite familiar with Gannt charts and work breakdown structures, while many of the mechanical engineering students had never been exposed to these topics. Conversely, some topics discussed, such as the details of creating a technical drawing package, were beyond the experience of the industrial engineering population, but was "old news" to the mechanical engineers. During the academic term, virtually every student in the classroom expressed lack of knowledge about the detailed skills and capabilities of the other disciplines. This provided wonderful opportunities for peer-to-peer learning. Topics that were foreign to students in one discipline were familiar to students in another. It was common for students to share experiences from their discipline and explain concepts to their student colleagues (Wojahn, 2000). By the end of the quarter, students openly (and largely without having to be encouraged), engaged in dialogue about their relative skills and abilities, and how various disciplines could contribute to the project.

Team-Training Exercises

A series of small team exercises (Hensel, 2001) was incorporated as active learning activities throughout the academic term. Three design teams were formed to perform activities related to the classroom widget design case study. These teams were used on several activities over a period of about three weeks. For example, each team prepared a needs assessment and mission statement for their widget project. Each team interviewed the professors in the role of customer, and prepared a formal statement of work that was shared with the rest of the class in brief presentation. The needs assessment role play was conducted within a one hour period, and students were given a homework assignment to return to class with a draft statement of work.

As the course progressed, the class was introduced to formal methods of concept development, through a brief lecture lasting approximately 30 minutes. These methods included traditional brainstorming, group drawing, and empathy methods. The brainstorming roleplay lasted approximately 30 minutes. Each of the three design teams was charged with creating a list of at least 20 widget concepts within 8 minutes. The team then used Pareto's rule to identify the top two concepts from their list in the next 8 minutes. The team was allotted 4 minutes to prepare a one page report describing their three concepts for the rest of the class. During the next 10 minutes, the three student teams debriefed the class on their design concepts. The widget concepts resulting from the brainstorming roleplay are presented in Table 3.

Table 3. Top widget concepts proposed for study by each of three classroom design teams, generated in 20 minutes, and actively engaging all students in the classroom.

Team	Concept A	Concept B
Alpha	Laser Range Finder	Impact Force Sensing Hammer
Beta	Heated Coffee Cup Holder	Vibrating Alarm Wristwatch
Delta	Torque Wrench with Digital Readout	Portable Vibrating Back Massager

During the second team learning activity of the facet, group drawing, each of the design teams was separated into two groups of three students, with faculty members filling in where needed. Each person in the group was given a grided 11"x17" piece of paper. Each student was asked to draw a sketch of their assigned concept on the paper, without speaking. After two minutes, they passed their paper clockwise to their neighbor, who was then instructed to build upon the ideas they received on the paper from their neighbor. Again, without speaking, each team member was to add detail, solve problems, and give further definition to the design. After another two minutes, the pages were again passed clockwise, and the last group member was asked to add details to the sketch. One student on each team was asked to annotate the sketch from the perspective of a mechanical engineer, an industrial engineer, and an electrical engineer. Now, after a total of six minutes, each sketch was passed clockwise again, back to the originator. The originator was given two minutes to assimilate information from their team-mates, and expand upon their initial design renderings. Eight minutes into the exercise, students were told to put down their pens and pencils, and talk to one another. They were encouraged to discuss the different design concepts that had been rendered, and how various people would interpret the phrases listed in Table 3 to mean quite different things. The students were given seven minutes for this discussion, and an opportunity consolidate their three views into a single rendering for each concept. Each of the six design concept drawings was presented to the class during the next 15 minutes. The students had gone from a basic needs statement at the beginning of class, to six fairly well defined concepts in just 90 minutes. During the peer review, several problems and ill-defined features of each concept were identified. The students were quite adept at pointing out areas where another team may have glossed over details – often striking at the heart of the design issue. This identification of issues led directly into the final interactive learning activity for the session.

During the third team learning activity, empathy methods, each team of six students was asked to pick one of their two concepts for further study. These are listed under the column labeled "Concept A" in Table 3. Each of the size team members was rapidly assigned an empathic role to play. For example, for the coffee cup holder design concept, one student was identified as the coffee, one as the user, one as the controller, one as the heater, one as the holder, and one as the replaceable cup. Students were given these role assignments within 5 minutes after the identification of issues from the prior session. Each team was then given about 10 minutes to use an empathy method to resolve issues identified during the prior design review, discuss system integration and function, and propose solutions. During the final 15 minutes of the class, the professors reviewed each empathy role play with the entire class, and re-iterated how, with more preparation, these techniques could be used to identify root cause problems, and in some cases, develop solution strategies. The students left class with several tools – brainstorming, group drawing, and empathy methods – that they had learned about, understood, and finally applied to a classroom case study. Each student was challenged reflect on ways they might utilize these new skills with their individual design project teams.

As a homework assignment, each sub-team was given five days to prepare a min-technical data package for each of the six concepts listed in Table 3. The team was charged with preparing assembly drawings, part drawings, and a bill of materials for the embodiment design of their concept. One example of a student generated embodiment design is shown in Figure 2. Six fairly complete sets of drawing packages were prepared, one for each of the concepts listed in Table 3, by sixteen students in five days. Students were encouraged to provide as much detail, including as much support for component cost and supplier identification, as they could accomplish in the time available.

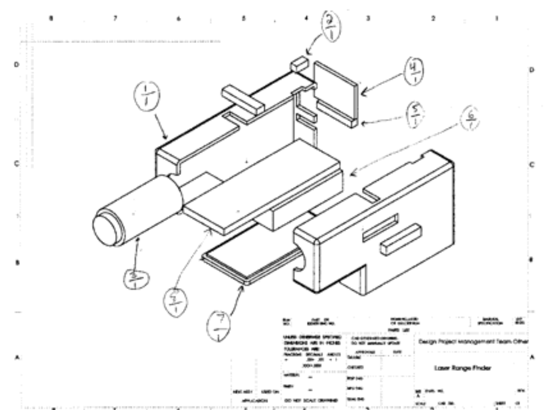

Figure 2. Embodiment design for a widget.

The preliminary embodiment designs similar to the one shown in Figure 2 were then used during the next facet of the design process, feasibility assessment. Each student team analyzed the feasibility of each design concept from the perspectives of cost, technology, performance, and schedule using the existing RIT Hammer as the baseline. For each perspective of assessment, the students scored their concept on a scale ranging from 0 (impossible), 1 (worse than the hammer), 2 (same as the hammer), to 3 (better than the hammer). The students again prepared a report on their feasibility assessment for peer review by the class. Figure 3 show illustrates the radar charts used by the students to share their assessments with their classmates, and how they made a decision for moving to the next phase of design.

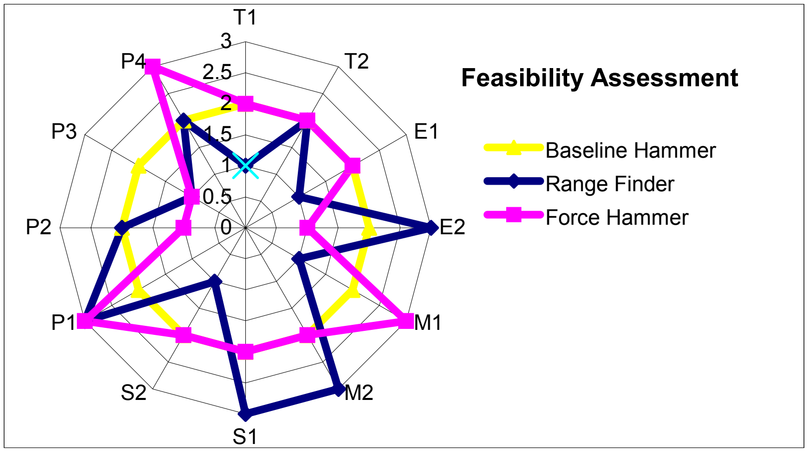

Figure 3. Feasibility assessment for a widget. Students used a graphical technique to compare alternative design concepts from a variety of technical, economic, market, schedule, and performance perspectives. Each alternative was rated as "better than," "same as," or "worse than" the baseline hammer.

Other learning activities completed during the quarter included project planning, personality types role-playing, "customer" interviews, design structure matrix construction, quality function deployment, patent searching, and team values and norms.

Assessment of Learning Objectives

As of press time, assessment of the design project management course is on-going. Sixteen students who took the design project management course are now leading multi-disciplinary design teams, along with five additional students who did not take the design project management course. A preliminary design review will be conducted in February 2003, and a critical design review in May 2003. Surveys of project managers and team members will take place at that time.

Informally, the professors observe that all 21 student teams are off to an excellent start, three weeks into their respective projects. The trained team leaders have a clear sense of where their team is headed, and are offering guidance to other team leaders as well. All of the teams have completed small group team building exercises, participated in a contract negotiation workshop, and completed a facilitated brainstorming session for their project. Customer contacts have been established, and most team members have visited their customer site for a briefing on the background of the project. Over 110 students are on track, and have a clear indication of their project. Anecdotally, the authors note that past teams, without trained team managers, would often be floundering and still seeking a clear understanding of their project at this point in time. This year, it appears that every team has a fairly well-defined understanding of their project.

Recommendations and Plans for Future Work

Based on our experiences with the course during the first year, and our assessment of results during the winter and spring quarter, we anticipate making several improvement to the course for the Fall 2003 offering.

1. Student managers will be aligned with their individual projects earlier in the quarter. This will require an earlier commitment from faculty mentors and company sponsors.
2. Additional engineering disciplines will participate. This requires extensive logistics collaboration between departments. In the next offering, students from computer engineering and microelectronic engineering will join the students from mechanical, industrial and systems, and electrical engineering.
3. Continue the assessment of the design project management course throughout the duration of subsequent design project course sequence.

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