A Senior Design Course
That Simulates an Industrial Engineering Environment

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Abstract
A Senior Design Course That Simulates an Industrial Engineering Environment
The Electrical Engineering capstone senior design course, like most, allows students to develop practical engineering skills. At the University of Tulsa, we have augmented this to simulate an industrial engineering design environment. The projects involve both the solution of technical problems and the development of interpersonal skills. The fall semester is a team approach with the same design for all teams. The spring semester is individual design. Plans must meet certain financial, scheduling, and performance constraints.

Team formation begins with student interviews. A team consists of three students and a professor who acts as mentor. To properly simulate an industrial engineering *design environment*, the process is conducted in a business environment requiring professional attire and demeanor. The groups perform a feasibility study, select two possible designs and obtain mentor approval. In *product development*, the teams prepare a parts list and submit a requisition to the purchasing agent, the EE department secretary. After the parts have been received, a prototype of the design is built and tested to verify that it meets the design specifications. Then, a final design is assembled and packaged.

Halfway through the project, there is an organization *restructure* and change in specifications. The next step is to *market* the product. At a Sales Fair, the company sells to customers consisting of faculty, staff, and graduate students.

In addition, the students are formally directed to people skills and financial planning. The texts are *Rich Dad / Poor Dad*, *Great Connection*, and *Skill with People*. To develop the softer engineering aspects, numerous reports and presentations are made by each student, individually and as part of teams. These include project and the people skills areas. As part of the people development, the students evaluate their peers. All comments must be stated positive to encourage better performance.

Material for the course is placed on a website. Correspondence with the professor is by email. Because of the intensity of the class and the time restrictions for performance, this is the only effective tool to resolve problems quickly.

I. Introduction

An important part of an undergraduate engineering program is the practical application of engineering concepts. A senior design project class often accomplishes this. In this forum, students apply their engineering knowledge to the development of a product. While many senior design courses allow students to develop practical engineering skills, these courses often do not capture the other features of an industrial engineering environment. Items such as project management, finance, manufacturing, and marketing are missed.

At the University of Tulsa, we have addressed these limitations for our Electrical Engineering students. We have a two-semester capstone program. The fall semester is a team approach with the same design for all teams. The spring semester is an individual design. For sake of brevity, the majority of the paper will address the first semester.

The senior design course is structured to simulate an industrial engineering design environment. The projects involve both the solution of technical problems and the development of interpersonal skills. Students interview for team positions. Design plans must meet certain financial, scheduling, and performance constraints. The organizations are restructured and the specifications change during the project. Then the product must be built and sold in a competitive marketplace.

In addition, the students are formally directed to financial planning and people skills. They prepare reports and make presentations about their reactions to the topics. The texts are *Rich Dad / Poor Dad*, *Great Connection*, and *Skill with People*.

II. Course Structure and Implementation

Our most recent implementation of the course occurred in the Fall 2000 semester. The class begins with *team formation*. *S*tudents must interview for team positions. The process simulates an industrial engineering environment, where job candidates interview for positions. Each student prepares a resume and schedules interviews with two professors. The results of the dialogue are used to determine team members.

A team consists of three students - a project manager, a design engineer, and technical support person – as well as a professor who acts as a team mentor. The team selects or hires the professor of their choice. The students select a name for their company. This is used in product promotion, presentations, and recruiting new members.

In order to properly simulate an industrial engineering *design environment*, the process is conducted in a business environment. Professional attire and demeanor is required for all students. Jackets are required for presentations and recommended for interviews. All reports and written material must be typed and drawings performed on a computer-aided system.

All teams work on the same project; however, each team determines its own *design implementation*. The groups have one week to perform a feasibility study and select two possible designs. The mentor must approve the plans. Accepted designs bear the mentor's signature with date and time approved (time stamp). The design must then be sold to the Vice-President of Engineering, the course instructor. Only two teams may have a similar design. In case of conflict, the earliest time stamp wins.

After a design has been approved, the next step is *product development*. Teams prepare a parts list and submit this requisition to the purchasing agent, the Electrical Engineering department secretary. To reduce costs, a single vendor is used and orders are submitted to the vendor only one day a week.

In order to meet the competition, the final constructed product must cost less than $50.00. After the parts have been received, a prototype of the design is built and tested to verify that it meets the design specifications. Then, a final design is assembled and packaged.

Half way through the project, there is an organizational *restructure* and a change in specifications. Each group must let-go one employee. Then they can rehire one employee. The process is without direction from the mentor or professor. The reorganized team then modifies the original design to incorporate the changes.

The next step is to *market* their product. Each team presents their product at a design fair at the end of the semester. The students sell their product to customers consisting of faculty, staff, and graduate students. The project with the most profit wins.

To develop the softer engineering aspects, numerous presentations are made by each student, individually and as part of teams. These include project proposals, project prototype, project package, and product marketing. In addition, presentations are made for the skills books. Length of the presentations is prescribed to be very short. This forces focus on the main topics, provides more presentations in a fixed time, and is less intimidating.

As part of the people skills development, the students evaluate their peers. The presentation evaluations are conducted on member outside the team. All comments must be stated in a positive, affirming to encourage better performance. At the end of the semester, each student evaluates his team colleagues. This part is kept strictly confidential to give the professor insight into the team dynamics.

III. Technology today

All material for the course is placed on a website. In addition to the regular class meetings, correspondence with the professor is by email. Because of the intensity of the class and the time restrictions for performance, this is the only effective tool to resolve problems quickly.

The best way to get a flavor for the class is to include actual course information. The following information is directly from the student assignment.

COST ANALYSIS

The Senior Design involves developing a product. As part of the simulation, the different companies (teams) will market and sell the design. This is in a competitive environment.

Customers will purchase units during a Sales Fair. Make your best commercial presentation with props, displays, and any other items that will sell your product. Remember everything must be in good taste that is acceptable to your mother.

In the real world, and your presentation, product performance can often be overcome with excellent product promotion. That is why product image, advertising, and packaging are so important.

The fair will be after the Christmas party on the last Friday of the semester. Start time is 1:00 PM.

Selling units is one thing. Making a positive cash flow is another. Therefore, use the following criteria for developing a costing structure.

After the first 500 units are sold, some costs may be reduced because of economies of scale, purchasing negotiation position, and learning curve. Keep the unit costs for the first 500. It is the incremental over 500 that reduces costs.

1. Bill of materials

Prepare at least two complete Bill Of Materials for all the components of the product.
Bill of Material Basic is for the components necessary to meet the specifications.
Bill of Material Custom is for the complete system as marketed.
Bill of Material Other is for any additional models you may have developed.
All the following discussion applies to every bill of material.

2. Parts

Use unit prices (quantity = 1) prices from Digi-key for each component.
For foreign items not purchased from Digi-key, use actual cost plus a 10% penalty.
After 500 units, costs may be reduced by 50%.
Calculate a total parts cost.

3. Purchasing Overhead

Add a factor of 75% to the costs for purchasing overhead.

4. Printed Circuit Board

This price is used since your actual setup may be exorbitant for your single prototype unit.
If a printed circuit board is used, assume a cost of $5.00.
After 500 units, costs may be reduced by 50%.

5. Assembly

Set-up cost is $5.00 per unit.
Resistor and capacitor mounting, no charge.
Other component mounting, $0.50 per component.
Soldering, $0.02 per point.
After 500 units, costs may be reduced by 50%.

6. Manufacturing Cost Total
Total the cost of parts, purchasing overhead, pcb, and assembly.

7. Manufacturing Overhead
Add a factor of 50% of the manufacturing total cost to cover overhead.

8. Engineering Development
Engineering development is $10,000 for the first 500 units.
Add a cost of $20.00 per unit for less than 500.
After 500 units, costs may be reduced to $2.00 per unit as an engineering override.

9. Production Cost
Total the manufacturing cost, manufacturing overhead and engineering cost for a production cost.

10. Administrative and General Overhead
Add 15% of the production cost to pay for the front office.

11. Base Cost
Total production cost and general overhead for a unit base cost.

12. Pre Sale Report
Prepare a detailed breakout of the computation of Base Cost prior to the Sales Fair.
Submit this report prior to the start of the Fair.
Click here for an example available on-line.

13. Profit
Compute profit for each sales order.
Profit is (Selling Price - Base Cost) * Units Sold
Total the profit from each sale to obtain a gross profit.

14. Sales Report
Prepare a combined sales report.
Each order is documented with Units Sold, Selling Price, Base Cost, and Profit.
Total the orders with Total Units Sold, Average Selling Price, Total Sales Dollars, and Total Profit.
It is strongly recommended that you prepare an Excel spreadsheet for the report, prior to the fair.
Submit this report at the conclusion of the Sales Fair.
Click here for an example available on-line.

15. Comment
The projected total sales among all teams is expected to be in the range of $500,000 to $750,000.
This will depend highly on your ability to promote.
It will be a fun, exciting, and stimulating session.

EVALUATIONS

MATERIAL
1. Did you understand the topic? Y( ) Could Improve ( )
2. Material quality? Y( ) Could Improve ( )
3. Material length? Outstanding ( ) Too short ( ) Tool Long ( )
4. Was it interesting? Y( ) Could Improve ( )

POISE
1. Stand erect on both feet? Y( ) Could Improve ( )
2. Use adequate hand gestures? Y( ) Could Improve ( )
3. Speak loudly and clearly? Y( ) Could Improve ( )
4. Look at audience? Y( ) Could Improve ( )
5. Attire professional? Y( ) Could Improve ( )

TOOLS
1. Use visuals or equipment? Y( ) Could Improve ( )
2. Visuals good quality? Y( ) Could Improve ( )
3. Rank the presentation: 1( ) 2( ) 3( ) 4( ) 5( )
   1=go back to freshman 5= TU engineer
4. Comments for improvement must be stated positively: ____________________

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Team or individual name being evaluated __________________________________
Your name ______________________________
You must evaluate at least three teams.

IV. Observations and Outcomes

With the forum structure and the directed assessments, there is substantial feedback from the students. These have been used to tweak the course over the last four years. In the process three themes continually are the focus of the evaluations of the class.

The emphasis on people and financial skills is universally lauded. Typical comments are "I have sent this book to my siblings." Perhaps the most common reflection is "I wish someone had told me about this sooner." A particularly poignant and frequent one follows the idea "That is why he does that" or "If I had known this sooner, I would not have behaved a particular way."

The requirement for numerous presentations gets very high marks. The majority of students declare they were initially insecure and intimidated about getting if front of a group. However, by the end of the class, they are comfortable and some even have learned to enjoy the art of speaking.

The other theme is the intensity and fun of the class. It requires a tremendous amount of work, but it lets the students do what they wanted to do – make something work. The sales fair brings out the competitive spirit and reveals who are the best advocates. Several students have indicated they have taken jobs in engineering marketing because of this segment.

Perhaps the best commentaries come from former students. Just yesterday, I received another. It was as follows. "Dr. Durham did not give us much material; we had to do all the data gathering ourselves. What I learned from the class has made my job in the telecommunications industry a walk in the park."

Some local company recruiters ask for recommendations of students based on particular skills that we have evaluated in the class. After all, what we are providing is skilled engineers to the marketplace.

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Marcus O. Durham is a Professor of Electrical Engineering at the University of Tulsa. He is also Principal Engineer for THEWAY Corp and is President of Advanced Business Technology, an entrepreneurial business firm in the emerging e-Commerce arena. He is a registered Professional Engineer, a state licensed electrical contractor, a FCC licensed radiotelephone engineer, and a commercial pilot. Professional recognition includes Fellow of the Institute of Electrical and Electronic Engineers, Diplomate of American College of Forensic Examiners, and the IEEE Richard Harold Kaufmann Medal. He is acclaimed in Who's Who of American Teachers, National Registry of Who's Who, Who's Who of the Petroleum and Chemical Industry of the IEEE, Who's Who in Executives and Professionals, Who's Who Registry of Business Leaders, Congressional Businessman of the Year, and Presidential Committee Medal of Honor. He received the B.S. in electrical engineering from Louisiana Tech University, M.E. in engineering systems from University of Tulsa; and the Ph.D. in electrical engineering from Oklahoma State University, Stillwater.

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