# FRESHMAN DESIGN PROJECTS
## *In the Environmental Health and Safety Department*

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Freshmen usually come to us without an engineering background. They are accustomed to working alone on small, well-structured problems, do not understand the laws of thermodynamics, and have little conception about conservation of momentum, energy, and mass. Consequently, we have been reluctant to give open-ended design problems to them in spite of the fact that the fun of engineering is working on real problems and finding solutions to them. It seems too big of a risk.

While incorporating engineering health and safety issues into the engineering curriculum is desirable and has been addressed by ABET,[1] meeting this major challenge is difficult given the many other ABET requirements. Past papers that address possible approaches include the work of Gute, et al.,[2] Bethea,[3] and Rossignol, et al.[4] Our approach introduces students to open-ended problems early in the curriculum. We find that their creative abilities provide fresh solutions to mundane problems.

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### FRESHMAN CURRICULUM

Northeastern University has a five-year cooperative education program in engineering. The freshman year has three quarters, and upperclassmen take two quarters of classes and of cooperative education during each of the next four years. The result is eleven quarters of classroom training and seven or eight quarters of industrial experience.

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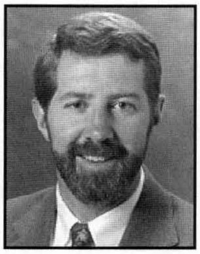

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To allow freshmen the opportunity to meet College of Engineering (COE) faculty early in their academic career, COE faculty take an active role with freshman engineering students. Engineering courses offered in the freshman year are

- *C-programming during the fall*
- *Problem solving using spreadsheets and MathCad in the winter*
- *Engineering design in the spring*

The engineering design course is divided into ten sections, with about thirty students in each section. The sections meet for 65 minutes three times a week. Our quarter system allows for just under eleven weeks of classroom meetings each quarter. Sections are divided by intended major and assigned to faculty from the appropriate departments. This paper is devoted to declared chemical engineering majors.

Engineering design uses a textbook developed by Northeastern's Gerald Voland, *Engineering by Design.*[5] He breaks down the design process into key stages that include

1. *Needs determination*
2. *Design goals and specifications*
3. *Abstraction*
4. *Evaluation of alternative designs*
5. *Ergonomic analysis*

In general, engineering design students are assigned a minor

## TABLE 1
### Proposal Outline for Student Project Design Submittal

GE1103 • Spring 1996
Minor Design Project • Due April 23, 1996
**"If there isn't a need why bother?" R.J. Willey 4/5/96**

**Summary:**

Excellent designs begin with a proper needs assessment and the correct statement of the problems to be solved. An excellent example of posing the proper questions before solving the problem at hand is space craft reentry. Your group is to prepare a 5-page proposal (double spaced and 12-point Courier font) and a 5-minute presentation about your major design project. This work will be due on April 23, 1996. Mr. Jack Price will review and assign grades on your oral presentations (25% of the total minor design project grade). Each group must go to the front of the classroom. After a brief introduction from each group member, one of your group members should serve as a spokesperson. That person should briefly define the need, the problem to be solved, and the methods to be used.

**Proposal Outline**

**Objectives**

Using a numbered list, state your objectives. Be as precise as possible.

**Background**

Who will be served by your solution/design? Where will your solution/design be used? What is the past history related to the problem? Are there any important references related to the problem that you are working on? Existing solutions and prior work on the problem should be described.

**Methodology**

Focus on what techniques you will use to help you solve the "problems" and succeed with a successful design. Use Prof. Voland's and class notes to obtain methods on how to proceed.

***Proposed Schedule*** • Include a proposed schedule that is similar to the schedule shown in Figure 2.6, page 88. Use weeks as the time period and adjust phases to match your problem/design.

***Person Loading Chart*** • Include a person loading (Gantt) chart like the one shown in Figure 2.7. Use hours as the time period and adjust the task list to match your problem/design requirement.

***Autocad Drawing*** • Include a schematic or layout drawing for the project that you are working on.

**Expected Results**

Begin with the end in mind. What are the "deliverables"? Who will benefit?

***Costs*** • What will be the costs involved? "Personpower" can be estimated at a direct cost of $45.00/hr. Other costs will involve materials and supplies to bring about the solution/design (not the cost of the final recommended design).

## TABLE 2
### Major Design Projects, Spring 1996

| *# Department* | *Location* | *Contact* | *Project Description* |
|---|---|---|---|
| 1. Mail Services | Basement | J. Devine | Workstation lighting evaluation |
| 2. Mail Services | Basement, Columbus Pl. | J. Devine | Noise level survey for letter-stamping machine |
| 3. Physical Plant | Mail room, Columbus Pl. | J. Devine | Employee fall protection from loading docks |
| 4. Physical Plant | Various | B. Mitcheson | Loading-dock assesment |
| 5. Environment Health | Various laboratories | S. Brehio | Quality control check on safety showers and eye-wash station survey |
| 6. Environment Health | Various dark rooms | S. Brehio | Evaluation of silver recovery options for environmental compliance |
| 7. Environment Health | Various computer labs | J. Price | Ergonomic evaluation of computer workstations |
| 8. Environment Health | Various laboratories | S. Brehio | Opportunities for waste minimization in the generation of HPLC solvent waste |
| 9. Environment Health | Various laboratories | S. Brehio | Strategies, facility requirements, and costs for a central organic solvent bulking facility |
| 10. Chemical Engineering | 8 Mugar | A. Bina | Design of flow measurement experiment |

and a major design project, each to be completed using the methods presented in Voland's text. In the chemical engineering section, these minor and major projects address the same problem. Our minor design project (see Table 1) consists of a needs assessment and proposed approach to one of the major design projects listed in Table 2. The major design project is execution of the actual work proposed.

Students are divided into groups of three at the second class meeting, providing a total of ten teams. Each team selects a project from Table 2—no duplication is allowed. Each team's interests are matched to a project.

Each project assigned to a team has a University administrator who serves as the "client." The student teams serve as consulting engineering services. Additionally, our Office of Environmental Health and Safety (OEHS) serves as a mentor and an interface between the clients and the consultants.

As Table 2 shows, design projects vary from noise surveys in the University mail room to the optimization of hazardous waste disposal. The projects introduce students to survey instruments, to data evaluation, to regulatory compliance issues, and involve interaction with a variety of people. Students begin learning engineering principles (*e.g.*, velocity measurements involving Bernoulli's equation), team skills, communication skills (written and oral), and economics. With a little investment and some oversight by the OEHS, the University benefits from the students' project recommendations (discussed in more detail below).

The minor and major assignments, the proposal, and the design solution comprise 55% of the course grade. The remaining portion is based on two examinations (30%) and daily homework assignments

(15%). AutoCad is also presented in this class (about one third of the lectures), and students are encouraged to make drawings of their major assignment using it.

As with any open-ended term project, students tend to put off work until the last minute, with the usual disastrous results. To avoid this outcome, students are required to submit a weekly log book and are given small assignments that push them 1) to get their groups together, 2) to begin meeting with their contacts, 3) to obtain background information, and 4) to work towards a solution. The logbook system also serves to identify early such problems as an inability to connect with the University contact or the existence of a nonparticipating member.

For the instructor, the project process is similar to managing a small consulting firm made up of all "rookie" teams. The students generally find their contacts during the first week and will begin the literature checks, but then their methods diverge. One year, two seniors were intentionally recruited to work with two freshman team members. With the advantage of the seniors' co-op and military experience, the teams attacked their project with vigor. Both design solutions—the redesign of a loading-dock area and the creation of a safety check list (see Table 3)—are now being implemented by the University.

## TABLE 3
### Loading Dock Safety Checklist
### Generated by Students Who Worked on Project #3

| *Pnts* | | |
|---|---|---|
| | | ***General Area*** |
| 3 | _yes _no | Are loading positions for trucks marked with lines? |
| 3 | _yes _no | Are dock guards in operable condition? |
| 1 | _yes _no | Are loading areas free of potholes? |
| 1 | _yes _no | Are floors cleaned daily? |
| 1 | _yes _no | Are trash containers emptied daily? |
| 2 | _yes _no | Are trailer wheel chocks provided for each truck? |
| 1 | _yes _no | Are trailer wheel chocks chained to the building? |
| 3 | _yes _no | Are proper warning signs clearly visible for general safety issues? |
| 3 | _yes _no | Is ventilation adequate? |
| 3 | _yes _no | Is lighting adequate? |
| 3 | _yes _no | Does the dock have a roof? |
| 2 | _yes _no | Does roof of dock have a drainage system (i.e., gutters)? |
| 3 | _yes _no | Is dock within height accordance of all trucks that will use the dock? |
| 3 | _yes _no | Are proper signs posted instructing drivers to turn off their engines? |
| 3 | _yes _no | Are first-aid kits readily available? |
| 3 | _yes _no | Are emergency telephones easily accessible? |
| 3 | _yes _no | Are fire extinguishers/sprinkler systems in working order and accessible? |
| 2 | _yes _no | Is noise level of dock in accordance with federal regulations? |
| 2 | _yes _no | Is dock equipped with handrail? |
| 2 | _yes _no | Is dock marked with vivid paint to display hazardous areas? |
| 3 | _yes _no | Are emergency exits provided, marked, and kept clear? |
| 1 | _yes _no | Are foot rails in place at the edge of the dock? |
| 3 | _yes _no | Are mirrors provided for "blind spots"? |
| 2 | _yes _no | Are storage areas of equipment, pallets, machinery marked and kept clean? |
| 1 | _yes _no | Are areas for drivers provided during loading and unloading? |
| 2 | _yes _no | Are pedestrian walkways clearly identified? |
| 2 | _yes _no | Are incline of ramps used for hand loading/unloading not too steep? |
| | | ***Training and Personnel*** |
| 3 | _yes _no | Is safety and health training provided to dock personnel? |
| 2 | _yes _no | Are employees tested or evaluated on their knowledge of safety procedures? |
| 2 | _yes _no | Are refresher courses in safety and hazard prevention provided to workers? |
| 3 | _yes _no | Are dock personnel trained in the use of bridge plates or dock levelers? |
| 3 | _yes _no | Are dock personnel trained in the proper care of heavy packages? |
| 2 | _yes _no | Are visitors given protective wear and area away from dock to congregate? |
| 3 | _yes _no | Are dock personnel familiar with using a manual and motorized equipment? |
| | | Are dock personnel provided with safety equipment (if applicable) |
| .5 | _yes _no | Hard hats |
| .5 | _yes _no | Weight belts |
| .5 | _yes _no | Gloves |
| .5 | _yes _no | Eye protection |
| .5 | _yes _no | Ear protection |
| .5 | _yes _no | Footwear |
| 3 | _yes _no | Are dock workers trained to secure loads for transport? |

*The above checklist is based on a ranking system of 1 to 3 points per question. A (3) is deemed critical, a (2) is deemed important, while a (1) is deemed optional. To find your total possible score, add the possible points column, disregarding those questions that are non-applicable. For each question answered "yes," give yourself the point amount given to that question. For each question answered "no," add no points. Add all your scored points. This will give you your total raw score. Now review your total raw score and make sure it complies with the following:*

*All the questions given a rank of (3) are answered "yes."*

*At least 80% of the questions given a rank of (2) are answered "yes."*

*Questions with a ranking of (1) are left to the discretion of the proper management.*

*If these compliances have been met, then your dock is in accordance with the safety measures we require. If this is not so, then adjustments and modifications must be made until the requirements are met.*

Eight of the ten groups functioned well. Their final designs were quite good. They succeeded, in part, because they were self-selecting and they shared a general interest in working on a real problem.

On the other hand, one of the eight all-freshman teams was not successful. No previous engineering work experience or effective leadership existed within the group. One student made his initial contact with the client regarding the design of a flow measurement system for two centrifugal pumps. He quickly assessed the situation, claimed the solution was easy, and stated that he should be done after just a few hours of work. He never included the other team members in the plans or their execution and they, in turn, never tried to participate, expecting this student to carry them through.

Other all-freshman teams turned in good-to-excellent reports. One team worked the mail room workstation lighting problem. As part of their presentation, they built a 3-D model of the room. The model ceiling had holes cut out at the existing lighting-fixture locations, and using a simple flashlight shining from above, the students were able to demonstrate the inefficiencies of the lighting grid. They then demonstrated how the placement of two additional lighting fixtures over the proper work area could correct the lighting. By exchanging the top of the 3-D model with the properly modified ceiling and shining the light through it, they were able to present their solution efficiently and observably.

Since students have generally been conditioned to work individually prior to entering college, one of our biggest challenges was getting them to work together. While team work is a novelty in the academic environment, when these students take on their first industrial co-op assignment, team work is often the expected mode of operation. An important feature of our approach is to develop team-working skills.

***Figure 1.*** *Student holding an iconic model made for Project #5 related to safety showers.*

Another related challenge was the division of work. While eight of the ten student teams handled the division of work quite well, in one team there was one student overly concerned about the "grade" and another more concerned about what he was "really learning." These two never reached a consensus about what the professor wanted and ended up giving individual solutions. Meanwhile, the group's third member watched in bewilderment while the other two argued constantly during team meetings.

Another poorly functioning group had a clear cultural divergence that led to little or no team effort. This group was not self-selecting, having been formed of late registrants who came to class for the first time on the second day. The members were from different countries and did not know each other previously. This team did not work well together primarily because one team member worked on the problem by himself and didn't include the other two members who, in this case, were satisfied that someone else was going to do the work.

We required two group reports and two presentations during the quarter. The first report was the proposal for the "client's approval" and was due about midway into the quarter. The corresponding presentations were limited to five minutes per group and were given on the day the proposals were due. The second, formal report described the final design solution intended to meet the client's needs. The second presentations were twenty minutes each and consisted of a summary of the design solution.

Several models, iconic (resembling the situation but not having the functionality) and analogic (not resembling the situation but having the functionality) were made by the groups as the projects progressed. Figure 1 shows one example of student creativity. The model shower pictured was made to help explain design requirements for American With Disabilities ACT compliance concerns.

Another group built a scale model of a process to recover silver generated in the University's photo labs. This model was constructed so that each major functional component could be removed. The students used the model during their presentation to help the class understand the functionality of their proposed silver-recovery system. The presentation was extremely rewarding for the class and the instructor.

## CONCLUSIONS

Open-ended, real problems are challenging to make work in the classroom. There is no instructor's solution manual available and each project is demanding, requiring constant attention by the instructor. Project paths can change as the quarter progresses. Common difficult situations center around a contact not responding or a group member not participating. Sometimes, design problems are too vague.

We encourage others to contact their Environmental Health and Safety departments to discuss a similar approach at their University. Not only will their students learn to alleviate persistent campus hazards, their school just might gain some inexpensive physical improvements.

## REFERENCES

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