AC 2007-343: DEVELOPMENT AND IMPLEMENTATION OF A JUNIOR-YEAR DESIGN COURSE IN A MULTIDISCIPLINARY ENVIRONMENT ALONG WITH MEDIA ART AND MARKETING

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Development and Implementation of a Junior-Year Design Course in an Interdisciplinary Environment Along with Media Art and Marketing

1. Background

Contemporary thought in engineering education is to provide the students with as much hands-on, real world experience as possible. Students are expected to hit the ground running in the work force immediately after their graduation and be savvy in many divergent skills such as teamwork, communication, project, people and business management. ABET (Accreditation Board of Engineering and Technology) has included the multidisciplinary team experience as one of the assessable outcomes for students enrolled in any accredited engineering program. Social commentators [e.g.¹⁾] have highlighted the need for businesses to succeed in a global environment and as such the education system must attempt to create engineers with global perspectives. There are several solutions to achieve this objective such as internships, co-op programs, student exchange programs, laboratory-intensive classes and the ever-popular Capstone Senior Design Project. This last and the most important topic of integrated design has been reviewed^{2,3)} and discussed extensively in literature and engineering education conferences. There is considerable variability in the scope; breadth and depth of these capstone projects, the team size and composition and the time, and sponsors and budget for the projects. Some of these projects are fairly involved requiring budgets of up to \$40,000⁴⁾ while some projects require graduate students as an integral part of the design team⁵⁾. One common theme in most of these projects is that the courses are designed for senior students enrolled mainly in engineering and other disciplines ⁶⁻⁹. While these projects are multidisciplinary, synchronization of course syllabi across the disciplines was not made.

In the above context, the Interdisciplinary Design Studies (IDS) project undertaken at Robert Morris University (RMU) in the spring of 2006 was a unique experiment by virtue of two features: Firstly, because the course was offered for mainly junior (along with some sophomore) students and not for senior or graduate students as is usually the case. The second novel feature of IDS project is that it involved *concurrent delivery* of three junior level courses where the *course content of all three courses was synchronized*. The courses involved in this project were ENGR 3650: Product and Tool Design (Engineering Dept.), ARTM 3307: 3D Computer Modeling Workshop (Media Art Dept.) and MARK 3700: Marketing Research (Marketing Dept.). The course content of all three courses was modified as required and the order of delivery of the topics was altered so that the students obtained a complimentary set of skills to work on their product development project as a team. The student teams containing one or more representatives from all three disciplines developed a product concept for consumer market based on some specified design guidelines, criteria and constraints. Art students contributed to the aesthetic appearance of the products and created sketches and 3D models for different product concepts. The competing concepts were tested by the marketing students in the field and gave feedback to the team. The engineering students then manufactured a prototype for the selected concept. The teams wrote a detailed project report and made oral presentation as a part of their project deliverables.

This paper discusses the challenges faced by both the faculty and students in working in an interdisciplinary environment and highlights the significant benefits from the course implementation. The effectiveness of the course delivery is presented in terms of student feedback, student performance in the course, and Criterion 3 and track-specific ABET outcomes assessment. Suggestions for future course improvements are also included.

2. Course Organization and Concurrent Syllabi

Course contents of engineering, art and marketing courses were substantially synchronized so that the students acquired complementary skills to better prepare them for their major design project. The master schedule for the concurrent syllabi developed and delivered for the Spring 2006 term is given in Table 1. The instructors were: Profs. Priya Manohar (ENGR 3650), Cathi Jones (MARK 3700), and Jon Radermacher (ARTM 3307)

Date	ENGR 3650	ARTM 3307	MARK 3700
Pre-term	Email students and inform them of three scheduled group meetings outside of class in order to avoid conflicts.		
Week 1	Introduce project, the benefits & the expectations. Make groups, gather contact info, submit list to Mark Faculty	Introduce project, its benefits, & the expectations. Make groups, gather contact info, submit list to Mark faculty. Design sketches assigned.	Tour of Engineering area Develop list of questions for Engr / Art students (client).
Week 2	Develop Gantt chart. Discuss product designs, their viability; narrow down to 2-3 ideas.	Discuss product designs, their viability; narrow down to 2-3 ideas.	Meeting #1 (6:00 p.m 30+ mins) with student groups to discuss and select one viable product concept.
Week 3	Understand product function. Research manufacturer websites for current production methods.	Potential guest speaker from CMU Product Design program or Ferris Crane from Media Art faculty.	Outlines of problem definition, hypotheses and research design due. Sample concept description and test due. Send concept description and test results to Engr / Art students.
Week 4	Conduct product teardown analysis. Engr / Art groups share refined design ideas and draft a description for Marketing students.	Engr / Art groups share refined design ideas and contribute input to concept description from Marketing students.	Meeting #2 Finalize the concept, verbiage and visual sketch. Problem definition, hypotheses and research design due. Concept description, sampling plan & test due. Pretest completed.

Table 1. Concurrent Syllabi for the Interdisciplinary Design Study Project.

Date	ENGR 3650	ARTM 3307	MARK 3700
Week 4	Conduct product teardown analysis. Engr / Art groups share refined design ideas and draft a description for Marketing students.	Engr / Art groups share refined design ideas and contribute input to concept description from Marketing students.	Meeting #2 Finalize the concept, verbiage and visual sketch. Problem definition, hypotheses and research design due. Concept description, sampling plan & test due. Pretest completed.
Week 5	Conduct preliminary design analysis. Bench marking / discern best-in- class product.		Revised outline of sampling plan due. Outline of analysis plan due
Week 6	Develop plans for prototype manufacturing. Develop Bill of Materials.		Project work.
Week 7	Research on manufacturing processes.		Data collection completed. Outline of data collection and analysis of results due.
Week 8	Design for manufacturing and design for assembly.	Art students submit final sketches / models to Marketing students to use as visuals in presentations	Supplemental meeting between ARTM and MARK students (6:00 pm. – 30 minutes, share visuals) Outline of interpretation of results, conclusions and recommendations due. Finalize visuals for the presentation.
Week 9	Considerations for the required tooling.		Meeting #3 (6:00 p.m. – 160 mins) Present research findings to Engr / Art students (client).
Week 10	Finalize preliminary design.		
Week 11	Manufacture functional prototype.		
Week 12	Work on final report.		
Week 13	Work on final report and presentations.	Engr / Art groups share graphic layout ideas for Engr final presentations.	
Week 14	Final presentations.		Students are invited to attend Engr presentations.

Table 1. Concurrent Syllabi for the Interdisciplinary Design Study Project (contd.).

Notes:

• Group members are required to attend the meetings unless they are registered for a RMU course that meets at the same time.

• All participating students are encouraged to converse and/or develop the project outside of class in person or via email.

3. Term Project Specifications

The details of the interdisciplinary term project as specified are given below.

Purpose: The purpose of the project is to give the students a hands-on opportunity to implement the ideas and techniques they learn in the class to design and develop a consumer product. The project is the major lab component of the course and worth 30% of the final grade.

Objectives: The objectives are to design a functional tool or a consumer product and subsequently manufacture a look-alike or work-alike prototype of it. Students are expected to keep a systematic record or logbook of all the activities. A tool can be a kitchen, gardening, wood or metal working tool. A consumer product may be a table lamp, broom, trashcan, a musical instrument, a toy etc. A detailed project report is to be written and a presentation is to be made based on the project work at the end of the term.

Background: The course is delivered with an interdisciplinary approach. Engineering students will form groups with students enrolled in Media Art (ARTM 3307 course) and Marketing (MARK 3700 course) departments. A typical group will consist of 2 - 3 engineering students, 1 - 2 art student(s) and 5 - 7 marketing students, for total 8 - 12 students per group. Each group is responsible for developing appropriate channels for communication, both on and off campus, with their team members e.g. e-mail and phones, face-to-face meetings.

Procedure: Engineering and Art students, in consultation with their marketing student colleagues, will develop ideas for new product(s). Marketing students will test these ideas to find out if the products have the potential to be successful in a market place. The first four weeks of the term are devoted by the engineering and art students to generating concepts and selecting 2-3 ideas for marketing students to work with. Marketing students will subsequently continue their work on the selected ideas in Weeks #4 - 8, and make final presentations based on their work in Week #9. While marketing students are conducting their field testing, engineering students work on other product development aspects such as benchmarking, subtract and operate procedure, plan for manufacturing, and development of bill of materials. Art students work on refining sketches as the ideas emerge and take more concrete shape. Engineering and art students will assist in developing the marketing presentation (if needed) and attend the final presentation by their marketing team members. The presentations made by the marketing students represent an opportunity for all students to learn about the marketability of their proposed designs. Engineering and art students are expected to attend team meetings listed in weeks #2, #4, and #8 while marketing and art students attend the final presentation by engineering students in week #14.

Design Guidelines: The guidelines for designing a product or a tool are as follows:

- The chosen product / tool must perform a useful task or a function
- Product retails under \$20.00, prototype manufacturing cost less than \$100
- Be benchmarkable, which means that there are similar commercially-made products available for comparison
- Maintain minimum standards for comfortable use (ergonomics) and safety
- Choose appropriate materials and processes with a view to maximize energy conservation, minimize environmental impact and facilitate sustainable development *via* recycling / reuse.
- Prototype must *look and feel* as much like the final design as possible
- Have some special characteristic(s) that will make your product competitive in the marketplace e.g. added functionality, lower cost, pleasing appearance, lightweight and so on.

4. Course Implementation

Student enrollment numbers in the three courses presented some logistical issues. After some discussions, it was decided to compose the product development teams as follows: each team would consist of three engineering and one art student. This set of four students was attached to *two* marketing teams, each with 4 – 6 students. The engineering + art team was charged with the responsibility of coming up with several product development ideas, which they presented to the marketing teams. The marketing teams selected two or more of these ideas per team for further exploration. Subsequently, each marketing team narrowed down their choice to one idea that they studied in detail. They conducted marketing survey and data analysis for this product idea and presented their results to the entire student body, faculty and outside marketing experts at the midterm. Each engineering + art core group chose one of these ideas and continued with further product realization process including design for manufacturing and assembly. Finally, the engineering students manufacture a proof-of-concept, look-alike, work-alike or comprehensive prototype as shown in Figure 1.



(a)



(b)

Figure 1: Two examples of the artistic visualizations of the products redesigned and manufactured by the students: (a) ice scraper, (b) tri-head, toothpaste-dispensing toothbrush.

The entire product development process ended for engineering students with a detailed design report and an oral presentation for the entire student body (show and tell session) at the end of the term. The intense work schedule kept students quite engaged with this project throughout the term and they found multidisciplinary experience to be interesting and enriching. The following section demonstrates several measures of effectiveness of the interdisciplinary approach.

5. Effectiveness of the Multidisciplinary Approach

The multidisciplinary approach was implemented at Robert Morris University during the Spring 06 term, and the achieved results were compared with those of the Spring 05 term. Several criteria were employed to determine the effectiveness of the new approach as presented in the following sub-sections.

5.1 Sample Evaluation Questions

The student evaluation was based on various tools such as assignments, presentations, mid-terms exams and project work. Some sample questions / tasks and their corresponding applicable ABET criterion are presented in Table 2.

Applicable ABET Criterion	Assessment Task	
#1 an ability to apply knowledge of mathematics, science and engineering	Estimate the production cost (manufacturing + overhead) for a simple product such as a floppy disk, ball-point pen, jackknife, or a baby's toy. The product will typically have less than 10 components. Remember that the upper bound for your estimate is $50 - 70\%$ of the retail price.	
#2: an ability to design and conduct experiments, as well as to analyze and interpret data	Plan for Subtract and Operate (SOP) procedure and teardown analysis Which features / properties will be tested? Methods of testing? Tools needed? How much accuracy / precision is required?	
#3: an ability to design a system, component or process to meet desired needs	Identify customer needs for the product you have chosen to redesign. Employ interview template provided in lecture notes. Determine importance rating for each need.	
#4: an ability to function on multidisciplinary teams	Multidisciplinary term project – details are provided in section in this paper	
#5: an ability to identify, formulate, and solve engineering problems	A manufacturing company plans to enter the market for school bags. Assume that the school bags are currently sold in the market at a rate of 1,000,000/year. Assume that the manufacturing company has hired a single distributor who would account for 30% of the total sales of the school bags. The company would like to estimate the quantity to manufacture (Q) per year given that their customer survey has resulted in the following data: $C_{definitely} = 0.4$, $C_{probably} = 0.2$, $F_{definitely} = 0.4$, $F_{probably} = 0.3$	

Table 2: Examples of student evaluation tasks in the context of applicable ABET criteria.

Applicable ABET Criterion	Assessment Task
#6: An understanding of professional and ethical responsibilities	Conduct information search for the manufacturer who makes the product you selected for benchmarking. Find out as much information as you can about the manufacturer regarding: company mission and vision, history, information about product, features, materials, company, manufacturing locations, problems, customers, market share, vendors; statistics on employment, payroll, inventories, capital expenditures, manufacturing costs, financial status, other products made by this company. <i>Information search must be conducted by</i> <i>employing only the ethical means as discussed in the class.</i> Summarize the information and include it in the assignment solution.
#7: an ability to communicate effectively	Progress report and presentation, final report and presentation
#10: A knowledge of contemporary issues	What are the main differences between benchmarking based on product metrics and benchmarking based on perceived customer satisfaction?
11: an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Use of CNC machines, rapid prototyping, hot Isostatic press, machine shop, AutoCAD, SolidWorks etc. to design and manufacture their prototype.

Table 2: Examples of student evaluation tasks in the context of applicable ABET criteria

Up to 70% of the student assessment tasks shown in Table 2 were identical to those from the previous year. The main difference this year was the introduction of the multidisciplinary nature of the term project. Thus, the differences in student performance depicted in Figs. 1 and 3 are mainly due to the multidisciplinary nature of teaching. Effort was not made in this study to collect statistics on learning effectiveness.

5.2 Student Performance



The engineering student performance in the Spring 05 and 06 terms is shown in Figure 1.

Figure 1: Student final grade distribution for ENGR 3650, Spring 05 and Spring 06 terms.

It is evident from Figure 1 that the students performed well during the Spring 06 term. In particular, the student performance in 'A' grade is significantly better than the Spring 05 term.

5.3 ABET Criterion 3 Outcomes Assessment

The relative amount of effort spent on evaluating these outcomes is shown in Figure 2. The quantity plotted on Y axis is not a measure of the outcomes assessment; it is a measure of how evenly the outcomes assessment effort is spread out across the board.



Figure 2: Relative amount of assessment effort spent on assessing applicable ABET outcomes in Spring 05 and Spring 06 terms.

It can be seen from Figure 2 that a heavy emphasis was placed on assessing ABET outcome 3, 7 and 11 (an ability to design a system, component or process to meet desired needs, an ability to communicate effectively, and an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice) in both terms. While this is both natural and appropriate for the body of knowledge being taught, the remaining applicable outcomes were not assessed well in Spring 05. In particular, Outcome 4 (an ability to function on multidisciplinary teams) was not addressed in Spring 05 term. On the other hand, during the Spring 06 term, the multidisciplinary approach and the attention given to the design of the assessment tasks has resulted in a more uniform distribution of the effort spent in assessing different ABET outcomes.

The student performance for the Spring 05 and 06 terms in terms of ABET outcomes assessment is shown in Figure 3.



Figure 3: Class performance with respect to ABET outcomes. (The current RMUdesignated benchmark for class performance is: 80% of the class scores >= 80% in the outcomes assessment for each of the applicable ABET criteria).

This chart demonstrates that the RMU-benchmark is met for all applicable ABET outcomes criteria for Spring 06 term including Outcome 4, which was not assessed in Spring 05 term.

5.4 ABET Track-Specific Outcomes Assessment

According to the existing course description, the following ABET *track-specific* outcomes are applicable for this course:

• *Outcome M1*: Proficiency in materials and manufacturing processes, understand the influence of manufacturing processes on the behavior and properties of materials

- *Outcome M2*: Proficiency in process, assembly, and product engineering and understand the design of products and the equipment, tooling, and environment necessary for their manufacture
- *Outcome M3*: Appreciate the necessity for manufacturing competitiveness and understand how to create competitive advantage through manufacturing planning, strategy, and control

The student performance for the Spring 05 and 06 terms in terms of ABET Track-Specific outcomes assessment is shown in Figure 4.



Figure 4: Class performance with respect to ABET track-specific outcomes. (The current RMU-designated benchmark for class performance is: 80% of the class scores >= 80% in the outcomes assessment for each of the applicable ABET track-specific criteria).

This chart demonstrates that the RMU-benchmark is met for all applicable track-specific ABET outcomes for both Spring 05 and 06 terms.

5.5 Student Instructional Report Results

Finally, the end-of-term student satisfaction survey was conducted using *Student Instructional Report II* (SIR II). In the present case, the number of student that participated in the survey was twelve. The survey is analyzed and a third party issues reports based on the survey data. These data given in Table 3 clearly shows that the students felt that they learned more and their interest level and knowledge increased significantly at the end of Spring 06 term.

Item	Spring 06
Course Organization and Planning	4.62
Faculty / Student Interaction	4.38
Effectiveness of Student Assessment Tasks	4.58
Course Outcomes (interest, learning, knowledge)	3.94
Use of Supplementary Teaching Tools	Very Effective
Overall Evaluation	4.30

Table 3: Selected survey items from SIR II report for Spring 06 terms.

5.6 Student Feedback

A student survey tool was designed by the Marketing faculty and approved by the Internal Review Board (IRB). The following is a sample of the comments written by the students on the survey:

Engineering:

- It was a complete hands-on experience through thorough design process application
- Too little interaction with marketing, too much with art
- Communication with marketing was poor
- Need to better facilitate group interactions overlap class times
- Exciting to see a product designed, researched and built!
- Never knew working in teams could be tough!

Art:

- Prototypes were built from an engineering, not design, perspective
- They did not give us credit for art work
- I now understand and respect the amount of hard work that goes in product design
- Adjust timeline we weren't on the same page!
- Had a tough time communicating "Hi, Have we met?!"
- Team roles and individual's role not very clear

Marketing:

- Feedback on our presentations from marketing professionals was valuable
- Needs better communication with team members
- Too much workload due to multidisciplinary project!
- Learned how to collect and analyze data for a real project
- Things are too rushed to be able to complete the market research project in eight weeks!
- Loved the idea of formal presentations

5.7 Challenges for the Faculty

The faculty needed to deal effectively with various issues that arose during the term. First and foremost was to organize and monitor the joint student meetings. Engineering and Art students were required to attend these meetings outside of their scheduled class hours, and this was an unpopular aspect of the project. Secondly, they needed to engage in note taking, a rapidly disappearing art, during team discussions so that students had a record of what was being discussed and decided. There was also an issue raised by marketing students as to the final choice of the product selected for making the prototype. This decision was made entirely by the engineering students depending on the feedback they received from the marketing group and also based on the what they felt they could manufacture within the given time constraints. Marketing and Art students, therefore, felt left out of this decision making process. Another challenge was that the faculty had to redesign the course content and modify the order of delivery of the topics so that the different skills and knowledge needed for product development are well synchronized.

6. Summary

An Interdisciplinary Design Studies project was implemented for juniors enrolled at Robert Morris University during the Spring 06 term. Students drawn from Engineering, Media Art and Marketing worked together as a team to create ideas for consumer products that not only satisfy the given design criteria and constraints, but also have a fair chance of being commercially successful. The students seemed to enjoy the learning opportunities that this course offered such as working in Interdisciplinary teams, following through a complete design process, interacting with industry professionals and the hands-on experience. On the other hand, perhaps not surprisingly, the students realized that the main bottlenecks in their way were time and project management, teamwork and communication. Notwithstanding these issues, the student performances in terms of course grades and ABET outcomes assessment has improved significantly in the IDS project. The IDS project approach has helped identify activities that are working well to enhance student understanding of the subject matter, enrich their learning experience, and to identify areas for further improvement.

7. Suggestions for Future Improvements

Based on the student feedback and the faculty experience, the following suggestions are made to improve the effectiveness of course delivery in future:

- Interdisciplinary interaction could be improved via appropriate scheduling of the classes to facilitate time overlap, improving communication, and adding a lecture on team work and leadership
- Assign a 'product champion', so that some individual is able to take overall responsibility of the project progress and there is accountability and ownership
- Redesign art course syllabus so that art students are able to participate with marketing and engineering students throughout the term

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