2006-1310: UNDERGRADUATE STUDENTS TEACHING CHILDREN: K-8 OUTREACH WITHIN THE CORE ENGINEERING CURRICULUM

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Undergraduate Students Teaching Children: K-8 Outreach within the Core Engineering Curriculum

Abstract

Outreach teaching is successfully implemented as a final project in core courses at UC Berkeley within the Bioengineering and Mechanical Engineering curricula. These activities have been ongoing since 1997. These courses include Mechanical Behavior of Engineering Materials, Polymer Engineering, and Introduction to Biomaterials Science. These final projects entitled "How Things Break," "Fantastic Plastic", and the "Human Body Shop" have been presented to children at the Lawrence Hall of Science (LHS), which is the public science center/museum at the University of California at Berkeley. A recent example, which will be described in this paper, is from a course entitled *Structural Aspects of Biomaterials* offered to junior and senior-level undergraduate students at UC Berkeley. The students who take the course are traditionally split between the Mechanical Engineering and Bioengineering programs. For the past two years, the final project has been to design an exhibit for the Lawrence Hall of Science, based upon topics learned in lecture. These topics vary from specific medical devices (replacement heart valves, total joint replacements) to engineering issues (fatigue and fracture, viscoelasticity). Working in teams, the students research various aspects of their topics and develop lesson plans for the exhibit. In addition to primary lectures by University faculty and researchers, the students receive instruction from LHS science educators and exhibit designers on current practices in communicating science to children and the public. On the exhibit day at LHS, the student teams present activities and demonstrations of their chosen topics as well as age-appropriate literature and assessment activities designed to measure the children's learning to a target audience of LHS visitors, children ranging in age from 4th to 5th grade who visit the museum. This final project has enormous potential for learning for both the undergraduate students and the younger children. The undergraduate students are given the unique experience of determining how engineering lessons can be most effectively presented while the younger children are exposed to interesting engineering research and applications in a format that is designed to attract and hold their attention. The lively interaction between undergraduates and the visiting children is a rare opportunity for a diverse group of youth to interact with University students, encouraging the children's interest in pursuing science and engineering as future educational objectives. The goals for this project are described in greater detail in this paper, along with the basic requirements and outcomes.

Introduction

The implementation of an outreach project based on student-teaching and group work concepts offers enormous benefit to all participants. The undergraduate students are engaged in an active learning process, while the 4th and 5th grade students who are being taught gain insight into engineering applications and solutions to common problems. Many educators agree that K-12 outreach is a vital part of maintaining and/or improving the numbers of students who study engineering at the university level[1,2]. Furthermore, although children are naturally interested in the technologies they see in everyday life, they are not always in contact with adults who have the expertise to entertain their questions. For these children, an outreach program can offer exposure to engineering skills such as analysis, development, building and testing through hands-on activities[2]. Boston's Museum of Science lists several reasons why engineering should be introduced to children at an early age. These include gaining the problem-solving skills learned through studying engineering, increasing motivation to study math and science by demonstrating relevant applications for these disciplines, and increased awareness for girls and minorities that engineering might be the right career for them[3]. Programs such as the GK-12 Fellows at the University of Colorado at Boulder, which develop curricula and activities for K-12 teachers, are shown to have a positive impact on K-12 teachers and students[4].

Student teaching and group work also have many beneficial aspects for undergraduate students. Humphreys et al.[5], Mooney and Mooney[6], and Smith et al.[7] affirm that traditional lecture-based teaching is not always the best way to impart information to undergraduates, and that they will profit from a more active role in their own learning. Mooney and Mooney also acknowledge that "… one learns more completely what one has to teach rather than what one simply hears or reads…"[6] and thus, by involving undergraduates in a student-teaching project, they will be required to gain a deeper understanding of the subject matter. Furthermore, group work is recognized as an important skill which is necessary for all engineers graduating from ABET-accredited programs[8]. The field of Bioengineering is inherently interdisciplinary. Newstetter says that Bioengineering "demands integrative thinking, cognitive flexibility and interdisciplinary problem solving,"[9] and all of these skills can be developed through group work with mechanical engineers and other bioengineers with different skills. With these facts in mind, the final project for *Structural Aspects of Biomaterials* was developed.

Structural Aspects of Biomaterials has been taught at the University of California at Berkeley for the past five years. This course is offered to junior and senior-level undergraduate students in both the Bioengineering and Mechanical Engineering departments, and is meant to highlight the intersections of these two fields through a focus on the mechanics of both natural and synthetic biomaterials. The typical course size is approximately sixty students. The syllabus of the course has undergone small changes while largely maintaining the same course objectives. The course content is summarized in Table 1. Topics covered include: basic mechanics of materials, tissue types and histology, synthetic biomaterials, orthopaedic applications, cardiovascular applications, and soft tissue applications. By the end of the course, students are expected to have an understanding of the relationship between the microstructure of a material and its mechanical properties as well as an appreciation for issues in medical device design and Food and Drug Administration (FDA) approval.

Goals of the Final Project

In designing a final project, the following objectives were kept in mind. The project had to demonstrate the students' knowledge of course content. Since this project is in lieu of a final, it was necessary that students display a strong understanding of the various topics covered in the course. The students were also to demonstrate outreach to the 4^{th}-5^{th} grade age group. This project was developed in collaboration with the education staff at the Lawrence Hall of Science (LHS), UC Berkeley's public science center/museum. Students from 4^{th} and 5^{th} grades make up a large part of the population which visits the Lawrence Hall of Science, often as part of school field trips. Finally, the projects were all conducted in teams, giving the undergraduates the valuable experience of working with their peers to accomplish a common goal. According to established best practices for implanting group work at the college level, the project teams were selected by the instructors and included different majors[10,11].

The staff members from LHS graciously offered their time to the students of this course by giving a project kick-off lecture, and by coming to class to evaluate the teams' progress midway through the semester. The final project was introduced to the students early in the semester, so that although they would not yet have all of the content information they needed, they could spend some time visiting LHS to get an idea of what museum exhibits could look like and thinking of creative ideas for display.

Project Development

In the kick-off lecture, students were shown past projects and given some guidelines for language and print size that would be appropriate for posters/signage. The students were also given the basic requirements of the project. In the early iterations of this project, it was found that the best way to have a diverse set of exhibits was for the instructor and teaching assistants to develop a list of ideas and have the students select from that list. In other years, students were allowed to submit proposals, but similarities between different teams' ideas often necessitated instructor intervention to assist in choosing new topics. For the Spring 2005 semester, the overall exhibit was entitled 'The Bionic Bear' to honor UC Berkeley's mascot and students were asked to select topics from a list which paired medical implants with design considerations, for example, "total hip replacement/wear" or "heart valve/fatigue". These medical implant/design consideration pairings were developed so that each engineering concept would be taught with a relevant application, as shown in Table 2.

Another element of successful group work is having a highly structured project[7,12]. To this end, various benchmarks were described which assisted students in developing their project over the course of the semester. These were:

- A write-up which included the history of the device and the current state-of-the-art configuration
- A lesson plan in a specified format
- A two-minute "elevator speech" demonstration for their peers, teachers and LHS staff
- Feedback on the project day from the elementary school students and LHS staff
- A write-up which detailed the project development, evaluation and lessons learned
- Team members' evaluations.

The written lesson plan encouraged the students to think about their exhibits from the point of view of "teachers". They were asked to develop one or two lesson objectives, explain their hook (how they planned to draw the children in), give details about their activities and assessment, and generate a list of the materials they would need for their exhibit. LHS supplied tables and electrical hookups as well as limited reimbursement for materials purchased, but students had to rely heavily on creativity to produce much of their exhibits. Students were mostly unfamiliar with developing a lesson objective. Although it was relatively simple to think of an activity that demonstrates how a pacemaker works, it was much more of a challenge to write down in words, exactly what they wanted the children to know by the end of their time together. Bloom's Taxonomy was introduced as a method for developing and evaluating lesson objectives[13].

The two-minute speech was to give the undergraduates the experience of pitching an idea quickly and concisely. They were asked to bring a working (but not necessarily finished) model of their exhibit and to explain their objectives and assessment. This was also the main opportunity for the teams to get feedback on their work before the big day.

Exhibit Day

On the day of the exhibit, all teams were asked to report to the museum for set-up before it opened. The LHS staff brought school groups through the museum by splitting them into two groups: while half the children were upstairs looking at exhibits, the other half was downstairs working with educators. After an hour or so, the two groups were scheduled to switch. Thus, the undergraduate students experienced a large influx of children when the school groups were admitted into the museum, which gradually tapered off as the children finished visiting every table. As the children's groups switched, the undergraduate students were again challenged by large groups of children. There were approximately 100 children in the exhibit area at any time, along with adult chaperones. Although, in the first year, many teams tempted children to their exhibits by using candy, this was discouraged the second year. Thus, teams resorted to extravagant costumes to pique children's interest. All groups were asked to provide a brochure that children could take as a memento of their exhibit. One group, whose topic was Balloon Angioplasty, created quite a craze by giving away balloon hats with their brochures. Another group, demonstrating sutures, had each child who visited their exhibit thread a suture through the pages of their brochure to practice being a surgeon. Some images of these projects are shown in Figure 1.

Evaluations

The objectives of this project for the undergraduate students were to demonstrate knowledge of course content and to provide outreach to 4^{th} and 5^{th} grade students. The undergraduates' mastery of course content was evaluated through written assignments over the course of the semester detailing their project development, as well as their performance on exhibit day (judged through observations) and a final written assignment evaluating their own performance in the exhibit. Knowledge of key course concepts such as the history of each group's implants and a structural analysis of the current state-of-the art was demonstrated clearly in the written assignments. Observations and self-evaluations provided insight into the value of this project as a teaching tool for the undergraduate students.

Some of the lessons learned by the undergraduates included:

"The best thing we did was keep things simple…"

"Calling on students specifically was important, although it may have put them into an awkward position; it discouraged lazy listeners and encouraged active participants."

"The hands-on activity was a much better success than the under utilized posters that we had prepared as background reading-- interactive is the way to go."

On final class evaluations, the majority of students (85%) stated that they preferred the final design project to the traditional final exam. While challenges of group work are documented to include unequal workloads, personality conflicts and scheduling difficulties among group members[14], there were few complaints regarding these difficulties in the course evaluations. Comments regarding this final project as opposed to a more traditional final exam included:

"The final project at LHS was great and a fun way to teach what we had learned to children."

"The project was far better than a traditional final exam-- although it is a lot of work."

"I genuinely enjoyed these presentations and plan to do more through the summer and next year. I am particularly interested in doing sessions with middle or high school girls discussing medical devices for women while encouraging more women to pursue engineering in the university."

The objectives of demonstrating knowledge of course content through outreach to 4th and 5th grade students were clearly met and the undergraduate students showed enthusiasm for what they gained from this experience.

Each undergraduate team had developed teaching objectives for their exhibit, however there was no formal emphasis on assessment of the children's learning. The children were asked pertinent questions about exhibit topics by the teaching assistants. These evaluations were always amusing and surprising. While very few children were able to independently discuss the details of what materials are best for dental implants, several demonstrated an understanding of broad concepts such as how resorbable sutures work or why creep should be avoided in artificial tendons.

Future Plans

This style of final project has been highly successful at both the undergraduate and graduate levels. Nevertheless, small improvements could be made. In the example described in this paper, the students were asked to choose topics which paired a medical implant with a design consideration. However, many groups had a much more difficult time finding time- and age-appropriate ways to discuss topics such as Plastic Deformation or Sterilization than they did in presenting their medical implant. LHS staff felt that the amount of time that the teams were forced to use on the design considerations detracted from the discussion of the medical implants that the younger children were more likely to appreciate. In future years it would be possible that the design considerations would be a greater part of the written work but a lesser part of the exhibit. One student did an alternate project by designing a classroom lesson and teaching it at a local school. Extending this option to more students could allow those who want it to pursue a more formal teaching experience. Further integration into the 4th and 5th grade classrooms through developing classroom materials which could be distributed ahead of the exhibit day could also increase the impact of this project. Finally, improved assessment tools would provide valuable feedback for the project's continued evolution. A more formal assessment of the undergraduates' experiences during the exhibit would assist in maximizing the project impact for the next year's students. Adding a more systematic assessment of the children would also provide feedback for the undergraduate students indicating teaching strengths and weaknesses.

Conclusions

The collaboration between LHS and UC Berkeley in creating exhibits which expose children to engineering concepts is ongoing. This final project provides a unique opportunity for undergraduate students to demonstrate their grasp of the subject matter taught in *Structural Aspects of Biomaterials* while informing and entertaining children who will hopefully take home a renewed interest in math and science and the goal of becoming engineers!

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Table 1: Class syllabus for Structural Aspects of Biomaterials

Overview of Biomaterials
Review of cell and tissues, structure-function relationships
Biocompatibility, foreign body response, and wound healing
Medical devices and FDA regulatory issues
Synthetic biomaterials and sterilization technology
Review of important mechanical properties
Biomechanical design issues - Plastic deformation - Fatigue - Fracture - Wear - Corrosion
Orthopedic tissues and biomaterials - Structure and function of orthopedic tissues - Mechanisms for damage and disease - Clinical treatments
Cardiovascular tissues and biomaterials - Structure and function of vascular tissue - Etiology of cardiovascular disease - Clinical treatments - Vascular devices - Biomechanical design issues pertaining to stents, balloon angioplasty, and pacemakers
Soft tissue reconstruction - Structural Properties - Wound healing - Stability - Biofixation
Dental tissues and biomaterials - Structure and function of dental tissues - Progression of disease - Clinical treatments - Dental materials/restorative materials
Tissue Engineering: Current issues and Future Directions

Table 2: Paired medical implant/design consideration topics

Medical Implant	Design Consideration
Stents	Shape memory
Pace Maker	FDA Approval
Balloon Angioplasty	Sterilization/ Biocompatibility
Vascular graft	Compliance match
Intervertebral disk	Plastic Deformation
Tendon	Creep
Corneal implant	Hydration/lubrication
Heart valve	Fatigue
Dental implant	Fracture
Total hip replacement	Wear
Fracture fixation	Corrosion
Contact lens	Surface treatments
Facial implants	Fixation
Sutures	Resorption
Cochlear Implant	Design requirements
Electroactive Muscle	Materials Selection

Figure 1: Photos of Exhibit Day at LHS. Demonstrations included (a) contact lenses, (b) creep, (c) pacemakers and (d) corneal implants.