Teaching Methodology in a First-Year Engineering Course

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Abstract **To be a successful engineer a student must learn to apply her training in the solution of problems. A first-year design course is described based on two projects. The first project is internal and the second is sponsored by an external engineering company. The student learns from practice the elements of engineering by solving the first project, then applies them to solve the second, which is a "real-world" project. The methodology has been developed by teaching the course several times. It is spelled out in a week-by-week syllabus that introduces various design tools to the course. In teaching the course, several problems have been identified; these are described and their solutions discussed. The author plans to continue to develop the course and to quantify the results.**

To be a successful engineer a student must learn not only the technology of engineering science but also how to apply it in solving real-life problems. This is best accomplished by introducing best practices in first-year studies, reinforcing them in the intervening courses and culminating the education in a capstone project.

At Penn State Berks, the first-year engineering program uses two projects. In the first project the Instructor designs a simple machine from a kit such as Fischer Technik, Legos or Erector Set. Our best successes have been with Fischer Technik. The course guides the students through a reverse engineering process to analyze and test the Instructor's design, then improve on it.

Table 1 lists the weekly topics for this Simple Machine project which covers the first seven weeks of the course. Week-by-week the student learns how to analyze and test the existing design, then conceive and evaluate alternate designs.

The students do this in teams. The deliverables are a written team report and a team presentation to the Instructor and the rest of the Class. An important part of the course is to become proficient in working in teams, resolving conflicts and subjugating individual goals to team goals and achievements.

To supplement the two projects, the course introduces design methods, providing readings from engineering texts and quizzes based on these readings. The projects present students with the opportunity to use methods such as literature search, defining customer requirements, brainstorming, Pugh decision charts and conducting physical tests of prototypes.

The second project is proposed by a local engineering company, many of whom are members of our Industrial Advisory Council or The Learning Factory. This project gives the student to practice the application of what she learned in the first project.

New projects have been identified for each term that the course was taught. They have included medical devices, food-processing equipment, solar-panel installations, re-purposed surplus equipment and laboratory test equipment. The ongoing effort to identify these projects and keep a continuous flow of new projects has been beneficial to both the school and the engineering companies.

The outside company uses two documents to present their proposal to the students. The first is an overview of the company, their products and markets. The second is a work statement introducing the project and detailing the deliverables the company expects from the students.

We have always found the students to be enthusiastic about doing "a real engineering project". We prefer to use local companies so visits are easy to arrange. For most projects we schedule a student tour in the first weeks of the project. A second benefit for the students is that these local companies frequently offer internships and employment.

We experienced several problems in implementing this process. Intellectual Property Rights and Information flow need to be considered in a successful implementation.

Our school has a policy, which we believe is commonly held, that students own the Intellectual Property arising from their work at the school. Some companies are uncomfortable with this and have required all the students to sign IP and NDA agreements before beginning the project. Our policy is that any student has the right to decline and be assigned to another project (usually internal) which does not have these requirements. To date, no students have elected this option. Instead all of them have chosen to do the external projects, explaining these projects were more interesting and more beneficial to their studies.

Another problem that we recognized is the need to nurture the creativity of the students. For successful innovation, the students need to be able to ask the company questions to clarify a point, get specific operating parameters or to explore how the company might implement a specific student innovation. Because the teams operate autonomously, we needed a mechanism to distribute the questions and answers that one team received among all the teams. Initially, we had difficulties facilitating this bilateral flow of information between all the students and the individual experts at the sponsoring company. We tried several mechanisms, including group e-mails, GoogleDocs and Box but did not achieve the easy flow of information we sought. We had the best success when we designated two individuals, one from the school and one from the company, to manage the liaison. We encouraged everyone in both organizations to direct their questions to these individuals, who then managed the flow, asked the questions and distributed the answers.

The Instructor guides the student teams to manage the second project based on what they learned in the first project. During the last week of the second project the deliverables are a written report and a team presentation to the client company. The best presentations include prototypes, models, calculations and video demonstrations. We have allocated 15 minutes for each team to make their presentation and take questions. Given this time constraint, we discouraged power point presentations. Instead, we encourage students to use display posters with graphics, topics and key words to focus the discussion of their work with the sponsors. Representatives of the client company meet with each team, hear their presentation and question them. Usually the presentations lead to detailed discussions between the students and the company. The companies then award certificates to the teams for various categories of performance, i.e. best design, most innovative approach, and best development process. Hard copies of the certificates signed by the Instructor and a Company representative and suitable for framing are mailed to the student's home addresses.

Our experience has been that the lessons learned in this first-year experience have helped the students to understand the application of the engineering science material they study in subsequent years. This culminates in their capstone project where the members of our Industry Advisory Council and The Learning Factory are a source of real-life projects.

Having offered this course for several years, with a wide variety of client projects, the authors plan to measure the effectiveness of this program in several ways. They will query the students at the beginning and end of the course to capture their incremental knowledge about engineering projects. They also plan to query the client companies to learn what value they receive from the projects.

Table 1: Analysis of Simple Machine Project

Lesson 1	Literature search; Simple Machines; Design Methodology
Lesson 2	Hand-sketch & CAD drawings of the kit parts and the assembly
Lesson 3	Build existing design from CAD drawings; Test using procedures written by Instructor
Lesson 4	Create matrix of Needs and Features; List customer needs
Lesson 5	Teams use brainstorming and negotiation to create alternate designs
Lesson 6	CAD drawings of alternates; Build and test alternates
Lesson 7	Evaluate Alternates for Needs and Functions matrix; Pugh to select best
Week 8	Write Final Report. Make Poster Presentation to Rest of Class

Table 2: Design of Company Project

Week 0	Company Presentation to Class
Lesson 1	Literature search of the Company, their products and their competition
Lesson 2	CAD drawings of the elements of the interface
Lesson 3	Create matrix of Needs and Functions
Lesson 4	Team does brainstorming exercise of possible solutions
Lesson 5	Layout, CAD and Build Design solutions
Lesson 6	Test designs; Populate Needs matrix; Pugh selection
Week 7	Final Report and Poster Presentation to Company