Abstract

In the senior year of an engineering program many students will have the opportunity to enroll in courses that offer Capstone engineering design projects [1]. In many engineering students’ educational career these are the most interesting and rewarding courses because they offer the student the ability to apply the culmination of their education to an engineering design problem. This is often described favourably by the student as their first “engineering” experience and in general it provides a greater appreciation for the field of engineering and a motivation for greater knowledge. If this type of experience could be offered to first year students it would significantly enhance their engineering education. However, the challenge for a first year engineering program is balancing the required background knowledge for design against a procedure for demonstration; this is an even greater challenge for a common curriculum. Just as the Capstone represents the tip of an engineer’s education, we offer the Cornerstone Design to represent the base [1-2]. The objective of the Cornerstone is to instill in first year engineers enjoyment from learning, motivation to continue learning, and genuine intellectual curiosity about the engineering in the world around them. This paper will present our work in structuring and delivering the Cornerstone Design Project as a product dissection and modeling to 1000 first year engineering students in a Design and Graphics course. The paper will also report on student feedback regarding the project and its effect on their motivation and engagement to the course material.

2. Design and Graphics in First Year Engineering

McMaster University's first year engineering class has an enrollment of 850 to 1000 students per year. It is a common first year with approximately half of the students taking the Engineering Design and Graphics course each term (September – December, January–April). In the summer term, the course is offered with a limited enrollment.

The Design and Graphics course has two primary objectives in engineering design: visualization and technical communication. Students develop graphical visualization skills through technical sketching and explore technical communication through two-dimensional and three-dimensional computer-aided design. At the conclusion of the course the student have learned the necessary skills to read engineering drawings, create engineering drawing, and how to design using the solid modeling methodology.

The Cornerstone project was first offered in the summer of 2007 to 41 students. The summer enrollment is largely composed of students that struggled with the course material during the regular session. With the high attrition rate in engineering programmes [4], there is a pressing need to motivate students through differentiated instruction and practical application. This group of students was the first test case to determine if a dissection/reverse-engineering project would effectively meet this requirement. At the conclusion of the summer course, the project was very well received by the students. The best illustration of this enthusiasm was the response...
that “I actually felt like I was an engineer.” Based on the success of the summer course, the project was embedded in the regular first year course and has since added a course competition between the terms.

2 Dissection / Reverse-Engineering

As engineering accreditation bodies require more outcome-based curriculum and increased design content there has been some shift towards what the student can do rather than what the student will know. The dissection method of teaching design has been applied to freshmen engineering courses [5-8] as an effective method of teaching design and introducing engineering practice.

2.1 McMaster Engineering Freshmen Year

The McMaster University engineering freshman year is a common curriculum providing the foundation for upper year courses, regardless of discipline. The design and graphics course is composed of weekly lecture, CAD laboratories, and freehand sketching tutorials. The three components run in parallel: lectures introduce new topics; labs develop CAD and solid modeling skills; and tutorials teach technical freehand sketching and visualization skills. While each was effective, students had some difficulty resolving the connection between each component. The dissection approach was introduced to tie lecture, laboratory, and tutorial into a cohesive target to enhance motivation and overall learning.

2.2 McMaster Engineering Cornerstone

The McMaster Engineering Cornerstone project uses the dissection/reverse engineering approach. Groups are restricted 3 members within the same lab section and the dissection product is assigned based on laboratory day. There are ten lab sections, with two running per day. The five products selected for the September 2007 offering were: mechanical ball mouse, wind-up LED lantern, disposable camera, random orbit polisher, and a machine counter. Products are selected based on number of parts, safety, cost (<$15), and availability. Using off-the-shelf products can make product equivalence a challenge; a scaling factor is incorporated into the evaluation to compensate for differences. The project is divided into two components: conceptual and applied. The conceptual component is a group submission, whereas the applied component has both group and individual elements of assessment. After the final submission of report and CAD files the individual group members then complete peer- and self-evaluations.

3 The Cornerstone Project

The project is framed as the group being newly hired engineers and as a small team their first assignment is to evaluate a competitor’s product. Based on preliminary data from a pre-production model, the group must first conceptualize how the competitor’s device works. Once receiving the production model, the team's task is to benchmark the product and create a technical report with a complete set of engineering drawings.
3.1 Conceptual Component

With only a visual inspection of the exterior of the product the team must sketch several isometric pictorials and explain how the product works in a short report that references additional hand sketches of the internal operation. Based upon their explanation, the group must also state the total number of parts they believe make up the product and propose a benchmark procedure.

This component has two goals:

1. independent research, and
2. technical communication.

The project products are selected to be inexpensive and commonly available, so that most students would have likely used that product or one similar in function. It is this familiarity with the product that offers the most poignant result; many of the students must admit that they do not know how it works.

For most students, this is their first design and graphics course. The project is introduced after they have developed the basic skills in technical freehand sketching and software part modeling. The technical report requires them to assess how they communicate the conceptual design effectively between members and for the final submission.

3.2 Applied Component

In the second part of the project the group must:

1. benchmark the product and record results,
2. disassembles the product,
3. measure and model each part using a solid modeling software application,
4. assemble the product in the software application,
5. re-assemble the physical product,
6. benchmark the product and record results, and
7. write a technical report of how the product works with a complete set of engineering drawings.

As a group the members divide the parts evenly among themselves for modeling and then combine them together for the final assembly. A level of approximation is permitted according to the part complexity and mechanical function, for example, a part which is key to the mechanical function of the product would be permitted very little approximation. The assembly required the group to integrate their parts and to make modifications for minimal interference.

The final report consists of a technical description of operation, benchmark results, bill of materials, a part characteristics table (surface area, volume, radii of gyration), and a complete set of engineering drawings using the CSA drawing conventions. The material and finish are not required components of the assignment and all parts are assigned a density of 1 kg/m$^3$.

The group is assigned a time for an oral examination on the project and related course components. From this examination a portion of the group work is assessed as well as an individual mark.
4 Results

4.1 The Final Product

Figures 1 - 3 illustrate the quality of final submissions and the complexity of the products. In general, all submissions are of similar high caliber.

Figure 1: Overview of past projects.

Figure 2: Example-1 of project complexity and detail.
4.2 Student Feedback

The September 2007 offering of the freshmen design and graphics course had 420 registered students with 388 (92.4%) students voluntarily participating in the project survey. The course requires no prior sketching or CAD experience and as figure X shows, 72.3% and 73.9% have no prior experience, respectively. Student response was very positive with 84% responding that the Cornerstone project was an effective method of practicing and enhancing the course material. The project also increased the motivation to learn more domain specific knowledge and to learn more general engineering knowledge in 60% and 68% of respondents, respectively. The following student quote illustrates the positive response:

“It was a demanding but very rewarding project since it utilizes every aspect of the course and shows you what engineers must do to create parts. I had no previous drafting experience but after working through this course I feel confident in my ability to create parts through the three stages of design. This project and course are probably the most important part of first year engineering.”

The observations are significant when considered against the fact that the majority of first year students have no background in drafting/sketching and CAD (see figure 4).
5. Discussion and Conclusion

The Cornerstone project has proven successful at implementing a “hands-on” problem in the practice of engineering that offers a balance between being fully open ended and completely prescribed. Through this balance the student feedback has confirmed that this project has provided an enjoyment from learning, a motivation to continue learning, and a genuine intellectual curiosity about the engineering in the world around them.
Bibliography


