

If You Let Them Build It, They Will Come: Hands-On Projects For Freshmen to Enhance Student Learning

James A. Newell
Department of Chemical Engineering
University of North Dakota
Grand Forks, ND 58202-7101

Introduction

The heart of engineering education is to facilitate the development of bright, creative students into highly skilled problem solvers. However, in many cases, students receive little contact with actual engineering problems or any “hands-on” experience until their sophomore or junior years. It is impossible to estimate how many potential talented engineers leave the major because of the lack of visible application for the chemistry, physics, and calculus that dominate their freshman year.

Christiansen¹ observes that “the aim of teaching is not only to transmit information, but to transform students from passive recipients of other people’s knowledge into active constructors of their own.” One mechanism for attaining this goal is to involve engineering students in “hands-on” projects as early as their freshman year. The benefits of such an activity are clear and many. Ohlsson² argues that the key to effective teaching is to emphasize the process of acquiring and applying disciplinary knowledge. Through these projects, students will have the opportunity to apply the knowledge that they have obtained in their preparatory courses.

However, it is not sufficient to simply assign a “pre-packaged” hands-on activity. To maximize the educational benefits of the project, students must be involved in all stages including project selection and scheduling. Fosnot³ observes that learning occurs “through engagement in problem posing as well as problem solving, inference making and investigating, resolving of contradictions, and reflecting.” Therefore, a complete educational experience would require student involvement in all phases of the project.

At the University of North Dakota, second semester freshmen take an Introduction to Chemical Engineering course that focuses on development of problem solving strategies and provides an overview of chemical engineering as a major and a career. This course uses the exceptional textbook “Strategies for Creative Problem Solving” by Fogler and Leblanc⁴ as a guide and a hands-on project serves as the major experience of the semester. The various presentations (oral, poster, written report) that result from these project serve as the basis for the majority of the grade in the class. The students have covered most of the material in the textbook prior to undertaking the major steps in the project. The freshmen are involved in seven distinct phases of this project. These phases are:

- I. Group Formation
- II. Project Selection
- III. Project Planning
- IV. Experimentation
- V. Analysis
- VI. Presentation
- VII. Assessment

The use of oral and written presentations as evaluation tools provides the students with an opportunity to clarify their thinking and understanding of the project^{5,6,7} as well as to begin to develop the important presentation skills valued by industry and ABET.⁸

Procedures

I. Group Formation

During the third week of the semester, students are required to form four-member groups. They are permitted to select their own teams. Typically, this is the first class in which students begin to identify themselves and their classmates as chemical engineers. Allowing them to select their own teams provides the opportunity for them to develop friendships and study teams with which they are comfortable. These study teams often carry through the rest of the chemical engineering curriculum.

II. Project Selection

By the fifth week of the semester, students are required to identify and select a project. The only direct guidance that they are given is that their projects must demonstrate a chemical or engineering principle and that it be suitable for the required presentations. They are also told that the project must have a budget of not more than \$50 (excluding basic chemicals and equipment) and that all group members must agree on the project. The lack of specific guidance is deliberate. They are asked to brainstorm for ways of obtaining and developing a project idea. Invariably, the potential resource list consists of the library, the internet, the other faculty, and the more advanced students. Typically, the freshmen will approach sophomore and junior chemical engineering students to discuss project ideas. In addition to providing ideas, this process helps to break barriers between classes and to vertically integrate the program. The project must be approved by the instructor before work can begin. Recent projects have included aspirin production, soap manufacturing, film processing, ester formation, measurement of lead-contamination in campus drinking water, electroplating, beer-brewing, and dyeing of fabrics.

III. Project Planning

Students are required to develop and submit a Gantt chart detailing the project timeline and a deployment chart which assigns individual responsibilities. In addition to providing a schedule for performance, the Gantt chart requires the student to break the project down into specific tasks. Thus, the development of time management skills becomes an additional benefit of this project. The students are also required to submit an itemized list of required materials and a detailed budget.

IV. Experimentation

The students are required to schedule time in the undergraduate laboratory to conduct their experiments. All members must be present during time in the lab. Additionally, either the instructor or the lab supervisor must be present during the lab time. Although the amount of lab time required varies by project, most groups require three to four, three hour intervals to complete the experimental phase of the project.

V. Analysis

Students are required to perform simple data analysis. Typically, they will generate plots involving means and error bars. They are expected to interpret their experimental results, discuss the key findings and limitations, and make recommendations for future study. All students have access to word processing, spreadsheet, and graphing software.

VI. Presentation

Results of the project are presented in three different ways. First, each group constructs a poster. This poster is presented during the engineering open house. During this event, students from local high schools are bused to the university. They walk through the engineering exhibits and posters and ask questions. Additionally, the dean and the University President also visit the poster presentations. Each team member is required to present the poster for a 45 minute period during the open house. The instructor evaluates both the poster itself and each individual presenter.

Next, each team provides a single technical report based on the project. This report consists of an abstract, an introduction, a results and discussion section, conclusions, recommendations, and references. The students are also given an opportunity to decide how points should be divided amongst their teammates.

Finally, every student gives a ten-minute oral presentation describing their project and key findings. They are evaluated by both the instructor and the other members of the class. Care is taken to make this a positive learning experience for the students and the evaluation and grading are performed with the recognition that this is the first public speaking experience for most students.

VII. Assessment

Students are asked to comment on the positive and negative aspects of the project during their course evaluations. The responses have been overwhelmingly positive. Students report that the projects were actually fun. They also say that while most of them were petrified of the poster and oral presentations, that they discovered that the presentations went far better than they expected. Students seemed to really enjoy the opportunity to apply their knowledge. Over 90 percent of students responded that they were more likely to remain in chemical engineering as a result of having taken this course.

References

1. Christiansen, C. R., D. A. Garvin, and A. Sweet, Education for Judgment: The Artistry of Discussion Dealership, Harvard Business School Press, Cambridge, MA, (1991).
2. Ohlsson, S., "The Enaction of Thinking and Its Educational Implications," *Scandanavian Journal of Educational Research*, Vol. 27, pp. 73-88, (1983).
3. Fosnot, C. T., Enquiring Teachers, Enquiring Learners: A Constructionist Approach for Teaching, Teachers College Press, New York, (1989).
4. Fogler, H. S. and S. E. LeBlanc, Strategies For Creative Problem Solving, Prentice Hall PTR, Upper Saddle River, NJ, (1995).
5. Schulz, K. H. and D. K. Ludlow, "Incorporating Group Writing Instruction in Engineering Courses," *Journal of Engineering Education*, Vol. 85, No. 3, pp. 227-232, (1996).
6. Hawkins, S., M. B. Coney, and K. E. Bystrom, "Incidental Writing in the Engineering Classroom," *Journal of Engineering Education*, Vol. 85, No. 1, pp. 27-33, (1996).
7. Newell, J. A., D. K. Ludlow, and S. P. K. Sternberg, "Progressive Development of Oral and Written Communication Skills Through an Integrated Laboratory Sequence," *Chemical Engineering Education*, Vol. 31, No. 2, pp. 116-119, (1997).
8. Engineering Accreditation Commission of The Accreditation Board for Engineering and Technology, "Engineering Criteria 2000", 2nd Edition, (1997).

Biographical Information

JAMES NEWELL

Dr. Newell received his B.S. from Carnegie-Mellon in 1988, his M. S. from Penn State in 1990, and his Ph. D. From Clemson in 1994. After one year as a Visiting Assistant Professor at Clemson, he became an Assistant Professor at the University of North Dakota in 1995. He was named the Dow Outstanding New Faculty member by the North Midwest Section of ASEE in 1997.