# AC 2007-2697: EFFECTIVELY IMPLEMENTING THE INTERDISCIPLINARY SENIOR DESIGN EXPERIENCE: A CASE STUDY AND CONCLUSIONS

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# Effectively Implementing the Interdisciplinary Senior Design Experience: A Case Study and Conclusions


## Abstract

Providing an interdisciplinary capstone design experience in the senior year is an effective approach to address industry needs and the requirements of ABET Criterion 3d ("… an ability to function on multi-disciplinary teams.") Additionally, interdisciplinary senior design allows a rich set of project deliverables and thus enhances possibilities for funded or mission-driven projects such as overseas infrastructure relief. The breadth of deliverables made possible by interdisciplinary senior design also facilitates institutional goals regarding faculty development and scholarship by enhancing undergraduate research possibilities. However, numerous obstacles to interdisciplinary design can prevent an effective implementation and the associated benefits. In this paper we outline a set of tactics for implementing an effective interdisciplinary senior design experience. Since these tactics are derived from our own successes and failures, our experiences illustrate the tactics as a case study. Our goal as a general engineering program offering a B.S. in Engineering with concentrations in Electrical, Mechanical, Computer, Biomedical, and Materials Joining, is to involve every student in an interdisciplinary design experience with two or more concentrations.

We have identified seven key elements that we believe must be coordinated across disciplines in order to conduct an effective interdisciplinary senior design experience for all students. (1) *Faculty roles* must be defined, assigned, and appropriately credited. This may be handled by someone in a leadership position such as a dean or chairman initiating (and possibly maintaining) a senior design committee populated by the faculty teaching and supervising senior design teams. (2) *Design projects* must be identified, defined, and selected according to a set of criteria agreed-upon by the faculty involved. Project diversity may be vast, including for example: externally funded research, industry projects, international humanitarian projects, and student design competitions. Such projects can vary widely according to institutional motivations, stakeholder characteristics, and required deliverables. Project selection criteria may include fulfilling institutional objectives, matching available student disciplines with project needs, and fulfilling educational objectives. (3) *Student teams* should be formed in a way that acknowledges individual student motivations and preferences (although there is some debate on the importance of this point). Team members must also represent the academic disciplines needed for a project and satisfy the requirements of individual faculty supervisors for student capabilities. (4) *Resources* must be allocated among teams and faculty including funding, team facility space, and lab access. This may require external fundraising for teams with large budget needs. (5) A *design class structure* must be created to deliver content and organize the design experience with compatibility for each academic discipline. (6) A c*ommon design process* must be agreed upon for the projects that is broad enough to accommodate the diversity of projects and yet specific enough to provide guidance and accountability to individual teams and faculty supervisors. Finally, (7) *project assessment* criteria and procedures must be agreed upon by the involved faculty for equitable evaluation of teams and individual team members. Our tactics for each of these key elements and results will be discussed.

# 1 Introduction and Background

## 1.1 Introduction

Student involvement in interdisciplinary teams is not only an expectation of industry but also has become a required outcome of the ABET engineering criteria. ABET criteria now include outcome 3d which states that "engineering programs must demonstrate that their students attain …an ability to function on multi-disciplinary teams."[1] This requirement can be met in a number of ways, including a structured simulated experience or by an actual capstone project that requires the involvement of several disciplines.

Our university offers a bachelor of science degree in engineering (general engineering) with concentrations in biomedical (BME), computer (CE), electrical (EE), mechanical (ME), and materials joining engineering (MJE). Much of the curriculum is interdisciplinary. All engineers take core courses including Statics, Dynamics, Circuits, Mechatronics, and Thermodynamics. Design projects have been included in several of these courses. In parallel, the Department of Engineering Technology offers a bachelor of science degree in engineering technology, with concentrations in electrical (EET), mechanical (MET), and materials joining engineering technology (MJET).

## 1.2 Background

An emphasis on design projects (Appendix A) is a historical strength of our school of engineering, and has been developed especially well in the last 10 to 15 years as senior design projects have become more ambitious and have also expanded to include significant applied research projects. In addition, underclass courses have also embraced the project experience to a large degree. We view this project orientation as a significant strength, defining our programs and providing a distinct educational advantage for our students.

Senior design initially consisted of one-semester individual projects. These were changed to team projects in (1992) and, at the recommendation of an ABET visiting team, to two-semester team projects in (1997/98 school year.)

Our first fully interdisciplinary projects were begun in (2001/02) as electrical and mechanical students worked together on an EMG-driven artificial arm prosthetic project, and electrical and mechanical students worked on an SAE Formula racecar. (Mechanical students designed the chassis and mechanical systems, while electrical students developed the instrumentation and dashboard displays). In (2001/02) a team of electrical, mechanical, and computer engineering students, along with computer science students, developed a walking robot for the SAE competition, taking first place at the national competition.

During the period from 2001 to 2006 we offered three separate course tracks – EE Design (including CE students) I and II, ME Design I and II (including BME students), and MJE[i] Design I and II. The major interdisciplinary projects during this period are itemized in Table 1.

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[i] Formerly known as Welding Engineering (WE)

**Table 1: Major Interdisciplinary Projects From 2000/01-2005/06**

1. The Phoenix Project – autonomous navigation and flight by a radio-controlled helicopter (EE, ME, CE)
2. Artificial Arm – a powered prosthetic with artificial muscles controlled by EMG signals (BME, ME, EE, CE)
3. Formula SAE – Formula-style racecar for the annual SAE competition (ME, EE)
4. L.E.G.S. (LeTourneau Engineering for Global Solutions) – an inexpensive prosthetic leg for manufacture in developing countries (BME, ME, MJE)
5. Walking Robot – an SAE competition walking robot to autonomously seek a light beacon while navigating an obstacle course (EE, ME, CE, CS)

All senior engineering students began meeting together once a week for most of the spring semester in (2003) in a seminar format to discuss issues of engineering ethics, standards, and professionalism.

It became apparent that students were not uniformly prepared for senior design, so in response we implemented a major curriculum enhancement in 2006-2007 to build upon the existing project-emphasis strength and further improve engineering design projects. The changes required no new faculty resources and did not change the credit hour requirements of any degree plans. This curriculum change to enhance interdisciplinary design throughout the curriculum involves the following items:

1. Specific preparation for design in the Fundamentals of Engineering design course, taken by all program freshmen
2. Specific design experiences in selected core courses and upper level concentration courses
3. Sophomore and senior level design seminars
4. Junior level apprenticeship on senior design projects

Beginning in the 2005-2006 school year, a number of disadvantages to the senior design course began to surface:

1. Each faculty member serving as a senior design course instructor had oversight of up to six projects, some interdisciplinary and some not.
2. Faculty project sponsors who monitored project progress were not always grading faculty.
3. Unless assigned to teach a design course, faculty project sponsors received no "official" time to work with project teams, and often met with teams several hours a week as an overload.
4. Students on interdisciplinary projects often reported to two different faculty members, each assigning a fraction of their grade.
5. Engineering technology students were utilized but not fully integrated into many of the project teams.

For these reasons, a common interdisciplinary senior design experience was implemented in 2006-2007. The curriculum changes described in this section are expected to lead to a higher quality senior design experience through improved student preparation throughout the curriculum, increased faculty supervision in senior design, and fully interdisciplinary projects. The rest of the paper details implementation of the interdisciplinary senior design experience.

### 1.3 Literature

Obstacles to interdisciplinary teamwork can include disciplinary competition, communication problems, and scheduling difficulties. Since interdisciplinary team dynamics can serve as a major roadblock to the success of interdisciplinary design teams, some authors have developed and deployed a set of curricular tools to enhance teamwork in this context[2,3]. These methods included (1) multiple and varied opportunities for projects in teams, (2) early involvement in senior project teams, (3) specific training for teamwork, (4) coursework in and application of project management techniques, and (5) the use of multiple items of feedback to determine the contribution of each team member. Similar curricular tools have been used in our interdisciplinary design curriculum for the 2006-07 school year.

Rover, et al.[4] identify a key need for their interdisciplinary design project (which involves electrical engineering, computer engineering, computer science, and systems engineering) is to arrive at a problem definition such that “students in different engineering disciplines have the necessary discipline-specific information and also understand the multidisciplinary aspects of the problem.” Two of the most important aspects of this are user scenarios and interface descriptions. The user viewpoint provides common ground for all disciplines involved, and the interface information provides a link between the sub-projects of each discipline. These principles extend beyond problem definition and highlight the importance of design documentation (communication) for successful interdisciplinary design.

Goff and Vernon[5] have experimented with interdisciplinary design early in the curriculum by combining engineering and industrial design students. The student teams conducted a variety of design projects with both functional and aesthetic goals using the LEGO Mindstorms kits as a design platform. The project was deemed successful, and the paper itemizes some of the implementation logistics along with sample projects.

Skokan et al.[6] reference the role of interdisciplinary design in enabling humanitarian design projects with needs that often transcend the boundaries a single discipline. In 2003 they implemented humanitarian projects in their institutions senior design courses in part to “to demonstrate the value and ingenuity that can be derived from cooperative design efforts among traditional engineering disciplines.” The humanitarian design projects chosen for the course must be open-ended and interdisciplinary and have included: “community water projects, curriculum help for rural and inner-city schools, building design and construction, and engineering solutions for economic expansion.”

As evidenced by the select articles discussed here, the scope of interdisciplinary design is perhaps even larger than the spectrum of design itself (if that were possible.) Numerous issues threaten to cripple interdisciplinary design if not properly recognized and addressed, such as adequate teamwork coaching or meta-disciplinary problem definition. Also shown here is that interdisciplinary design can and does occur virtually anywhere in the curriculum. This is illustrated by the example of a freshman-level introductory course using LEGO robotics as a design platform, contrasted with a capstone design course tackling international humanitarian design projects. In this paper we detail our tactics to address the seven key elements identified in order to enable the effective implementation of an interdisciplinary senior design experience for our students.

## 2 Faculty Role Definition

Faculty roles must be defined, assigned, and appropriately credited to facilitate an effective senior design experience. This was handled by the dean of engineering commissioning and maintaining a senior design committee populated by the faculty teaching and supervising senior design teams. Each faculty member involved with a senior design team, along with the engineering department chair and one additional faculty member familiar with design, became members of a design committee that met weekly throughout the fall semester. Responsibilities of the design committee are itemized in Table 2.

**Table 2: Responsibilities of Senior Design Faculty Committee Members**

1. Selection of the senior design projects
2. Assignment of students to teams (based on student preferences)
3. Selection of courses for embedded design projects
4. Oversight of design seminars
5. Development of assessment criteria and grading of mid-semester design reviews
6. Development of assessment criteria and grading of final presentations

In the past faculty involved in Senior Design fell into one of two categories: "course instructor" or "project sponsor." Three separate discipline-specific design courses were each overseen by a faculty member from that discipline serving as a course instructor. This faculty member was regarded as the instructor of the course and was responsible for teaching a range of design topics relevant to the particular discipline, coordination of students from that discipline, and grading of all students within that design course, regardless of which project they were involved in.

The other faculty role was that of "project sponsor." The project sponsor was a faculty member nominally associated with a given project team. The loosely defined role of the project sponsor primarily consisted of providing relevant technical assistance either upon request of the students involved or where the faculty member saw a need to offer such advice. While the project sponsor was associated with a particular project rather than a discipline, for most teams the obligation of students to follow the advice of the sponsor was rather limited. The control of the project sponsor over the direction of a project and its associated activities was not explicitly outlined, and thus the role of the sponsor tended to be more nominal than directional.

In revising the structure of the Senior Design course, there was seen to be a need to more directly tie faculty members to specific projects and thus the previous "course instructor" and "project sponsor" roles were eliminated in favor the new faculty role of "project director." Each multidisciplinary project team is now assigned a project director, who is an instructor for one section of senior design. As the name implies, the role of the faculty director is to direct the project and each director now maintains ultimate control of their particular project. The director serves as the instructor of the course section allocated for their project, determines overall project direction, ensures students attain necessary technical competencies, and determines grading criteria and ultimate grade allocation. The project director has the ability to decide what the project will address, student roles on the team, and budgetary issues. The director also has the ability to impose stop points on the project, halting further project progress until necessary competency or quality in previous work has been achieved. In return for these responsibilities, each faculty director receives either 3-hours of teaching credit for both Fall and Spring semesters (for supervising large teams), or a 3-hour credit for one semester (for supervising small teams).

The increased control of the faculty director over their specific project is seen to have many positive benefits. First, the faculty member is now in a better position to control and direct the educational aspect of project work. The faculty member can now ensure that technical competency in important areas is actually attained through the project process by directing the areas to be addressed and controlling progress until sufficient progress is made. The student is also in a better position to learn and to benefit from the greater engineering experience of their director. The director can now help prevent inexperienced decisions which would be catastrophic to overall project outcomes, while still providing sufficient opportunities for students to learn and develop their experience by self-direction in less critical areas. As student skills are increased, greater responsibility in decision making can be passed to the student while the project director's oversight provides a safety net.

The second major benefit of the altered faculty role is an improved quality in project outcomes. As the student learning experience improves, their ability to perform technically also improves with a corresponding improvement in project outcomes. Better control of project scope creates more realistic expectations of what the student should achieve and helps ensure that students are able to focus better on their allocated workload.

## 3 Design Projects

Design projects must be identified, defined, and selected according to a set of criteria agreed-upon by the faculty involved. Project diversity may be vast, including, for example: externally funded research, industry projects, international humanitarian projects, and student competitions. Such projects can vary widely according to institutional motivations, stakeholder characteristics, and required deliverables. Project selection criteria may include fulfilling institutional objectives, matching available student disciplines with project needs, and fulfilling educational objectives.

The faculty agreed that projects available for senior design would come from four sources:

1. Intercollegiate competitions, particularly SAE
2. Funded research projects needing design development
3. Industry projects
4. Humanitarian/service projects

Our senior design faculty selected ten design projects for the current year based upon the following guidelines:

- Every project must be approved by faculty members as being reasonable in scope and appropriate in level of difficulty.
- Every project should be interdisciplinary, involving students from more than one concentration.
- Every project must have a faculty director to whom the students present progress and results.
- Appropriate numbers of students for each project from various disciplines must be agreed upon by the faculty.
- Results of every project must be demonstrated and shown to work completely by the end of the second semester.

Current (2006-07) design projects include:

- **ACL (BME, ME)** - quantify the effect of ACL injury in the human knee using a programmable test mechanism and an electronic controller designed by the team.
- **AISC (MJE, EE)** - increase the quality and reliability of drawn-arc stud welds made through galvanized decking onto coated steels.
- **AMI – Accessible Medical Instrumentation (EE, CE, BME)** - design and build an affordable vital signs monitor that is appropriate for home use and is accessible for persons with vision, hearing, or motor skills impairment.
- **Coil Design (MJE, EE)** - efficiently produce coil-end butt welds on advanced high strength metals.
- **I-TEC Powered Parachute (ME, MT)** - design and fabricate a durable aerodynamic mast system to shorten takeoff distances for powered parachute flights, specifically for use by indigenous peoples served by Indigenous People's Technology and Education Center.
- **L.E.G.S. - LeTourneau Engineering for Global Solutions (BME, ME)** - design and test a culturally appropriate, durable and affordable lower limb prosthesis for use in developing nations.
- **LIRA - LeTourneau Robotic Arm (EE, ME, CE)** - design a new electrical joint capable of infinite rotation and to incorporate this joint into a full-scale industrial robot.
- **SAE Aero Design (ME, MT)** - design and build a high-lift radio-controlled airplane to compete in the SAE Aero Design competition.
- **SAE Formula Car (ME, EE, MT)** - design and build a formula style racecar to compete in the SAE Formula competition.
- **SAE Mini-Baja (ME, MT)** - design, build, and test two off-road Baja vehicles to compete in the SAE Mini Baja competitions.

## 4 Student Teams

Assigning student team members in this interdisciplinary project environment requires the consideration of:

1) Student motivations and preferences,
2) The number of students in each academic discipline needed for the projects, and
3) The skills (level of ability) needed within each discipline.

While items (2) and (3) are primarily determined during the identification and selection of design projects (described in the previous section), this information must be brought forward to the assignment of team members and integrated into this step.

It is believed that allowing students to work in an area of personal interest is very important, but perhaps not essential, to having successful teams. Senior design teams typically require much more work than normally required for the 3 semester credit hours awarded for each of the two semesters. It is not unusual for the student team members who are leading (officially or unofficially) to average 20 to 30 hours or more per week of work outside of class time on a senior design project. It is difficult for a student to motivate themselves to work at this level of commitment if they do not have an inherent interest in the project and a true desire to see it succeed.

On the first day of class, the faculty directors of each project present a brief description (typically PowerPoint and about 5 minutes long) of their project. This presentation is essentially a recruiting presentation by each faculty member to attract quality students to their projects. The students are also given a written document with a two to three sentence description of each project. Any special requirements, such as fundraising, student travel costs, or the necessity to remain after graduation to complete the project (for some SAE competition projects) are clearly communicated to the students. After the projects are described the students are given a simple form on which they can specify their preferences for project participation. The students indicate their major, discipline, their top 3 choices for a project, and a description of any experience relevant to their preferred projects. These project preference forms are due at the beginning of the next class period.

The senior design faculty committee, composed of all of the project faculty directors, then meets to assign students to the various projects. The committee takes into account the three items mentioned above: 1) student preference, 2) project disciplinary needs, and 3) project skill needs. In addition to these three items, strong consideration is also given to prior participation on a project as a junior member. In the 2006-2007 academic year, 10 different project teams were formed with a total of 60 senior students. Approximately 75% of these students were assigned to the first choice of their project preference. Only one student was assigned to a team that was not one of their 3 top choices and this student was contacted first to make sure that the assignment was acceptable. All projects were able to receive the number of students needed from each discipline to meet the project requirements.

## 5 Resource Allocation

Resources needed for project completion fall primarily into the two areas of funding and space (facility and lab). Both of these needs vary greatly from one project to the next. The source of the resource also varies among projects.

From a funding standpoint, projects fall into three broad categories:

1) Projects requiring no significant funds,
2) Projects requiring funds - provided by an external funding agency (either industrial or research based), with fundraising primarily handled by the faculty director, and

3) Projects requiring funds – provided by donors (primarily competition based projects), with fundraising handled solely by the students.

Of the 10 senior design project during the 2006-07 academic year, one project is essentially in category (1), four projects are in category (2), four projects are in category (3), and one project is a combination of categories 2 and 3.

Projects requiring funds raised by students (in category 3) bring some interesting challenges, with individual project funding needs ranging from a few thousand dollars to approximately 25 thousand dollars. In recent years, the total dollar amount raised (and spent) by students has been over 75 thousand per year. The faculty director provides oversight for the expenditure of these funds, but the primarily responsibility for budgeting rests on the students. Students understand that when they indicate a preference for one of the category (3) projects, they are taking on the responsibility for raising the necessary funds for successful project completion. If sufficient funds are not raised, then the students' grades in the course will be adversely affected. Raising funds (selling their project) and budgeting with real money provides a very valuable learning experience for the students.

Space allocation is somewhat less complicated than project funding. The School has available seven rooms (from 10ft x12ft to 20ft x 20ft) dedicated to senior design project facility space and lab space is also utilized where appropriate. The projects for 2006-07 are housed in the following manner.

- Seven projects are housed in the dedicated senior project rooms. Two projects share one of the rooms, with one of the rooms remaining open.
- Three projects are housed in undergraduate teaching/research laboratories. These projects are all based on applied research projects that require the equipment in these labs.

Most (six) of the seven dedicated rooms are located within a "Machine Tool and Design Lab" building, which houses metal-working and welding equipment to facilitate project fabrication when needed. This facility is available to the students on a 24 hour, seven day a week basis. There is currently discussion on the possibility of shutting the facility down during early morning hours (perhaps 3am to 7am) to prevent students from working with potentially dangerous equipment when they are fatigued.

## 6 Design Class Structure Development

A design class structure must be created to deliver content and organize the design experience with compatibility for each academic discipline. We have structured our Senior Design course to include the advantages of both team-focused meetings and class-wide instruction. One course section is created for each design project, with the faculty director serving as the instructor of record and receiving teaching credit. Students enroll in the section corresponding to their assigned project. (In some cases two smaller "half-sized" projects are combined into one section in order to satisfy minimum enrollment requirements needed for a class to "make." In this case each project director receives half of the teaching credit.)

During the fall semester of the year-long senior design sequence (3 credit hours per semester), students enrolled in ENGR 4813 Senior Design also enroll in ENGR 4400 Senior Design

Seminar (see Appendix B for descriptions), which is a meeting of all students in senior design one day a week for the fall semester in order to cover material needed by every student. Students are required to attend this zero-credit, pass-fail, seminar as a graduation requirement. While no outside work is required from this seminar, to keep the students engaged, the faculty member who is presenting a given seminar may choose to give a pass-fail quiz at the end of the seminar to ensure students have captured the needed material. Students may have no more than two unexcused absences from this seminar. Teaching of this seminar is the responsibility of the senior design faculty committee (Table 2). Table 3 lists the topics typically covered in the Senior Design seminar.

**Table 3: Senior Design Seminar Topics**

- The Design Process
- Needs Analysis
- House of Quality
- Teamwork Principles
- Ethics and Standards
- Graduate School
- "Incident at Morales" (Ethics)

In addition to Senior Design Seminar, Senior Design students also meet with their faculty director at other regularly scheduled times for project updates, guidance, additional instruction, and team presentations. This time is completely controlled by the faculty director and can be used as needed to set forth project goals, receive updates, and monitor progress. During the spring semester, when projects are headed toward the finish line, no seminar is given and all class days are used at the discretion of the faculty director. Since several of our teams have 10 or more individuals and are multi-disciplinary, this time can be used to update the entire team as to the progress of individual sub-teams.

## 7 Common Design Process Definition

Common design process elements must be agreed upon that are broad enough to accommodate the diversity of projects and yet specific enough to provide guidance and accountability to teams and individual faculty directors. Each project has the educational objectives of senior design combined with unique project achievement objectives, such as winning an international design competition or providing engineered solutions to meet the needs of the poor. A danger to avoid is that project achievement can become so compelling that even faculty directors may loose sight of the long-range educational purposes of senior design and over-prioritize short-term achievement. In spite of the importance and urgency of accomplishing project achievements, a basic set of common deliverables must be fulfilled in order to satisfy both ABET and institutional criteria.

Defining a list of common deliverables basic and general enough to be agreed upon for all projects proved to be a difficult (and therefore ongoing) task. The process started with compiling an extensive list of general design process steps based on the experience of individual committee members combined with a search of the design methodology literature[7, 8, 9, 10, 11, 12]. The list was then refined through several iterations of collective feedback, keeping in mind that projects span the spectrum through mechanical, electrical and biomedical disciplines as well as varying in objectives across SAE international competitions, international service-learning, and lab research. Voting by the senior design faculty committee consists of designating whether a particular step should be required of all senior design teams (unless waived by the committee), or whether it is only recommended (and can be waived at the faculty director's discretion). Voting results according to the rubric in Table 4 are shown in Appendix C. Of the steps included in the candidate list (Appendix C), none were voted as "optional" (meaning students could omit them at their discretion) by any members of the faculty design committee.

**Table 4: Voting on Design Process Steps**

| Importance | Interpretation |
|---|---|
| Required | step is *required* of all teams (committee can waive) |
| Recommended | step is *recommended* (faculty director can waive) |
| Optional | step is *optional* (students can omit) |

Voting and consensus building was not completed in time to fully implement a common design process in the 2006-2007 school year, and this is viewed as critical future work in order to improve the interdisciplinary design experience next year.

## 8 Common Project Assessment Standards

Project assessment is conducted by three sets of evaluators (Table 5): the project faculty director reviews all work and assigns the final course grade, the senior design faculty committee reviews presentations and the mid-term brief and provides grade input, and external industry representatives review the final design presentations. Rubrics have been developed to provide some level of consistency among evaluators. Additionally, some faculty directors implement assessment instruments[13,14] (under development) in order to assess outcomes such as an ability to perform stakeholder needs analysis or an ability to work on teams. Quantitative grading is performed by the senior design faculty committee, and the project faculty director determines the final grade by weighting the committee grades along with the other grades from the semester.

**Table 5: Project Assessment Components and Evaluators**

| | Evaluators | | |
|---|---|---|---|
| **Components** | Project Faculty Director | Senior Design Faculty Committee | Industry Reviewers |
| Midterm Design Brief (15 Pages) | Rubric | Rubric | |
| Midterm Presentation (20-40 Minutes) | Rubric | Rubric | |
| Final Design Presentation (30-45 Minutes) | Rubric (Appendix D) | Rubric (Appendix D) | Likert scales (Appendix E) |
| Final Design Report | Grading | | |
| Outcomes Assessment Instruments | Qualitative Review | | |
| Design Notebooks | Grading | | |
| Other Reports & Prototypes | Grading | | |

Two presentations are required of each team during the fall semester. One presentation is given approximately the 8th week of the semester when the students present the fall semester midterm design review. This presentation is 15 minutes in length with 15 minutes of Q&A. A second presentation is given during finals week when the team presents the end of semester review and is 30 minutes in length with 30 minutes of Q&A. A minimum of 3 to 4 faculty members are present at these presentations, with 2 to 3 outside engineering professionals present at the end of semester review. External reviewers and faculty members not involved in the project are given priority in directing questions to the team members. Each external reviewer and faculty member evaluates the presentation and Q&A session (sample rubrics are shown in Appendix D and Appendix E). A portion of the team's final grade is a result of these two presentations.

## 9 Conclusions and Future Work

The consensus among faculty is that the curricular changes have been very effective for implementing interdisciplinary senior design. A second consensus is that much ongoing and time-consuming work remains. The engineering faculty are very positive about the changes, as evidenced by a notable increase in involvement and enthusiasm (largely enabled by the availability of teaching credit for serving as a faculty director). It is generally felt that the ongoing changes are a path to greater consistency among projects, and a consistently higher level of project scope and technical difficulty.

Of the ongoing work the three largest items remaining are: agreeing upon common design process elements, refining the administration of assessment reviews and rubrics, and implementing a sophomore seminar and junior design course to provide the design process methodology needed to prepare students for the best possible interdisciplinary senior design experience.

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**Appendix A Design Project Emphasis Curriculum Overview**

## Freshman

**Fundamentals of Engineering Design**
(Existing Course)

## Sophomore

**Design Seminar**
New Course
(0 credit)

- Course Project(s)
- ASME Design Project
  (or Other Appropriate)

## Junior

Course Project(s)

**Engineering Design** – New Course (3 credit)
- Discipline Specific
- Initially only for Materials Joining concentrations
- Possibly more concentrations later.

## Senior

**Design Seminar**
New Course
(0 credit)

**Senior Design I and II**
- Project Specific (vs existing discipline specific)
- Approx. 5 sections each semester

## Appendix B Description of New Courses for Interdisciplinary Senior Design

**ENGR 4813 Senior Design I**
Applications of design principles to a capstone engineering project. Projects are team based and include developing design specifications, conceptual designs and final designs. Project requirements include significant oral and written communication components. Examples of projects include intercollegiate competition, industry sponsored, applied research, and service projects. Class 2. Lab 3. Prerequisites: Senior standing and consent of instructor. Corequisite: ENGR 4400. (Fall)

**ENGR 4823 Senior Design II**
Completion of final design, fabrication, testing, and reporting of the engineering design projects initiated in ENGR 4813. Class 2. Lab 3. Prerequisite: ENGR 4813. (Spring)

**ENGR 2400 Sophomore Design Seminar**
Seminar topics emphasizing skills necessary to successfully complete design projects, including the study of design project case studies. Class 1. Prerequisite: ENGR 1812. (Spring)

**ENGR 4400 Senior Design Seminar**
Seminar topics emphasizing skills necessary to successfully complete design projects. Topics may include ethics, standards, environmental, sustainability, manufacturability, health and safety. Economic, social, and political considerations are also addressed. Class 1. Corequisite ENGR 4813. (Fall)

**MJET 3413 Design Topics in Materials Joining**
Conventional and modern methods of joint design for static, dynamic and cyclic loading. Effects and control of residual stresses and distortion. Fracture mechanics, limit load and reliability-based methods with application to flaw assessment. Service temperature and environment considerations. Structural life improvement, principles of failure diagnosis, and use of numerical methods. Quality concepts, codes and standards, cost estimation and process selection. Class 3. Prerequisites: ENGR 2313. Corequisite: MEGR 3323 or METC 3323. (Spring)

## Appendix C Candidate Design Process Steps with Committee Voting Results

| | # Votes | |
|---|---|---|
| | Required | Recomm. |
| **I. Task Clarification** | | |
| 1.1 Background research (e.g. experts, books, web, patents, previous teams) | 9 | 0 |
| 1.2 Review of applicable standards (e.g. ASME codes) | 2 | 6 |
| 1.3 Identification of stakeholders | 5 | 4 |
| 1.4 Customer needs analysis (collection & aggregation of stakeholder needs) | 4 | 5 |
| 1.5 Competitive benchmarking data (collected after specs identified) | 2 | 7 |
| 1.6 Problem Definition | | |
| 1.6.1 Problem statement / goal setting (1-3 concise sentences) | 9 | 0 |
| 1.6.2 Requirements & constraints definition | 9 | 0 |
| 1.6.3 Specifications with target values | 8 | 1 |
| 1.6.4 QFD (relating requirements, specifications, and benchmarking) | 1 | 8 |
| 1.7 Business case / market analysis (profitability assessment) | 2 | 7 |
| 1.8 Scheduling: task breakdown, individual assignments, & milestone setting | 9 | 0 |
| 1.9 Budgeting | 7 | 2 |
| 1.10 Fundraising | 2 | 7 |
| | | |
| **II. Concept Generation & Selection** | | |
| 2.1 Identification of overall function and break-down into sub-functions | 9 | 0 |
| 2.2 Creative concept generation (e.g. brainstorming, mind maping, C-sketch) | 5 | 4 |
| 2.3 Formation of multiple solution concepts | 6 | 3 |
| 2.4 Establish evaluation criteria (for concept selection) | 5 | 4 |
| 2.5 Feasibility estimation of concepts (order-of-magnitude calculations) | 4 | 5 |
| 2.6 Concept selection matrix (with justification) | 4 | 5 |
| 2.7 Communication of results (design review report, presentation) | 9 | 0 |
| | | |
| **III. Concept Implementation & Testing** | | |
| 3.1 Preliminary design - add detail to solution concept(s) | | |
| 3.1.1 Calculations (application of engineering analysis) | 9 | 0 |
| 3.1.2 Failure Modes and Effects Analysis (FMEA) or Risk assessment | 3 | 6 |
| 3.2 Detailed design - specific components and dimensions determined | | |
| 3.2.1 Apply 1 or more published DfX technique(s) | 2 | 7 |
| 3.3 Final design: Ready to send out for fabrication | | |
| 3.3.1 Bill of Materials | 4 | 5 |
| 3.3.2 Manufacturing drawings | 3 | 6 |
| 3.3.3 Manufacturing and assembly process plan | 2 | 7 |
| 3.3.4 User's guide / instruction manual | 2 | 7 |
| 3.3.5 Communication of results (final report, final presentation) | 9 | 0 |
| 3.4 Testing (at any point in phase III) | | |
| 3.4.1 Fabrication of design | 7 | 2 |
| 3.4.2 Test results (compared to specifications and benckmarking) | 9 | 0 |

## Appendix D Design Evaluation Rubric Sample (Final Semester Presentations)

| Attribute | 1 - Not Acceptable | 2 - Below Expectations | 3 - Meets Expectations | 4 - Exceeds Expectations | Score |
|---|---|---|---|---|---|
| General Preparation | Minimal preparation, all team members not available | Inadequately prepared, visual aids incomplete, organizing duties during session | Well prepared, team ready to present project, all major support elements ready | Superior preparation, thorough content, good preparedness for unexpected question | |
| PRESENTATION CONTENT | | | | | |
| General Explanation of Project | Project not understood | Project poorly understood, significant omissions exist | Project understood and all major issues are appropriately identified and addressed | Superior understanding of project goals, constraints and solution path | |
| Project Progress | No significant progress toward goals is apparent | Limited progress in pursuing path to project outcomes | Project on track, solid contribution toward achieving goals and outcomes | Exceptional progress, team shows superior quality of work and is making significant progress toward | |
| Plan for Project Completion in Spring Semester | Plan is beyond the scope of what can be reasonably be achieved | Plan is unlikely to succeed or likely to experience excessive problems | Plan likely to achieve desired outcomes | High likelihood of project success, contingencies are well accounted for. | |
| PRESENTATION MECHANICS | | | | | |
| Order of presentation | totally disjointed, no organization | some items presented out of order | organization as per guidelines | superior organization enhances communication | |
| Time Utilization | far too long or far too short | somewhat too long or too short | appropriate length | | |
| Quality of Visual Aids | not clear or unreadable | difficult to read | clear and readable | superior clarity and readability | |
| Use of Visual Aids | Didn't use visual aides or blocked screen constantly | Relevance of visual aids not often apparent, overly reliant on visual aids | Balance between visual aids and oral presentation | Excellent use gestures to provide emphasis and supplement visual aids | |
| Speech quality | Unintelligible or had to clarify numerous points due to communication problems | Voice hard to hear, words slurred or voice trails off, spoke too slow or too fast, monotone with little emphasis | Voice clearly heard, words clearly enunciated, did not speak too slowly or too rapidly | Voice projected very well, clear enunciation, did not speak too slowly or rapidly | |
| HANDLING OF QUESTIONS | | | | | |
| Answers to Questions | non-responsive | evasive or inaccurate | clear and direct | very clear and complete | |
| Group Handling of Questions | clearly at least one member unable to respond | not all members participate appropriately | all members participate appropriately | all members can answer questions on all aspects of project | |

**Appendix E** **External Industry Reviewer Evaluation Form**

Senior Design Presentations: Fall-06
Input from External Reviewer

THANK YOU! Your input is very valuable to us!

Name: ________________________ Company: _____________________

Date: _______________ Team Presenting: ___________________________

Please rate, on a scale of 1 to 5 (5 being best), the students on:

**Notes:**

1. The rating should be based upon information given in this presentation.
2. If there is no information given relevant to a particular item, then please leave blank.

| | |
|---|---|
| 1. Ability to apply knowledge of math, engineering & science. | 1 2 3 4 5 |
| 2. Creativity in design of systems, components, or processes. | 1 2 3 4 5 |
| 3. Combining broad-based knowledge, techniques, skills and modern tools to successfully complete the project. | 1 2 3 4 5 |
| 4. Communicating effectively. | 1 2 3 4 5 |
| 5. Commitment to quality, timeliness, and continuous improvement. | 1 2 3 4 5 |
| 6. Decision making based on cost/benefit analysis. | 1 2 3 4 5 |

General Presentation Ratings: (scale of 1 to 5)

| | |
|---|---|
| Overall | 1 2 3 4 5 |
| Delivery | 1 2 3 4 5 |
| Visual Aids | 1 2 3 4 5 |

COMMENTS AND SUGGESTIONS (Continue on Reverse Side if Needed)

GUIDELINES

- The total length of each team's project review will be either 45 or 60 minutes, depending on the size of the team. Student presentations will be either 20-25 or 30 minutes long, followed by 20-25 or 30 minutes of questions. A faculty chair will supervise the session and determine starting and ending times.
- As external reviewers, your questions take priority over those of the faculty reviewers. You are more than welcome to ask the students "tough" questions. We particularly want them to be questioned on their methodology, as well as their results.
- We and the students also solicit your suggestions and constructive criticisms. However, we do ask that you maintain a constructive and respectful tone.
- Thank you again for your valued participation.

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COMMENTS AND SUGGESTIONS (cont'd)