A Note on Mechanical Dissection with Pre-college Students

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ABSTRACT

Engineers design and build machines to fulfill human needs. Very few of these machines are completely new from the ground up; most are the result of engineers taking existing subassemblies and components, modifying them, then marrying them together into a complete system. Lest this task sound rote and lack-luster, there is considerable creativity involved in this process. True design inspiration is often the result of seeing the novel application of a mechanism. This means being familiar with the myriad machines and mechanisms that surround us, and being able to see their use in domains far beyond their original intent.

This paper begins by discussing a lab-based course created at Stanford that gives freshman and sophomore level mechanical engineering students hands-on exposure to machines. This course provided the impetus for the development of dissection exercises for use with pre-college students. This development is the main topic of this paper.

1 BACKGROUND

1.1 Mechanical Dissection at the College Level

A course called "Mechanical Dissection" (ME99) developed at Stanford and sponsored by the National Science Foundation Synthesis Coalition attempts to get students to ask (and learn to answer) the question of “How did others solve a particular problem?”. It is based on the hypothesis that current design and mechanics courses can be made more meaningful to students if preceded by a lab-based course aimed at exposing students to the technology that surrounds them. This is especially true for students who have had limited “hands-on” experience in their lives. We believe that students should and can improve their ability to reason about function and form in mechanical designs. The course is designed to be positioned as a foundation experience, prior to mechanics courses. It is targeted at freshman- or sophomore-level engineering students and assumes exposure to basic physics but *no* prior exposure to the vocabulary of engineering, statics, strength of materials, or sketching.

Specifically, the course objectives are to:

1. give mechanical engineering students an <u>understanding of machines</u> through hands-on dissection experiences and exposure to the vocabulary of mechanical systems.

   In order to achieve this objective the students in ME99 participated in four actual “dissections”, consisting of the disassembly and reassembly of various machines. Each dissection was preceded by a discussion or activity that related to the external functioning. Some of the machines considered were a ten-speed bicycle, a dot matrix printer, and a fishing reel.

2. develop an <u>awareness of Design Process</u> through hands-on design exercises. These exercises highlight the importance of functional specifications in design and how they map into specific functions, and the non-unique mapping between functional specifications and the final design solution (*i.e.*, multiple solutions).

3. make students aware of the <u>power of clear, concise communications</u> (oral, written and graphical). An example of how this achieved is by having them present descriptions of machines and critique each other’s work.

4. develop <u>resourcefulness and problem solving skills</u> through labs that require students to acquire an example of a class of machines then reason about the function.

In some ways this course can be thought of as a case studies course, where the case is the hardware itself. The objectives of ME99 could be likened to learning language; we start exposing our children at a very young age to stories and literature by reading to them, and then at a slightly older age we teach them the rules of language and encourage them to read as well as create their own stories. ME99 is a course about exposure; exposure to the language of the mechanical things that surround us. It is an exposure that may be missing for many students in our current programs. Furthermore, we believe that such early exposure has the potential to impact subsequent courses.

1.2 Mechanical Dissection in Pre-College Years

In working with the students during the first offering of ME99 in the fall of 1991, we began to realize that the early “exposure” mentioned above should start well before the freshman year in college. Students who feel comfortable with the machines that surround them are more likely to choose engineering as a profession or at the very least be more informed consumers. Ideally, “exposure” should start when students are very young, then be reinforced time and time again as they progress through primary and secondary grades.

To experiment with middle school students’ interest in seeing how things work we offered a workshop module during the San Jose State University-sponsored “Expanding Your Horizons Conference” in the Spring of 1992. “Expanding Your Horizons in Science and Mathematics Conferences” (or EYH) started in 1976 as a single grassroots conference. Their purpose is to encourage young women to enter mathematical, scientific, and engineering careers. Recognized by the Congressional Task Force on Women, Minorities and the Handicapped in Science and Technology in 1989 as “an exemplary program,” EYH has expanded to included 115 sites nationwide (of which San Jose State is one) that reach over 30,000 young women annually, present them with thousands of female career role models as well as expose them to many career choices in science, mathematics and engineering.

The balance of this paper looks at the development of a workshop module for use with middle school students as part of an EYH Conference, implementation of the module, and future directions in our work.

2 OVERALL OBJECTIVES OF THE WORKSHOP MODULE

In developing a dissection module to be used with young women in an EYH Workshop module we established a number of objectives. We wanted the students to:

1. have a positive (i.e., successful) experience in disassembling and reassembling a machine.
2. develop an understanding of the relationships between power storage, power transmission and control.
3. extend the ideas developed in item 2. to a number of other machines.
4. work with practicing engineers and engineering students as role models.

In the next sections we discuss how we realized these objectives.

2.1 Selection of a Machine

In selecting a machine for the students to work with we identified several requirements and constraints:

- the machine had to be small enough to fit on a desktop workspace, while at the same time it needed to be large enough for two or three students to be able to work on it and see what was going on
- the machine had to be light enough for middle school-aged students to maneuver
- disassembly and reassembly must be possible without destroying components
- unit cost must be less than $10
- few tools should be required for assembly and disassembly
- the machine should have multiple actions
- students should be interested in the machine.

We thought of a number of different machines (e.g., blenders, carburetors, cameras, clocks) but none of these really fulfilled the majority of the requirements/constraints listed above. We found the most fertile "hunting ground" to be toy stores, hardware stores, and second-hand shops. There we found numerous possible machines for use in the workshop (e.g., food scale, razor, tape player).

We ended up selecting a plastic toy made by the Tomy company. This toy is deceptively simple: the user pulls on a "baby" animal tethered to its "parent". Upon release of the "baby", the tethering string retracts, pulling the "baby" to the "parent" and the "parent" flaps its wings. When the "baby" reaches the "parent", flapping ceases and the "parent" rolls across the surface upon which it is sitting.

Now that we had selected a machine we could start developing the lab.

2.2 The Lab Write-up

The task of developing the structure or context in which the students would disassemble and reassemble the toys was a balancing act; we wanted enough structure so that the task could be accomplished in the time allotted (fifty minutes in this case), but enough freedom so that the students could ask questions, make a few mistakes, and still recover. The lab sheet that resulted included:

- a specified initial step during which each team worked with their machine and clearly identified the specific steps of operation
- a check-list of disassembly/reassembly instructions (including warnings about particularly difficult and/or critical steps)
- color photos of the interior with labeled components
- questions for the students to answer in written form in which they mapped the internal mechanisms to the external function.

As part of the lab we built a working foam core model of the key internal components. This model was invaluable as a teaching aid, as will be discussed below.

2.3 Implementation

Students worked in teams of two during the lab. Each team was supplied with a toy, necessary tools, a receptacle for collecting parts, lab write-ups (one per student), and a coach. Coaches were all engineers or engineering students. We got the coaches together for several hours during the week prior to the Conference in order to brief them. This included actually going through the lab and having them experience firsthand some of the potential failure modes of the toy. Because the module was being presented to young women, all of the coaches were women.

The role of the coaches was to give the groups guidance when and if needed, and to point out interesting features of the toy design. It was up to the students to actually disassemble and reassemble the toys.

The first ten minutes of the 50 minute lab were spent giving an overall introduction (e.g., team members meeting one another, discussion of what the teams would be doing during the hour), and having the groups “play” with their toy. The next thirty minutes were spent in disassembly and reassembly of the toy. The coaches took the teams up to the foam core model (which was located at the front of the classroom during this period) where they could point out components and their functional relationship to each other and external performance. Using the model, the coaches could also show the teams how the mechanism and power source in the toy could be modified slightly to realize the carriage release of a toaster, or the up-and-down motion of a sewing machine. The coaches also monitored their team's progress and suggested when reassembly should begin (we wanted to make sure that all toys were up and running by the end of the session).

During the last ten minutes we brought the entire group back together to review concepts and their reaction to the experience.

3 EXECUTION AND FUTURE DIRECTIONS

On March 14, 1992, the lab module described above was offered on a voluntary basis to sixty young women as part of the EYH Conference at San Jose State University. The majority of the students appeared to be very interested in the exercise. They were surprised by what they saw inside and that they were actually able to reassemble the toy such that it worked in the end.

In observing the students' interactions with the machines and each other we became acutely aware of several things:

- The selection of the machine to work with is critical. In retrospect, the toy that we choose was too complex for a fifty minute exercise; at least 1.25 hours should have been devoted to the exercise. The short period of time made the presence of coaches critical. While most of the young women were excited by the toy, several were decidedly unenthusiastic. One possible reason may be that they felt that this particular toy was "too young" for them. Selecting a machine that they can more easily relate to might generate more universal enthusiasm within the group.

- One session of taking machines apart is not enough to get students comfortable with the concept of "tinkering". It seems that a certain comfort level may be achieved only through the process of disassembling and reassembling a number of machines. This observation has led us to design a series of dissection exercises for use in a middle school classroom. This is where we are currently directing our energies.

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Key Words

Mechanical dissection, design process, exercises, tinkering, machines