Session #: ____________

A REAL-WORLD SENIOR ENGINEERING DESIGN SEQUENCE

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1. INTRODUCTION

The Purdue University Calumet engineering programs conclude with a two-semester senior design sequence that attempts to mimic what engineers do on the job. The objective is to take students from the typical classroom experience where most problems take ten minutes to an hour, have a defined answer, and are solved independently; to a typical engineering job that can have a project timeline spanning months or years, does not have a unique solution, is completed by a team, and may not even have been clearly defined.

In the following material, the course is detailed in a fashion so that all or pieces may be incorporated into existing or new courses at other universities. Section 2 covers overview items, the next covers the first semester, and the following covers the second semester. These are followed by discussions of grading and ABET standards, and concluding remarks, including planned updates to the course sequence. One professor is in charge of each class, designated in the following as PIC, each team has a (faculty) advisor with the best match to project needs and, as appropriate, an external advisor.

One issue that is continuously raised by the Purdue Calumet Engineering Advisory Committee, made up of practicing engineers, is weakness in engineers' writing and speaking skills. Thus, the course Written and Oral Communication for Engineers was developed and made a prerequisite for senior design, since speaking and writing are significant components of the design sequence. To earn an 'A' grade, a student must be competent in both.

Besides a detailed syllabus for each semester, instructions are available for the literature search procedure, work plan, final report, design review, and final presentation. Please contact the authors.

2. OVERVIEW

This is a capstone sequence, i.e. the course sequence is to be taken during the last two regular semesters before receiving the degree. Students in all four engineering majors -- civil, computer, electrical, and mechanical -- take the sequence together to provide cross-discipline experience. The first semester course is 2 credits, the second is 3.

2.1. Learning Objectives.

Students are required to pursue an idea from conception to realistic design and, perhaps, construction and testing in a "real-life" environment. By the end of this two-semester sequence each student should be able to:

1. Learn material needed for a project that was not taught in courses taken.
2. Identify goal(s), the necessary activities, and the key problems.
3. Prioritize tasks, manage time, control expenses, and prepare plans to complete a project on schedule and within budget.
4. Work cooperatively as part of a team (interdisciplinary if possible, as in industry).
5. Communicate effectively, both orally and in writing.
6. Demonstrate the multiple engineering skills necessary for a 21st century engineer.
7. Formulate and solve engineering problems, recognize relevant parameters, identify principles, and make appropriate and reasonable simplifying assumptions and approximations.
8. Design (and build and test) a system, process, or components related to the project.
9. Understand and apply the engineering code of ethics.
10. Evaluate the impact of an engineering activity on society and the environment.

3. SEMESTER ONE

Project ideas from faculty and industry are presented. Students are also encouraged to submit project descriptions, and these have resulted in some interesting projects. Each student considers the projects submitted, and, after discussions with faculty and fellow students, submits the form described in Section 3.2. If a project is submitted from an outside organization, an industrial advisor willing to work with the team and the faculty advisor must be designated. A list of some recent project titles is in Table 1.

Students are told that their requests will be considered, but, as in an industrial setting, they may be assigned to a project that is considered high priority by the PIC. All projects are team projects, individual projects are not allowed. Teams may have two to four members.

Each team selects a team leader. The team leader is responsible for the work distribution (in cooperation with the members), and the completion of tasks (to the extent possible). The team leader can be changed. The team leader does not prepare all reports, but must read and approve them. The team leader is expected to perform an appropriate share of the technical work. Each team member is expected to have specified responsibilities as identified in the Work Plan, Section 3.6.

Each project is assigned a faculty advisor, who is critical to the success of the project. All team members are expected to meet with their advisor weekly.

3.1. Class Activities.

The class meets one to two hours per week, but not every week as most of the work is done by the teams and advisors outside of regular class time. The first semester opens with a description of the learning objectives, procedures, and the motivation behind the course. The first three weeks are devoted to project and team member choice. Before the semester, project ideas are solicited from local companies and faculty, and a list prepared for the students. The second class is used for discussion of potential topics.

Those times the class meets as a whole, after project selection, are devoted to:

Oral presentations by the students

Technical writing (by the technical writing expert)

Placement office, resumes, and interviewing (with later opportunities for a practice interview and resume review) (by staff from the placement office)

Library facilities (by a library staff person)

Safety (by an engineer from a local company)

Table 1. List of Recent Senior Design Projects

Automotive Proximity Alert System (APAS)
Electronic Device Curve Tracer
CargoEzTable
2011 Moonbuggy Design
Urban Wind Turbine Data Acquisition System
Comparison of Reactor Tray Designs
Drilling Rig Mast Structure Analysis
Hydraulic Differential Pressure Amplifier
Direct Evaporative Cooling Heat Exchanger Evaluation
Flood Modeling of Hart Ditch
Concrete Canoe
CFD Analysis of Suburban Wind Environment
Design of a Solar Water Heater System for the Fitness Center
Simulation & Virtual Reality Visualization of a Steel Casting Ladle
NiSource Bailey Station Condenser Loop Modeling Project
CFD Modeling of an Industrial Boiler
Duct Simulation
Building a Wi-Fi Embedded System Terminal
Real-Time Simulation & Implementation of BLDC Motor Control
Position Determination for Mobile Robot
3D Visualization of Microfluidic Systems
Human Brain Neuronal Fiber Connectivity Visualization
FPGA - Based Data Acquisition
Traffic Network Simulation at I80/94 and I65
Practical HB-LED Lighting Module
Control System for an Electric Scooter
Rolling Mill Analysis- Mittal Steel /IN Tek
Air to Ground Communication Systems
Virtual Laboratory Based on IBR Cubic Environment
Analysis of a Diesel Engine Manifold
Formula SAE Brake Design
FEA of an Airplane Wing
Elastic Stresses in Concrete Folded Plates
Batch Anneal Furnace Energy Optimization
Landmark Identification and Guidance System
High-Brightness LED Lighting
Real-Time Data Monitoring for Transformers

3.2. Project Interest & Faculty Signature Form.

This is the form students use to request topics and team members. It is due to the PIC in the second week of the semester so teams can be assigned and start working on their projects. To complete this form, the students first list the three courses of most interest. Then they talk with at least three faculty members who they would like to work with or have projects of interest. Finally, based on their meetings with faculty and class discussion, they list their preferred projects and team members. The data from these forms is used by the PIC to assign the projects and teams. Some projects may be assigned based on need rather than student interest.

3.3. Proposed Project Description.

This is a brief statement of the problem, less than one page, and is to be approved by the advisor. Projects are assigned at the beginning of week 3 (out of 15), and this document is due at the beginning of week 4. The format is

Background. Example: Hearing loss is increasing because of exposure to loud noises and music. Only 37% of people who need hearing aids use them.

Objective. Example: The objective is to provide a simple hearing screening method that would be accessible in a public institution.

Approach. Example: A computer-aided screening device with a maximum cost of $1,000 will be designed, built, and tested.

Outcome. Example: The anticipated outcome is an interactive program and hardware that can be easily incorporated into institutional computers such as in libraries. The program would have a graphical user interface (GUI) and an output to a set of headphones for acoustic tones. The intensity of the tones is then adjusted to test for the hearing threshold at different frequencies.

3.4. Weekly Progress Reports.

These reports are to be emailed to the PIC with a copy to the advisor by a designated time each week (from the project assignment date to project completion when classes are in session). Their purpose is to ensure that the team members, the advisor, and the PIC are all aware of the project's current status, activities, and possible problems. The entries are to be short, succinct phrases rather than complete sentences. (This should take only a few minutes each week.) Note that the team is expected to meet with the advisor each week. The format is:

Project Title:

Date:

Accomplishments for Week:

Name 1:

Name 2:

Plans for Coming Week:

Name 1:

Name 2:

Problem Areas:

Advisor: The team met with our advisor on

3.5. Literature Search Procedure Summary.

This is the first major document required. It starts with a revised project description with the four items described in 3.3 above. This is followed by a list and justification of the key words used for the literature search, the process and database sources used, and a list of the literature found. It focuses on the procedure but not the results. The results become part of the final reports for both semesters. Grading includes a focus on technical writing, and required rewrites are common.

3.6. Work Plan.

The work plan starts, again, with an updated project description. Then the required work is broken down into tasks with objectives and activities, each with a brief description and responsibility assigned to one or more team members. It concludes with a time line for the tasks, presented as both a table (milestone log) and a Gantt chart.

The work plan, a conventional industrial tool, is an important document because it forces the students to determine the things that are needed and the order they will be addressed with a time line. The students are not used to large, complex team projects, and generally have no idea of the multiple steps required. Before work plans were required, each semester typically ended with a mad rush, the work was disorganized, and successes were limited. Now there still may be a mad rush, but teams are more organized and professional, and the results are better and more consistent. The work plan is updated regularly for oral presentations.

3.7. Oral Reports.

Each student will make at least one oral presentation to the class during each semester. Engineers must learn time discipline in oral presentations, so the students are limited to speaking for 3.5 to 5 minutes. Visuals (power point presentations) are expected. These are individual presentations done by one team member, and are graded by the PIC based on how well the material is organized and presented, and how well the presenter knows the material.

3.8. Resume and Mock Interview.

Following the session with a representative from the campus placement office, students have the opportunity for a mock interview. At the interview, the student's resume is also reviewed. This is not part of the course, but is an opportunity for the students.

3.9. Design/Safety Report and Review.

The design/safety report describes the first semester's results. An updated work plan must be included as an appendix. The literature search provides some of the basis for the introduction and/or background sections; references to the material found in the literature search must be included. The report is graded for technical writing by the technical writing expert, and for technical content by the team advisor. An opportunity is provided to have the technical writing expert review a draft version and then meet with the team members to discuss the draft. This makes the writing a quality learning experience.

The concluding activity for semester one is a design review (a standard industrial practice) conducted by the team advisor(s) with the assistance of a committee of faculty members and (perhaps) outside experts. The review is held after the design/safety report has been submitted to allow the committee members time to read the report and prepare for the review. It consists of an oral presentation (no more than ten minutes per team member) highlighting the technical details, issues, and future plans, followed by a discussion with the committee. The purpose is to ensure that the project is headed in the right direction and is capable of successful completion in semester two. The committee establishes the grade for the design review. If the design plans are deficient and it appears unlikely that the team will be successful in semester two, the team will not be allowed to continue. Either satisfactory revisions are made, or the team could be assigned a new project.

4. SEMESTER TWO

The objective of the second semester is to successfully finish the project. The results of the first semester and the design review provide the basis for a revised work plan with specific goals or outcomes which the team will be expected to accomplish. In addition to the work plan, a team may need to write a test plan and/or an operating manual.

Since this is a project course, most of the time is devoted to work on the project. Class sessions are used primarily for student oral reports. There are guest lectures on:

- Technical report writing, and discussion of issues from the design review reports (by the technical writing expert)
- Engineering ethics (by a professional ethics expert)

The oral reports and weekly progress reports continue.

4.1. Revised Work Plan.

The work plan is revised based on results to date and the feedback from the design review. This provides a reference for evaluating the results obtained upon project completion. (It is a statement of what the team expects to accomplish; the actual accomplishments will be weighed against it as part of the course grade.)

A list of three identifiable outcomes that are to be achieved, one at the end of each month, is to be at the end of the Project Description. The outcomes must be clearly stated. The work plan must include specific activities to accomplish each of these outcomes or objectives. Hardware construction and testing, software codes and testing, design calculations, simulation models, and experiments are all suitable activities. The work plan should be updated regularly, and discussed in the oral and written reports.

4.2. Status Reports.

Monthly status reports, no more than two single-spaced pages in length, are to focus on the results since the last report. They must be clear to a supervisor with limited knowledge of the project. The status report must contain the following parts:

- INTRODUCTION: Brief background/description, time frame and coverage of report.

PROGRESS SINCE LAST REPORT: By tasks or outcomes as designated in the work plan. The report must specify the status of each task, and contain a brief summary of the results obtained.

PROBLEMS AND ACTIONS TAKEN (or to be taken): Describe any problems. If none, say so.

PLANS FOR NEXT PERIOD:

WORK PLAN MODIFICATIONS: Changes made in the schedule must be clearly identified. The report must have an updated schedule (milestone log) attached.

Students are encouraged to include detailed write-ups of completed tasks suitable for inclusion in the final report as attachments. The intention is, as a piece of the project is completed, to write the relevant part of the final report while the material is fresh, and therefore have parts of the report finished before the end-of-semester rush. This also provides the advisor an opportunity to review the work and make suggestions. The appendices must be described in the report.

4.3. Test Plan.

A test plan is a list of the steps required to successfully evaluate a new device or computer code, or complete an experiment. It is a standard industrial/research "tool" to ensure that the process is planned and that the goals are achieved. It differs from a work plan in focusing specifically on the tests and in having more detail. If appropriate, it will be required. It can be in outline form. It becomes part of the final report.

4.4 Operating Manual.

Any completed device or computer code requires a set of (clear) instructions for potential users. The manual is to be part of the final report.

4.5. Ethics Paper and Discussion.

Following the lecture on engineering ethics, each student writes a two-page individual typed paper discussing how ethics impacts his/her project. If there are no ethical issues, the paper can be on how ethics impacts some engineering issue in the news. These papers are discussed in a subsequent class.

4.6. Final Report.

The final report describes the results of the two-semester sequence. Again, the report is graded for technical writing by the technical writing expert, and for technical content by the team advisor. An opportunity is provided to have the technical writing expert review a draft version and then meet with the team members to discuss the draft.

The final report must contain a chapter on constraints, and impact on society and the environment. This chapter is graded separately by the PIC.

4.6. Final Team Presentation.

The final team presentation is the culminating activity. All senior design students and engineering faculty are expected to attend, and to participate in the grading. Demonstrations are encouraged. When this is not possible, such as the work is off-site; a video can be used. (A video has the advantage of being well organized and also avoids the possibility that the demonstration might fail.) Teams have a fixed time limit, typically ten minutes per member, and are stopped if they exceed this limit. Any demonstrations have to be done within this time limit. Additional time is provided for answering questions.

5. GRADING CRITERIA

The components of the final grade are listed below. They are specified as to team or individual and who does the grading – the professor in charge (PIC), the team advisor, or the technical writing expert (WE). To earn a grade of 'A', a student must excel in all aspects, demonstrating technical proficiency, ability to work in a team setting, and good oral and written communication skills.

Individual oral presentations (PIC)	Sem. 1
Team literature search (PIC)	Sem. 1
Team work plan or revised work plan (PIC)	Sem. 1, 2
Individual status report (PIC)	Sem. 2
Engineering ethics paper (individual) (PIC)	Sem. 2
Team final report	Sem. 1, 2
Writing and format (WE)	
Technical content (advisor)	
Design review (advisor and committee)*	Sem. 1
Final team presentation (individual grade)	Sem. 2
Individual project advisor's evaluation	Sem. 1, 2
Individual evaluation by team members	Sem. 1, 2

Individual evaluation, including attendance, participation,
and general quality of work (PIC) Sem. 1, 2

* If a passing grade is not earned on the design review, the team will not be allowed to proceed to semester two.

6. RELATIONSHIP TO ABET STUDENT OUTCOMES

Each of the outcomes has to be related to one or more of the learning objectives for the course sequence. The weighting depends on how strong the connection is. There are eleven ABET outcomes. Nine of the eleven, as listed below, are covered in at least one of the two courses.

Outcome a:	An ability to apply knowledge of mathematics, science, and engineering.
Outcome c:	An ability to design a system, component, or process to meet desired needs within realistic constraints.
Outcome d:	An ability to function on multidisciplinary teams.
Outcome e:	An ability to identify, formulate, and solve engineering problems.
Outcome f:	An understanding of professional and ethical responsibility.
Outcome g:	An ability to communicate effectively.
Outcome h:	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
Outcome i:	A recognition of the need for, and an ability to engage in life-long learning.
Outcome k:	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

7. SUMMARY COMMENTS

The two-semester senior engineering design sequence has existed at Purdue Calumet since the beginning of the four-year engineering programs, over 35 years. The course has been updated on a regular basis as different faculty have brought in their ideas and experience.

The focus is on teams and cross-disciplinary interactions, and on the activities and skills the students will need in the future. It appears to work, the evaluations from the students and from outside evaluators are excellent.

As the evolution of this design sequence continues, it has been proposed that the material on engineering ethics and the societal impact of engineering solutions, currently covered in two dedicated courses taught by non-engineering faculty, is to be instead incorporated into multiple existing engineering courses. The credit for the first semester design course will be increased from 2 to 3 credits to allow more time for their treatment.