AC 2007-1814: USING THE EXPERIENTIAL LEARNING MODEL AND COURSE ASSESSMENT TO TRANSFORM A MULTIDISCIPLINARY SENIOR DESIGN COURSE SEQUENCE

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Using the Experiential Learning Model and Course Assessment to Transform a Multidisciplinary Senior Design Course Sequence

Abstract

Rochester Institute of Technology (RIT) has long been committed to experiential learning within its undergraduate engineering curriculum. With one of the oldest cooperative education programs in the country, RIT firmly believes in learning through doing. This paper describes how an experiential learning model is also incorporated within the classroom in order to improve student learning within a large-scale, multidisciplinary capstone design course. The experiential learning model is referenced while redesigning a course to ensure that planned activities give full value to each stage of the process. The learning methodology is based on an existing educational model which includes four basic stages; active experiences, reflective observations, abstract conceptualization, and active experimentation. Motivations for course transformation are based on continuous course assessment which revealed improvement opportunities within student learning. Beginning in 2006/07, student-centered workshops replaced traditional lectures for instruction of product design and development. An annual course assessment conducted during the summer of 2006 motivated the course modifications and feedback (faculty and student) from the first offering of the workshop series in the fall of 2006, reveals an improvement in student learning and engagement.

This paper includes an overview of the course assessment process, which involves faculty from four engineering departments; the redesigned course delivery methodology, created through the application of an experiential learning model; results of feedback from students and faculty; and future plans for continued course refinement.

Key Words

Capstone design, experiential learning, engineering education, multidisciplinary teams, engineering design process, design education, course assessment, active learning, textbook selection

Introduction

Rochester Institute of Technology (RIT) has long been committed to experiential learning within its undergraduate engineering programs. With one of the oldest cooperative education programs in the country, RIT firmly believes in learning through doing. RIT's Kate Gleason College of Engineering offers accredited undergraduate degree programs in mechanical (ME), electrical (EE), industrial and systems (ISE), computer (CE), and microelectronic engineering. As a degree requirement, each year almost 400 fourth and fifth year engineering students from ME, EE, ISE, and CE enroll in a multi-disciplinary senior design (MSD) course sequence which spans two academic quarters (22 weeks). The MSD experience is a *studio course* in that it adopts a general approach to student interaction that is hands-on, instructor facilitated, and student-centered [1]. Refer to companion paper by Walter et al, 2007 [2]for more details on the overall MSD program at RIT. Like its peer institutions, RIT strives to continuously improve curriculum structure, integration, and assessment. The MSD course sequence is particularly crucial to this ongoing improvement due to its culminating nature. Accordingly, the Accreditation Board for Engineering and Technology (ABET) Criterion 3 Program Outcomes and Assessment states that engineering programs must demonstrate that their students attain the following set of attributes upon graduation [3]:

(a) An ability to apply knowledge of mathematics, science, and engineering

(b) An ability to design and conduct experiments, as well as to analyze and interpret data

(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) An ability to function on multi-disciplinary teams

(e) An ability to identify, formulate, and solve engineering problems

(f) An understanding of professional and ethical responsibility

(g) An ability to communicate effectively

(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(i) A recognition of the need for, and an ability to engage in life-long learning

(j) A knowledge of contemporary issues

(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

In accordance with these criteria, there is a progression in the curriculum where fundamental scientific and other knowledge acquired within the earlier years is applied in later engineering courses through a well integrated experience. Through the progression of courses within an integrated curriculum, a student can ideally experience all stages of the experiential learning model described within this paper, on a much broader scale. The MSD course sequence serves as the culminating experience for students in mechanical, electrical, industrial and systems, and computer engineering at RIT.

This paper provides an overview of the MSD program outcomes; assessment practices which involve faculty from four engineering departments; recent course modifications based on annual assessment, specifically a redesigned course delivery methodology created through the application of an experiential learning model; results of feedback from students and faculty; and future plans for continued course refinement.

MSD Program Learning Outcomes

Due to the nature of the capstone design experience coupled with its timing which closely aligns with graduation, the learning outcomes for the MSD program directly support attributes identified by ABET. The MSD experience also relies heavily on technical skills and knowledge that students acquire through their respective engineering program coursework as well as foundational courses. After a comprehensive MSD course assessment and evaluation during the summer of 2006, the MSD program educational outcomes (student learning expectations), describing what students are expected to know and be able to do by the end of the MSD experience, are as follows:

1. Ability to explain the product development process in the context of the product life cycle.
2. Ability to perform a critical analysis of requirements, engineering specifications, and the relationship between them.
3. Ability to *integrate* theory from a broad range of courses, laboratory exercises and co-op experiences to the solution of an engineering design problem.
4. Ability to employ a rigorous design process that includes ideation, analysis, synthesis, implementation, and test against engineering specifications.
5. Ability to document product development activities.
6. Ability to effectively communicate technical, discipline specific information through oral and written means.
7. Ability to work effectively in a multidisciplinary team environment, to communicate and make tradeoffs, within and across disciplines, to meet project requirements.
8. Ability to explain the impact of project schedule, critical paths, and budgetary constraints on the effective execution of an engineering design.
9. Ability to be perform a self-assessment of skills, aptitudes, and preferences against project roles and responsiblities.
10. Ability to assess the societal impact of design choices and to make ethical engineering design decisions.

Table 1 demonstrates the relationship between course learning objectives and ABET (a) through (k) criteria.

Table 1: MSD Course Learning Objectives Mapped to ABET Attributes (a – k)

MSD Objectives (abbreviated)	**ABET Defined Attributes**										
	(a)	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**	**(i)**	**(j)**	**(k)**
1. product development process		X	X						X		
2. critical analysis	X				X				X	X	X
3. *integrate* theory and apply	X				X				X		
4. employ a rigorous design process		X	X		X				X		X
5. document product development							X		X		X
6. effectively communicate							X		X		
7. work effectively in team				X					X		
8. execute engineering design		X	X					X	X		
9. self-assessment				X					X		
10. societal impact and ethical engineering design						X			X	X	

Of particular interest in Table 1 is the assignment of all MSD learning outcomes supporting ABET's criterion associated with life-long learning (i). Past educational research suggests that successful experiential learning experiences promote student self-directed learning readiness and shows promise in regards to promotion of life long learning [6]. Identified variables that may be key to achieving these successes include assigning real, open-ended projects; providing an immersion experience within the project; conducting project activities away from campus; establishing high expectations and providing necessary support system for students. The MSD experience at RIT involves student teams solving real-world open ended problems; provides weekly "immersion" experiences every Friday for student teams and their faculty Guides; requires high-levels of individual and team expectations; and provides a redesigned workshop, seminar, tutorial series that offers a necessary support framework for students.

The only suggested variable not present is a location of immersion away from campus. Most student teams spend all day Friday in the engineering classroom building working on their projects. Over the past year, a building expansion project has been underway which will significantly increase the size of the existing engineering building at RIT. The entire top floor of this expansion building will serve as the new home of the multidisciplinary senior design program beginning in the fall of 2007. The space includes a large open Collaboratory (approximately 4000 square feet), Design Learning Center, Team Rooms, and a Computer Lab. Although this location is still on the RIT campus, its location is remote from classroom and normal building circulation areas. The Collaboratory's interior architectural treatments, including high spaces with expansive curved suspended ceiling systems, ample exterior windows, adjoining balcony, angled glass walls, and expansive open space will ideally enhance the immersion process. The space takes on the feel of a *design studio* rather than a typical college classroom. Faculty from areas such as fine arts and architecture who use studio spaces extensively in their curriculum recognize a relationship between the physical space and the subject taught. Therefore, they find design studios to serve as ideal environments for design education [4].

Assessment Practices

In 2002, the MSD program began as a small pilot project and has evolved into a college-wide initiative, involving four departments. This growth has been accompanied by annual program assessments based on feedback from the MSD program director, faculty advising team, and informal student feedback. Ideally, assessment methods are applied consistently year to year and should be part of an integrated program of assessment and feedback to affect positive change or maintain superior performance [5]. The MSD faculty team began developing a more integrated assessment plan in 2005 and during the fall of 2005/06 academic year, quarter-end MSD course feedback began to be collected using an electronic survey system from students enrolled in the MSD I course. While subtle course adjustments had been made each year leading up to this time, a major redesign effort was undertaken in the spring and summer of 05/06 in order to improve program alignment with departmental objectives; course content, lesson timing, and course delivery; communication climate; and student and faculty general satisfaction levels.

During the spring on 2006, a small working group, led by a newly appointed MSD director, began meeting once per week to create a strawman for a comprehensive assessment and redesign effort. The team's goal was to create a plan that would allow enough time for faculty engaged in

MSD to work together in an immersion type scenario while assessing, evaluating, and redesigning elements of the program with a launch date of fall 2006. This small planning group created a MSD Strategic Framework to serve as a starting point for the larger group. The framework included a suggested mission, vision, values, key differentiators, and goals. In the early summer of 2006, two half-day sessions were planned for the larger MSD team, including nearly twenty faculty and department heads representing four engineering departments.

The first session's objectives were to reach consensus on the most critical attributes of the desired "future state" of the program (including review of elements described in strategic framework and learning objectives); agree on priority changes to the program (such as project selection, course execution); and establish sub-teams to address issues raised off-line. The team agreed that the three priority areas for change included *project selection*, *course development and integration*, and *course delivery and logistics* and respective sub-teams were formed. A second half day meeting was held several weeks later to discuss progress made in each critical area. The project selection team proposed significant changes which grouped related projects into sets of disciplinary "tracks," consistent with academic programs and faculty interests. The course delivery and logistics sub-team focused their discussion on website issues, project assignments, space requirements, and course delivery requirements. Companion papers offer more details on results from the project selection sub-team and the overall redesigned MSD program [2, 7]. The following section of this paper describes the activities and results of the course development and integration sub-team.

Course Development

The course development sub-team created a series of experiences which follow an experiential learning model in order to improve student learning [8] within the MSD experience. The methodology is based on Kolb's [9, 10] educational model and includes four basic stages; active experiences, reflective observations, abstract conceptualization, and active experimentation as shown in Figure 1. Typically the stages or phases occur non-simultaneously and sequentially, although reflective observations can be made at different times throughout the overall model. Varying time durations are required in order to accomplish each stage. Two aspects are seen as especially noteworthy: the use of concrete, 'here-and-now' experience to test ideas; and use of feedback to change practices and theories [9]. Faculty advisors or Guides (as they are referred to at RIT) assigned to each MSD project team provide frequent feedback to teams in order for them to make necessary modifications to design practice, analysis, modeling, team dynamics, etc. Teams test their ideas continuously throughout the MSD experience, first with other team members and if necessary with project Guides or other faculty consultants.

As for the first two stages of the model (active experience and reflective observations), upon entering the course, a subset of students have had experience working with solving open-ended, multidisciplinary, real world problems. Thus, this subset of students would be entering the course after having accomplished the first stage and perhaps second stages of the learning model. However, the vast majority of students do not have this background and therefore, the classroom is an ideal setting to introduce interactive activities where the students can learn by doing or experiencing (stage one). Reflective observations of this experience are also incorporated into classroom activities or out of class assignments. Thought provoking questioning techniques are incorporated during Guide/team meetings in order to enhance reflective student observations.

The experiential learning model is applied while designing a course to ensure that planned activities give full value to each stage of the learning process. Prior to the recent redesign, the MSD course sequence was taught in lecture format which addressed the third or conceptual stage of the experiential learning model [11]. Under this format of instruction, most student teams were successful in meeting customer requirements as highlighted in various papers authored by students based on their MSD experiences [12, 13], however student and faculty satisfaction with the MSD experience necessitated course modification to many aspects of the program, most notably to the course delivery and content areas.

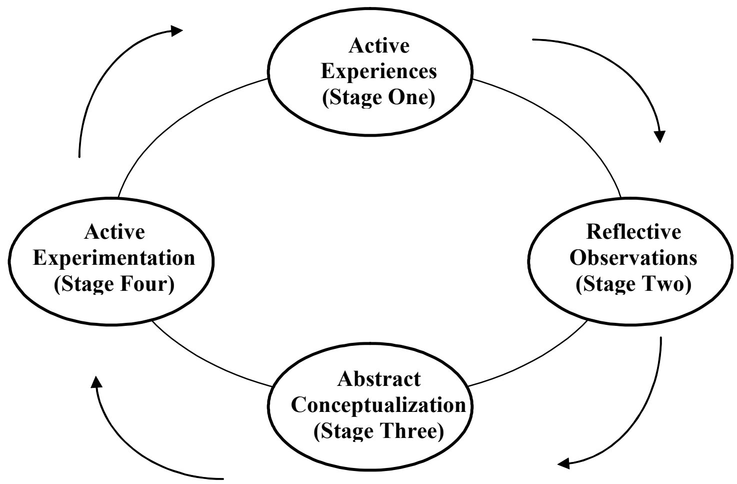

Figure 1: Experiential Learning Model

In response to program assessment, the course development sub-team designed a series of just-in-time workshops, seminars, and tutorials within MSD I and II as shown in Tables 2 and 3. To reduce startup time normally associated with beginning the design process, four full-day workshops were incorporated within MSD I during the fall of 2006. Each workshop included a one to two hour interactive classroom experience where various key design phases were the focus. During each of these workshops, teams are presented with necessary design related information and asked to practice the design methodology on their projects, given fifteen to twenty minutes to explore together in teams. Periodic brief break-out sessions for team work within the workshops provide a more interactive experience for the students. Attendance at workshops is required and topics include customer requirements, engineering specifications, concept generation, and concept selection. Other course activities which were added throughout MSD I and II were optional and briefer in nature. These include tutorials and seminars that address relevant course topics many of which are offered just-in-time for various course deliverables. Refer to the table included in the appendix for a complete listing of MSD I design phase information, course offerings, expected progress of students, and deliverables.

The new workshops, seminars, and tutorials are further augmented by a new course textbook. The course development sub-team selected this book after reviewing many choices. To ensure that their final textbook selection is the best option based on a specific set of criteria, a Pugh's matrix was developed and is included as Table 4. The identified criteria were based on desired content within the text. The resulting matrix provides helpful documentation while encouraging framed, objective, discussions where individual contributions are encouraged. The final textbook selected is authored by Ulrich and Eppinger [14]. The datum textbook actually had the highest score, however it is not multidisciplinary in nature and therefore not considered for the course. It was chosen as the datum because of the team's familiarity with its content and its wide use within mechanical engineering design education. Another text (B) had a similar overall score to the Ulrich text, however the chosen text was deemed more acceptable for the fourth and fifth year engineering students. Text (B) is an excellent choice, especially for students in an introductory design course, and as such courses are brought on-line within the college this text will be a strong candidate. In retrospect, customer requirements in the Pugh's matrix should also have includes a "depth of coverage" related item which would have more clearly shown that the selected textbook was the best choice in this case. The team which was comprised of nearly ten faculty members found that by using a tool such as the Pugh's matrix for textbook selection, it allowed the group to discuss this issue more productively and objectively.

Table 2: MSD I Course Activities

Week No.	Course Activities
1	*Workshop*: Course Introduction and Project Kickoff
2	*Workshop*: Translating Needs to Specifications *Tutorial*: EDGE website
3	*Workshop*: Functional Decomposition and Concept Generation
4	*Workshop*: Concept Generation and Selection *Seminar:* Preparation for Concept Reviews *Tutorial*: Advanced EDGE & Wiki *Seminar*: Drive Circuits for Output Devices
5	*Entrepreneurship Conference*: http://entconf.cob.rit.edu/
6	*Seminar:* Noise Immunity Techniques *Seminar:* Embedded Linux and Software Development *Seminar:* Preparation for Design Reviews
7	*Seminar:* How to prepare a drawing package? *Seminar:* Analog to Digital Conversion
8	*Seminar:* Preparation for Project Reviews *Seminar:* Harnesses, connectors, test points, LEDs *Seminar:* PCB Layout application and Surface Mount Tour *Seminar:* Fatigue analysis *Seminar:* Linux overview
11	*Focus Groups:* Informal Feedback Opportunity

Table 3: MSD II Course Activities

Week No.	Course Activities
1	*Workshop*: Course Overview
3	*Seminar*: Technical Paper Requirements
4	*Seminar*: What should be included on the project poster?
6	*Seminar:* Oral Presentation Skills
8	*Seminar:* Preparation for Final Project Review
11	*Focus Groups:* Informal Feedback Opportunity

Table 4: Textbook Selection Pugh's Matrix

		Weighting	Textbook A	Textbook B	Textbook C	Textbook D	Textbook E	Ulrich	Textbook F	Textbook G
	Customer Requirements		*DATUM*							
1	Problem Identification	13.64	-	2	1	1	1	1	0	-1
2	Develop Engineering Specs	12.64	-	1	1	-2	1	1	0	2
3	Generate Concepts	11.64	-	0	0	-1	-1	1	0	0
4	Form (Product) Generation	10.64	-	-3	-3	-3	-3	0	-3	-3
5	Modeling/Simulation	9.64	-	-1	0	1	-3	-3	0	-3
6	Team Dynamics	8.64	-	-2	-3	2	-1	-3	1	2
7	Testing	7.64	-	-1	-1	-1	0	-3	0	-3
8	Evaluate Concepts	6.64	-	-1	1	-1	0	1	0	0
9	DFx (Sustainability, Reliability, Maintainability, etc.)	5.64	-	1	0	0	1	2	-2	0
10	Product Development Process	4.64	-	-1	-1	-1	-1	3	-1	-1
11	Design Communication	3.64	-	2	1	3	2	-2	1	1
12	Ethics	2.64	-	2	0	0	2	-2	0	0
13	Budget	1.64	-	1	1	-2	0	1	-2	1
14	Timeline	0.64	-	1	-2	-1	1	1	-2	1
		Overall	0	-17	-33	-40	-41	-18	-40	-54

Students and Faculty Feedback

Feedback on the Multidisciplinary Senior Design sequence related to course structure and presentation is collected mid-quarter and at the end of the quarter. During the fall 2006 quarter, feedback indicated that the students had concerns with the new workshop format, but that they would be much more in favor of the new workshop format if they were given a chance to *immediately* apply what they learned during workshops (63% were in favor of this).

During the winter quarter, teams seemed much less receptive to the new workshop format (15% rated as good or very good in winter, versus 36% in fall), despite integrating breakout time for teams during workshops. This drop in student receptiveness may be caused by the workshop format itself and/or its content. Written comments collected during course-end student feedback from the winter quarter as well as ongoing focus groups with students by the guides will help distinguish common source(s) of the student's lack of receptiveness to the workshops. From many group discussions, it appears that the drop may be at least partially attributable to the large increase in class size between the fall and winter quarters, as well as a change in room configuration. Between the fall and winter quarters, the MSD I class setting changed dramatically from an audience of approximately sixty students in a large classroom in the fall to an audience of over 200 students in a large meeting area for the winter workshops. Class sizes at RIT are traditionally much smaller than this (20-40 students/class) and therefore students would not be accustomed to this type of large-scale instruction. Many students commented during winter quarter that they did not like the large class size or the room layout.

Additionally, the drop in student receptiveness to the new workshop format between the fall and winter quarters varied somewhat by project track, indicating that some projects may not have been set up to take advantage of the new format or that their faculty guides were not emphasizing the importance of the design process and providing adequate guidance in those areas. A recurring problem is that many students still do not realize that most of the workshop content is critical to the design process, and that being able to follow and document a formal design process is an important aspect of the Multidisciplinary Senior Design sequence.

In addition to feedback on the workshop format, the incorporation of project tracks into the course gave additional opportunities for student-centered class time, including reflection on the workshop topics and time to actively experiment with the workshop topics related to their own projects. One major change incorporated during this year was the addition of track-based meeting times, where there was no structured lecture planned, but when teams with similar topics would gather to discuss their work for the week. Feedback on this was favorable, with 40% of respondents indicating that this time was helpful to them. Another 40% were neutral and only about 9% felt that this time was a hindrance to their projects. The remaining students indicated that the time would have been helpful if they had used it differently.

Faculty feedback on the course changes to date has been informal, but very positive. In general, faculty are indicating that teams in the current academic year have an improved understanding of the design process earlier in their MSD experience as demonstrated by most teams during the week 5 Concept Review.

Course Refinements

Based on the results of feedback from students and faculty, several changes in the course offering have been implemented with others planned for the future. Changes that have been implemented to date include:

- Building in breakout time during workshops so that teams can immediately apply the information learned to their own project.
- Setting aside time each Friday afternoon for teams within tracks to get together and discuss their progress.
- Incorporation of a Week 5 Concept Review for teams to present all design concepts. This leaves four to five weeks prior to the end of the quarter to work on analysis before doing a detailed design presentation.
- Development of a detailed grading rubric for each course deliverable, and presentation of the relevant rubrics each week during the workshop. For example, during the concept evaluation workshop, the grading rubric for the Concept Review was presented to the students and teams were encouraged to review the criteria online before their own team's Concept Review.

Changes that may be implemented in the future include:

- Emphasizing the course objectives during workshops, which include being able to write design requirements, follow and understand a design process, and document product development activities, and not just perform the analysis required to complete a design project.

- Working with faculty guides to ensure that all teams understand the importance of the design process workshops early in the quarter.
- Addressing concerns over class size and room size for the student-centered workshops. This may involve finding a better space for the entire class to meet or finding a way to break the class into smaller sections while ensuring that content delivery is consistent across sections.

Conclusion

Rochester Institute of Technology is committed to experiential learning within its undergraduate engineering programs through its cooperative education program and course design. This paper describes how an experiential learning model is incorporated within a multidisciplinary capstone design course sequence in order to improve student learning. Previously, this course sequence was taught in a lecture style which addresses the conceptual phase of the experiential learning model. This paper provides an overview of the Multidisciplinary Senior Design program learning outcomes and their mapping to the ABET (a-k) attributes. Program assessment practices are also described which involve faculty from four engineering departments. A comprehensive program assessment occurred during the spring and summer of 2006 and motivated a significant, comprehensive program redesign. Elements of the redesign highlighted here relate to the course delivery methodology created through the application of an experiential learning model and selection of a new course textbook. Preliminary student and faculty feedback results after the first two offerings of the course reveal improvements in student learning and performance as well as areas where improvements are needed. Future plans for continued course refinement are presented.

References

[1] Little, P., [2001], *Use of Studio Methods in the Introductory Engineering Design Curriculum,* Journal of Engineering Education, July.

[2] Walter, W., et al, [2007], *Redesigning a College-Wide Multidisciplinary Senior Design Program at RIT*, Proceedings of the 2007 American Society of Engineering Education Annual Conference & Exposition, Honolulu, Hawaii.

[3] Accreditation Board for Engineering and Technology. Criteria for Accrediting Engineering Programs. Revised 29 October 2005. http://www.abet.org/ (6 January 2007).

[4] Dym, C., [2003], *Social Dimensions of Engineering Design: Observations from Mudd Design Workshop III*, Journal of Engineering Education, Jan.

[5] McGourty, J., Sebastian, C., Stewart, W., [1998], Developing a Comprehensive Assessment Program for Engineering Education, Journal of Engineering Education, Vol. 87(4), 355-361.

[6] Jiusto, S., DiBiasio, D., [2006], *Experiential Learning Environments: Do They Prepare Our Students to be Self-Directed, Life-Long Learners?* Journal of Engineering Education, Vol. 95(3), 195-204.

[7] Esterman, M., et. al, [2007], *Development of Integrated Project Tacks for a College-Wide Multidisciplinary Engineering Design Program at RIT*, Proceedings of the 2007 ASEE Annual Conference & Exposition, Honolulu, Hawaii.

[8] Tennant, M., 1997, *Psychology and Adult Learning*. Second Edition. London: Routledge.

[9] Kolb, D, A, *Experiential Learning: Experience as the Source of Learning and Development*, New Jersey: Prentice-Hall, 1984.

[10] Kolb. D. A. and Fry, R. *Toward an applied theory of experiential learning*, C. Cooper (ed.) Theories of Group Process, London: John Wiley, 1975.

[11] Stiebitz, P., Hensel, E., Mozrall, J., 2004, *Multidisciplinary Engineering Design at RIT*. Proceedings of the 2004 American Society of Engineering Education Annual Conference & Exposition.

[12] Gannon, J., Bailey, M., White, D., and Yu-Chuan Yang, R., 2004, *SOFC Durability Test Stand Design Challenges and Processes*. Lucerne Fuel Cell Forum.

[13] George, E., Bailey, M., 2005, *Retrocommissioning (RCX) Mechanical Systems on a University Campus: Student Capstone Experience*, Proceedings of the 2006 American Society of Engineering Education Annual Conference & Exposition, Chicago, Illinois.

[14] Ulrich, K.T., Eppinger, S.D., 2004, *Product Design and Development*, 3rd Ed., New York: McGraw-Hill.

Appendix – Table A-1 Course Activities, Anticipated Progress, and Deliverables for Multidisciplinary Senior Design I (Winter 2006-2)

Week No.	Design Phase & Programmed Course Activities	Anticipated Progress by Student Teams	Deliverables
1	**PROJECT PLANNING (PHASE 0)** *Workshop*: Course Introduction and Project Kickoff *Breakout:* Rest of day spent with individual team, Guide, and other Track project teams	Planning and Establishing Targets (weeks 1-3) Project plan / schedule including specific deliverables and due dates. Detailed, quantitative target specifications mapped to customer needs	
2	**PROJECT PLANNING (PHASE 0)** *Workshop*: Translating Needs to Specifications, 9:00 - 10:00 am: BIOENGINEERING, AEROSPACE, SYSTEMS, and IMAGING Tracks, 10:00 - 11:00 am: VEHICLES and SUSTAINABILITY Tracks *Tutorial*: EDGE website, 1:00 – 2:00 pm, Recommend that two team members attend (those editing and updating web content) *Breakout:* Rest of day with individual team, Guide, and other Track project teams	See week 1 for information	MSD I Schedule (3% of MSD I Grade)
3	**CONCEPT DEVELOPMENT (PHASE 1)** *Workshop*: Functional Decomposition and Concept Generation, 10:00 am – 12:00 pm *Morning Breakout*: Review engineering specs within your track with Guide, 9:00 – 10:00 am *Breakout:* Rest of day with individual team, Guide, and other Track project teams	See week 1 for information	Customer Needs (3% of MSD I Grade) and Specifications (3% of MSD I Grade)
4	**CONCEPT DEVELOPMENT (PHASE 1)** *Workshop*: Concept Generation and Selection, , 10:00 am – 11:00 am *Seminar:* Preparation for Concept Reviews, 11:00 - 11:30 am *Morning Breakout*: Review concepts generated and critical sub-functions within your track with Guide, 9:00 – 10:00 am *Advanced Tutorial*: EDGE & Wiki, 12:00 – 1:00 pm, Follow-up to the first tutorial for those interested *Seminar*: Drive Circuits for Output Devices *Breakout:* Rest of day with individual team, Guide, and other Track project teams	Customer Feedback Develop multiple concepts (on paper) and select most feasible. Update specifications	
5	**CONCEPT DEVELOPMENT (PHASE 1)** ***Concept Reviews*** *Entrepreneurship Conference*: http://entconf.cob.rit.edu/	Concept Review System design including architecture, sub-system definition, interface definition, and more detailed specifications. Appropriate engineering analysis including hand calculations and simulation / modeling. Determine greatest challenges / risks to project.	Concept Review (30% of MSD I Grade)

Week No.	Design Phase & Programmed Course Activities	Anticipated Progress by Student Teams	Deliverables
6	**SYSTEM LEVEL DESIGN (PHASE 2)** *Seminar:* Noise Immunity Techniques, 10:00 - 10:50 am *Seminar:* Embedded Linux and Software Development, 11:00 - 11:50 am *Seminar:* Preparation for Design Reviews, 2:00 - 3:00 pm *Breakout:* Entire day with individual team, Guide, and other Track project teams	<u>Proof of Concept (weeks 6-7)</u> Proof of concept breadboard, brass board, or simulation of high risk technologies defined in week 5. Use appropriate discipline specific methods to demonstrate confidence in selected architecture / design approach. Risk assessment for technology / cost / schedule.	
7	**SYSTEM LEVEL DESIGN (PHASE 2)** *Seminar:* How to prepare a drawing package *Seminar:* Analog to Digital Conversion, 11:00 - 11:50am *Breakout:* Entire day with individual team, Guide, and other Track project teams	See week 6 for information	
8	**SYSTEM LEVEL DESIGN (PHASE 2)** *Seminar:* Preparation for Project Reviews, 2:00 - 3:00 pm *Seminar:* Harnesses, connectors, test points, LEDs, 9:00 - 9:50 am *Seminar:* PCB Layout application and Surface Mount Tour, BIOENGINEERING and AEROSPACE Tracks, 10:00 - 10:50 am *Seminar:* PCB Layout application and Surface Mount Tour, VEHICLES and SYSTEMS Tracks, 11:00 - 11:50 am *Seminar:* Fatigue analysis, 2:00 - 2:50 pm *Seminar:* Linux overview, 3:00 - 3:50 pm	<u>Detailed Design to Meet Customer Needs (weeks 8-9)</u> Detailed design to meet all customer needs. All long lead items should be identified for ordering.	
9	**SYSTEM LEVEL DESIGN (PHASE 2)** *Technical Design Reviews*	See week 8 for information	Design Review (30% of MSD I Grade)
10	**DETAILED DESIGN (PHASE 3)** *Project Reviews*	<u>Detailed Test Plan and MSD II Project Plan</u> Detailed test plan with linkage to engineering specifications and customer needs. The results of this plan should demonstrate the design meets all customer needs and translated engineering specifications (both high level specifications and cascaded sub-system specifications). Develop project plan for MSD II.	Preliminary Test Plan (3%), MSD II Schedule (3%), and Mid Project Review (10%)
11	*Focus Groups:* Informal Feedback Opportunity, 12:30 - 1:30 pm, Provide supplemental feedback to the online survey		