Freshman Biomedical Engineering Design Projects: What Can Be Done?

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Abstract: During the 2000 ASEE meeting the question arose in the Biomedical Engineering division about the paucity of information on design projects for freshman introductory design courses (cornerstone courses.) This paper will present an overview of what can be gleaned from the literature on such projects.

Introduction: Design challenges in a freshman level introductory course can serve to introduce a student to the design process early in their career. A successful application of what skills an early engineering student has can lead to increased retention and interest on the part of the students. Finding the right personnel to man such a course, and finding the right design challenges, is necessary for a good experience. This paper will address the challenge of finding good design problems for use in Biomedical Engineering projects in a freshman course.

Methods: Several of the methods to generate these projects are enumerated below:

1. Go beyond your teaching team: The engineering faculty at Vanderbilt University were surveyed by the faculty in charge of the freshman introductory engineering course for design projects. This course covers the use of Excel, MATLAB, VRML programming, and very basic web page design, and concludes with a project and a project fair. The end result was a listing of design projects that could be used for all majors in the course, a listing of the BME specific design projects may be found in Appendix 1. Eight faculty from four departments proposed projects, all of which were attempted by student groups. A listing of the project titles and the basic skill required may be seen in table 1. It is worth noting that the skill level assumed in every case was that of the entering or mid semester freshman level.

Topic	Skills needed
Bone Density	Excel analysis
Peripheral Vascular Diseases	Literature survey
Bioreactor design	Literature survey
Fiber optic design	Literature survey
Assistive devices	Rough design layout
Spider web site	Web design
Free electron system	Literature survey
Prosthetic arm	Literature survey
Rooftop wheelchair design	Mechanical design
Reaction rates	MATLAB analysis
Cough monitor	Device specification

Table 1: Example Freshman Biomedical Engineering Design Projects and Skills Needed

2. Steal from the Senior Design course: Another suggested source of design projects is the current senior level design course. Some projects can be scaled down for introductory purposes, some can indeed be solved by freshman design teams, and some are already at the right level. Some example suggestions from the senior design course at Vanderbilt (taught by this author):

- Several projects at a local school for the severely handicapped involve rudimentary mechanical design skills. Freshman design teams can solve these.
- The local Cerebral Palsy foundation often has a list of needs for individual clients, such as a need for a ramp or other aids.
- VRML programming, often used in freshman design courses to give virtual tours of dormitory rooms, can also be used to design teaching programs for basic anatomy or function, such as visualization of the heart. Find some example teaching examples.
- A lecture or two on safety and the need for guarding, warning, etc. can form the basis for any student projects on campus safety, with documentation of hazards and attempts at correction. This can involve the suggestion for relocation of walkways away from driveways to correction of falls and trip hazards.
- If you are located near or have access to a Rehabilitation Hospital there are often several specific tasks that need to be done for a specific patient or procedure. Many of these are offered by the physical therapists themselves, they are the right persons to start with to find projects.
- Your local children's museum likely has needs for educational exhibits or software packages; they are worth surveying for projects.
- Your course web site might use updating or generation in the first place, give this task to a freshman design team.

3. Have your students develop PowerPoint teaching modules: A very good way to combine design and a learning experience is to have your students develop PowerPoint instructional modules based upon chapters in a designated text, such as the course text. This is the strategy pursued by Dr Blanchard at North Carolina State University as reported at the web site for her course: http://www.bae.ncsu.edu/bae/courses/bae465/2000/description.html, the materials

resulting from this work may be seen at:
http://www.bae.ncsu.edu/research/blanchard/www/465/textbook/. Any material which can be absorbed and abstracted by freshmen students is useful.

4. Go with your background and strengths: If you can make the right connections, go with your personal strengths in proposing student design projects. An exemplar of this is the work done by Dr Openshaw at the Iowa State University in the freshman design course he instructs in the introductory engineering design course (http://www.eng.iastate.edu/openshaw/engr170/maindesign/fall01/descriptions.htm). His mechanical engineering background shows up in the design project listing he posts for the class, which includes redesign of a tractor, redesign of a spoon, wheelchair adaptation, bowling ball ramp redesign, etc.

5. Do a web and literature search: The use of the term "freshman design projects" and variations on this theme will bring up a number of sites that can be inspected for Biomedical Engineering content:

- http://www.bme.jhu.edu/courses/580.111/pastprojects.htm is the web site for the Johns Hopkins freshman design projects from past years, some 41 design project web sites from past years are posted here that have biomedical engineering content. These are PowerPoint presentations of the design projects, which range in content from the design of a child restraint harness to heart simulators. Some of the projects have upperclassman involvement.
- http://www.lf.psu.edu/ is the learning factory website at Pennsylvania State that lists a palpation unit and a handicapped swimmer lift unit among a series of freshman through senior design projects.
- The ASEE web site is a good source for generic articles on freshman design, using the search term "biomedical engineering design" will yield about 13 complete papers on the topic, several of which refer to work being done on freshman design at Northwestern University and on design through the curriculum at Milwaukee School of Engineering. Unfortunately, no listings of freshman design projects could be found. The Frontiers in education web site yielded similar results (http://fie.engrng.pitt.edu/).
- The Whitaker Foundation listing of web sites for Biomedical Engineering programs was used by one student at Vanderbilt to locate the web listing for the 45 programs that have freshman design courses listed. This search however yielded the catalog description of the course in almost every case and therefore was worthless in terms of finding listings of actual freshman level design projects. It appears that large web sites on freshman design projects relating to biomedical engineering are rare.
- If your library subscribes to it, the International Journal for Engineering Education allows one to search past issues electronically. Volume 17 issues 4&5 is a special issue on Design Education for the 21st Century. A few of the articles mention freshman design courses. One project mentioned is the development of a wheelchair-mounted door opener, few other examples are given.

Summary and Conclusions: Examples of freshman design projects relating to Biomedical Engineering may be found in the literature, but as may be read above, the information is

scattered. One common thread is that the design projects in general are genuinely at the freshman level, with projects involving one or more the following list of attributes:

- Web page design
- PowerPoint presentation design of educational material
- Excel data analysis and display
- Literature survey and abstraction or decision making
- Elementary mechanical design for rehabilitation or related needs
- Device specification
- MATLAB modeling
- VRML modeling
- Educational display generation
- Basic observation of unsafe situations

Suggested sources for design projects are your fellow faculty, projects posted for the capstone design sequence, current textbooks and articles, your own strengths, and web and literature searches.

This work is supported partially by the Engineering Research Centers Program of the National Science Foundation under Award Number EEC-9876363.

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Appendix I
Vanderbilt University School of Engineering
ES130: introduction to Computing in Engineering
Fall 2001
Representative Biomedical Engineering Related Projects Proposed

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1 Measuring Bone Density Using CT Scans

Osteoporosis is best known as the loss of bone density and usually occurs in older women. As with other dysfunctions, early detection could be instrumental in preventing acute onset of the disease later in life. The motivation behind this project is to develop an automated, easy-to-use method to measure changes in bone due to osteoporosis. It is the intention of your company to use standard x-rays and create an algorithm that can calculate bone density based on how x-rays are absorbed by bone and the molecular content of bone. Clearly this can have long term implications in evaluating and following patients at risk with osteoporosis.

2 Detection of Peripheral Vascular Disease

While there are much more visible health care issues which affect fewer people such as cancers, diabetes which affects does not get a lot of attention. Diabetes affects an estimated 15.7 million people in the United States -- 10.3 million have been diagnosed, but 5.4 million are unaware they have the disease. It is a disease that one manages rather than cures. One of the big problems is that the poor solicit health care by crisis; their primary care physician is the ER. In a diabetic, the crisis is often peripheral vascular disease (blood vessels collapse) and they lose a limb or it gets gangrene and the person gets sick or dies from the sepsis. The goal of your research and design team is to design an inexpensive way to screen non-technically adept users for the onset of peripheral vascular disease. Possible solutions could involve thermography (temperature detection) and automatic data transfer (99% of all US households have a phone). Ethical issues involve understanding delivering medical care to the poor.

3 Bioreactor Design

One of the most common forms of treatment for diabetics is insulin injections. Since insulin is a protein, it is difficult and expensive to artificially synthesize correctly. Recent developments in genetic engineering allow the hormone to be produced from living cells in a stirred-tank bioreactor. Bioengineers are responsible for designing these large-scale bioreactors for such commercial processes. However, existing bioreactors have several limitations. Factors to be considered include reactor size, geometry, stir-speed, and inlet nutrient concentrations so that production of the protein product is maximized. Your design team as the engineers-in-training will analyze existing designs and come up with a potential hybrid design that optimizes the yield of insulin produced from a human cell bioreactor.

4 Clinical Raman Fiber Optic Probe Design

It is well known that the earlier you detect cancer, the better the prognosis of the patient. Thus, there is an entire field of research that is devoted to the development of novel methods for the early detection of cancers and precancers in a minimally invasive manner. One such method is based on light and the optical properties of tissues. Dr. Mahadevan-Jansen has discovered a new

method of detecting cancers before they can become cancers that can be applied in real time, can be automated and it minimally invasive. However, while this technique has been tested in the lab, she is looking to work with a commercial enterprise that can convert this laboratory-based system into a clinical one. The key component in the system design will be a fiber optic handheld probe that is capable of delivering laser light and collecting the tissue signals without interference from the room lights or the optical fiber itself. Thus the task of your company will be to design such a clinical Raman probe based on fiber optics that can be used in human patients.

5) Assistive Device for the Elderly

Most of know about the famous commercial "I've fallen and I can't get up". In response to a request from the Rehabilitation Center, your task is to develop an assist device for elderly persons and persons with a disability who sometimes fall and do not have the ability or strength to lift themselves without assistance. The assist device needs to be foldable and lightweight for portability but strong enough to support a person's weight.

6 Spider Website for Poison Control (BME/CS)

Dr. Michael Smith is extremely interested in the hazards of spider venom and has more than 100 35mm slides of different spiders in the US. He is soliciting the expertise of a software development group to develop a spider website (no pun intended!). One aspect of the resource development will involve organizing, labeling and digitizing the slides as part of the web-based resource.

7 Surgical Delivery Device for Free Electron Laser

The Free Electron Laser (FEL) at Vanderbilt University is a unique laser device that has a wavelength tunability range between 2 and 10 μm. In this mid-infrared spectral range, biological tissue shows strong absorption and therefore selected wavelengths are well suited for efficient and precise tissue ablation. In fact, Vanderbilt FEL center is the only place that can claim the unique distinction of having performed to date six human surgeries (3 on the optic nerve behind the eye and 3 on brain tumors) with the FEL. Given the wavelengths of interest (which are strongly absorbed in atmospheric air) and the high peak intensities of the laser (up to 10^{14} W/m^2), it is a real challenge to come up with a feasible device that can deliver the laser to the surgeon's hand. Your task will be to design such a device that needs to be accurate, safe for human use and sterilizable.

8 Mechanical Prosthetic Arm (BME/ME)

Prosthetics has long been a significant area within mechanical engineering. Due to advancements in various technologies prosthetics are becoming more useful and life-like. As a result there are an increasing number of companies focusing on new types of prostheses. Your start-up biomechanics company has received a federal grant to design an above elbow body-powered prosthesis for an amputee. It shouldn't weigh more than 5 pounds and should include elbow and wrist joints as well as a terminal device (hand mechanism). All machine components (gears, bearings, fasteners, etc.) should be selected from specified catalogs.

9 Automobile Roof-Top Wheelchair Carrier

Your company has been contracted by a wheelchair manufacturing corporation to submit a design for a rooftop wheelchair carrier that will enable a paraplegic to mount his or her intact wheelchair to the roof of a car. Presumably, the person will wheel up to the car, lock the wheelchair brakes, transfer to the driver's seat, then lower an apparatus from the roof, hook the wheelchair, then return the apparatus (with chair) to the roof.

10 Visualizing Reaction Rates from a Living Cell

A simple Matlab program has already been created to calculate 6 key intracellular reaction rates of a living cell for use in bioengineering and biotechnology research. Experimental data serve as inputs into this program and the output consists of 6 calculated rates as well as some statistical parameters. You are being asked to develop a product (code and/or procedure) for taking experimental data and displaying them in one or more descriptive formats (such as a metabolic flux network diagram) suitable for presentations and publications and providing the framework for comparing the analyzed data.

11 Electronic Cough Monitor (EE/CompE/BME)

You have been approached by a medical center to develop a system for monitoring the patient's coughing over a period of 24 hours. A doctor can get help in his diagnosis if he can find out the number and rate of coughing. The system will consist of a sensor to detect the presence or absence of a cough and a commercial chip that can keep track of time and number of coughs. The chip has a serial port built in to it so the doctor can download the data in his office for evaluation. The project will involve identification of a suitable sensor, programming of the commercial chip, and programming a computer serial port for data transfer. Additional circuits may be needed to condition the signal from the sensor for detection by the commercial chip. A cost analysis will also need to be performed.

Thanks to the following faculty at Vanderbilt who proposed and supervised these projects: Dr Bob Galloway, Dr. Todd Monroe, Dr. Anita Mahadevan-Jansen, Dr. Paul King, Dr. Duco Jansen, Dr. Michael Goldfarb, Dr. Robert Balcarcel, and Dr. Barat Bhuva.