Introduction

One of the high points of engineering is the exhilarating experience felt when a product that you conceived, analyzed scientifically, designed, built, and tested performs as you had envisioned. The earlier the student has such an experience, the more likely they will be motivate to pursue the rigorous course of study. The projects and skills in this course are geared toward this type of experience.

The approach here is to begin with the physics and chemistry that the students have previously learned, apply it to an interesting situation that they may have encountered or at least had an awareness of earlier and then apply the engineering design cycle to use these principles to build a working model that can be constructed and evaluated against the design.

> The bottle rocket example demonstrates this approach. Some students (but not all) are familiar with a rocket made from a 2L soda bottle, water, and air pressure. The flights can go surprisingly high. In Experiencing Engineering project, the rocket is taken through a quantitative design and construction cycle. A concept diagram for the entire project is constructed. First Newton's Laws (which had been previously studied in an earlier Physics course) are reviewed and applied to the flight of the rocket, including stability and drag considerations. Then a design is developed using a NASA simulator. However, the number of simulations is restricted so that a strategy of experimentation, which goes beyond one variable at a time is formulated. The design optimizes the volume of water, air pressure, fins, nosecone, weight, and constructability including the materials. The students then construct the rocket as closely as possible. Finally the rockets are tested in the yard, measuring the height with altimeters. Finally, there is an analysis and detailed report. Thus, the project is simple (all of the materials launch pad, bicycle pump with gauge are available for about $50), affordable, doable. The mathematical complexity can be varied depending upon the background and strength of the class. For example, the simulator equations can be presented, the drag equations, the calculation for terminal velocity have all been worked out and can be used as appropriate.

The source book has all of the material required for this project. For example in the skills section, there are sections covering concept maps, strategy of experimentation and data analysis. In the project section, there is a Newton's Law review, an analysis of rocket flight conditions, NASA simulation example, data spreadsheet example, and rubric for the report. There are similar sections for the Calorimetry project and the bridge project.

There is also quite a bit about problem solving approaches, ranging from dealing with frustration, Polya type heuristics, 5 minute problems, Fermi questions and formats for multi-step problems. Many classes begin with a 5 minute problem. We all have to learn to recognize problems in ambiguous situations, clarify them and apply the most appropriate strategy.

The Data into Information section includes data analysis, graphical analysis, and risk management, strategy of experimentation, ethics, and Bayes probability theorem. These are all skills used by engineers. They are generally not formally taught. However, they are explicitly presented here not only because they are used in engineering, but can be applied by the student in many areas. Bayes theorem is an interesting case. It is barely touched upon in most Frequentist statistic courses, yet the premise that new information leads to better estimates is essential as well as the fact that nothing is perfectly determined. Anyone who knows a woman who has gotten a false positive on a mammogram will immediately recognize the usefulness of this understanding of conditional probability.

This Experiencing Engineering Sourcebook addressed a number of points:

- Provide an opportunity to experience engineering before it is time to make a selection of a college major or even a school. It is a palpable loss when a student reports that they would have majored in engineering if they had known about it. The option to study engineering closes off early, especially since many colleges do not offer an engineering program.

- The emphasis here is on doing something with previously known science, thinking about it, and extending it to doing physical projects. There is a trend in many introductory tests to teach basic skills and foundational mathematics with the carrot that once these have been mastered, there are interesting things to be done. The intent is to use the existing foundation. The complexity of the mathematics can be adjusted based on interest and background.
- The course can be effectively taught by a science educator with lab experience. An engineering background in not needed. The framework is designed so that a science educator can quickly see the principles and use them.
- Cost: This source material is provided without charge. Much of the material has been compiled from existing web sites (reproduced here and includes a link to the original material). The projects have minimal expense and can be done for $100 or less. The projects can be done for less than a laboratory class.
- Skills: The Problem Solving and Data Information sections are stand alone. There are several reasons for this. Specific topics can be summoned to any of the projects as deemed appropriate. (Suggestions are made in the schematics at the beginning of each project section.) Second, many of the skills are not formally introduced in any curriculum, but are useful analysis skills both in engineering and in life in general. (Specific examples include risk management, strategy of experimentation, graphics analysis, thinking in terms of probability)
- The projects each stand alone and the skills are in a separate section and can be summoned to any of the projects as deemed appropriate. Although it can be taught as a one-semester course, it is more intended as a source book, using sections as they fit into an individual's plans and goals.
- Revisions will be made based on users input. I tend to be succinct and suggestions are welcome

A note about my background and perspective

During my career, I have worked as a chemical engineer in industrial research at Merck & Co. retiring as a Director in Chemical Engineering Research and Development. Over a period of 25 years, this included process development in the pharmaceutical field, start-up of commercial processes, the design, construction and start-up of a pilot plant and managing research groups. With Pall Corporation, I was active in developing and commercializing filtration products and on-site process trouble shooting. In the 80's, I took a break from industry and was on the chemical engineering faculty of Polytechnic Institute in Brooklyn teaching undergraduate and graduate courses before returning to industry. I left industry again 6 years ago and am on the Science faculty of Bard High School Early teaching a wide range of classes form 9th grade physical science, HS science, College Chemistry and now an Engineering course.

This work is the product of my effort to address the nagging question of how to put the Engineering experience into the HS or early college experience. (The well-known STEM curriculum Science, Technology, Engineering, Mathematics) has traditionally been short on the E.