# A problem-based, introductory course in biomedical optics in the Freshman year

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Abstract

For the past several years, Vanderbilt University has offered an elective freshman engineering seminar in the area of the student's major. This paper describes the development and implementation of such a seminar in the area of biomedical optics that is developed around laser vision correction.

Drawing on current paradigms in the learning sciences, the entire course is presented in the form of challenges. Emphasis is placed on continuous posing of questions to students as well as forcing students to formulate questions relevant to solving the challenges posed to them. For example, the grand challenge for the course is for students to identify and explain issues related to "fixing their mom's nearsightedness once and for all without needing contacts or glasses" A series of challenges help students explore the issues and engineering principles related to the eye as an optical system and the interaction of laser energy with tissue to define potential solutions. For each challenge students' initial intuitions are documented. Class lectures, discussions, and virtual experiments using computer-based animations are used to explore concepts in more depth.

Extensive use is made of laptops (required for engineering students at Vanderbilt since the fall of 2002) in this course. A browser-based student assessment system (VSAS) developed in our department was used in this course for the first time. The short answer and assay feature in particular lends itself extremely well for implementation in a challenge-based learning environment and allows for assessment of active knowledge by the students compared to commonly used classroom multiple choice systems. This paper will describe methods used and experiences gained in this new course as well as utility of the laptop-based student assessment system and assessment data.

## I. Introduction

In response to the outcomes of a self-examination in 2000, Vanderbilt University School of Engineering concluded that several of the objectives for the freshman year were not met [Overholser 2001]. Like many of our counterparts elsewhere, the freshman year is filled with General Chemistry, Calculus, Physics, a Humanities/Social Science elective and an Introduction to Computing in Engineering course. Moreover, our school has historically adopted a 'common freshman' year in the Engineering School. While students declare a major prior to the freshman year, the common freshman year for all practical purposes, postpones a real decision on the major until the beginning of the sophomore year. Many students, parents, and faculty have expressed the concern that we are not providing enough exposure to the field of Engineering as a whole, or to specific Engineering disciplines, to allow our freshman to make an informed choice. In addition, freshman are not exposed to the excitement and rewarding experiences of the engineering profession but instead get submersed in basic science courses. For the most part they are unable to relate material learned in these courses to their career choice, which could have a negative effect on retention rate. Certainly for a relatively new discipline within Engineering, namely Biomedical Engineering, it is often difficult for freshman to grasp what Biomedical Engineering really entails. We owe it to our Freshman students to expose them to their major andto faculty from the department of their selected major.

For the past three academic years, our Engineering School has experimented with a series of optional freshman seminars taught by engineering faculty to engineering students. These seminars are voluntary; if a student elects a seminar, he or she takes it on top of the usual course load. If a faculty volunteers to teach a seminar, he or she teaches it on top of the usual course load. In years past, over 10 seminars covering various areas of engineering have been taught. This paper describes one such seminar, "Laser vision correction", which was developed and taught by a Biomedical Engineering faculty member for the first time in the fall of 2002. Nineteen students enrolled in the course, 18 of which were Biomedical Engineering majors while one Mechanical Engineering major enrolled.

II. Course Objectives.

The instructional objectives of this course include:

1) expose freshman (biomedical) engineering students to one area of biomedical engineering that includes various aspects of Biomedical Engineering (medical, design, regulatory, ethical) as well as convey excitement for this field;
2) teach how the eye works as an optical system and how it can fall short in this function
3) teach how vision can be corrected, including concepts of laser vision correction;
4) introduce students to fundamental skills in engineering including problem solving, written and oral communication, library and patent searches.

III. Course Structure.

The course is a 1 credit hour course that met once a week for 1.5 hours. The entire course was presented in a challenge-based format. This approach involves a sequence of instructional steps called "generate ideas", "multiple perspectives", "research and revise", "test your mettle", and "go public", formalized in the Legacy cycle in the context of a HPL (how people learn) framework [Bransford 2000]. In this manner students engage in problem-based educational activities that not only teach them subject specific content knowledge but also help them develop into life-long learners and problems solvers. We hypothesize that exposure to this approach in the freshman year will prime students to become more adaptive learners in the later years of their studies.

The grand challenge presented to the students the first day of class was the following: "Your mom wants to get rid of her glasses/contacts once and for all. What can be done to make this happen? How does it work? Is it safe??". Without any prior knowledge, students brainstormed about these questions and entered their responses in the in-class assessment system using their wireless laptops as input devices (see section IV). Throughout the semester the challenge was revisited two more times, once mid semester and once at the end of the semester. In subsequent lectures the following issues were covered:

- Basic anatomy and physiology of the eye. In groups of two, students dissected a cow eyeball, drew the structures that they observed with specific emphasis on the structures that are involved in image formation. How does the light get from the outside world to the back of the eye? How is an image formed?
- What is a lens and what does it do? Demonstration experiments of light refraction were done. Students performed a virtual experiment to derive Snell's law using a refraction applet (simulation). The concept of refractive index was introduced.
- What elements in the eye constitute a lens?
- After identifying the cornea and lens as the relevant optical elements, the question is why do need glasses? Image formation, refractive power, myopia, hyperopia concepts were introduced.
- Correction of vision using external lenses (contacts or glasses) was discussed as well as the concept of astigmatism (and cylindrical optics). Lens/glasses prescriptions were analyzed.
- Revisiting the grand challenge leads students to consider modifications made to the optical elements of the eye itself (cornea in particular). The question then was how one can modify the shape/curvature of the cornea.
- What is a laser, how does it work? Why do we want to use a laser for this purpose?
- What laser properties are relevant and should be considered if we want to reshape the cornea?
- Students were introduced to concepts of monochromaticity of laser light and selective absorption of tissue.
- After introducing LASIK by showing a movie, students took a field trip to a laser vision correction clinic where they observed a LASIK procedure in the operating room and were able to interview the patient after the procedure and performed corneal topographic measurements on each other, the results of which were discussed collectively. In addition each student had the opportunity to operate the ArF excimer LASIK laser to cut a lens of predetermined focal length out of a piece of plastic.
- While the class was visiting the laser vision correction clinic, a technician was installing a state-of-the-art laser (a picosecond NIR (Nd:YLF) laser) that is used as alternative to the diamond knife in order to cut the corneal flap. Entirely unplanned, this fortuitous event presented a unique opportunity to contrast the two lasers and their interaction mechanisms with corneal tissue.
- An overview of business aspects, design issues, and regulatory affairs for medical devices was presented in the context of LASIK lasers and companies.
- Finally, each student was required to produce an informational brochure describing LASIK/laser vision correction. This particular activity constituted the "going public" phase of the Legacy Cycle.

Grading in the course is based on class participation (40%), grades on homework assignments (30%) and grade of the brochure (30%). Homework assignments included literature / library searches, patent searches and problem sets.

IV. Laptop Use

Beginning in the fall semester 2002, the Vanderbilt University School of Engineering required each entering freshman to purchase a wireless laptop computer, configured to predetermined specification. While many schools have been experimenting with such initiatives, integration of laptop in education, specifically classroom use to enhance the learning environment and serve a pedagogical role, has been limited. In this course the students were required to bring their laptops to class and the laptops were used for two purposes: 1) in-class access to interactive simulations and animations was used to conduct 'virtual experiments', in which data collected from simulations was then used to convey physical concepts; and 2) real-time, formative, in class assessment.

New principles of learning and instruction highlight the need to engage students in thoughtful use of knowledge. However, engaging individual engineering students in large classrooms simultaneously can be challenging. Technology such as classroom communication systems encourages students to apply conceptual ideas during class, by allowing them to respond to questions using hand held devices, and by displaying an aggregate of responses to the instructor and/or the class. This real time feedback provides a valuable way of measuring progress both to the instructor as well as to the students. However, these systems generally support only multiple-choice questions, and usually require proprietary hardware and software [Paschal, 2000]. Under the umbrella of our Engineering Research Center (ERC) for Bioengineering Educational Technology in which Vanderbilt, Northwestern, Texas and Harvard/MIT (collectively known as VaNTH) are partners, we have developed a browser-based solution: The VaNTH Student Assessment System (VSAS) [Brophy 2003]. VSAS allows for multiple choice, short answer, and essay responses to questions during class by using student's wireless laptops as input devices. This approach may increase learning potential for students because they need to rely more on generating knowledge and less on routine recall of memorized information. Moreover, the system lends itself very well to implementation in models of challenge-based learning that include phases of generating ideas and revisiting initial intuition after instruction. From the instructor's point of view, being able to ask questions requiring synthesis on the part of the students (rather than passive multiple choice), that are answered anonymously and that are available realtime, allows for tailoring lecture time to areas where students have difficulty. Additional advantages include increased student involvement and automatic archiving of responses.

V. Evaluation and Assessment

In the end-of-semester University-wide course evaluations students are asked to score a number of items including the 'overall course rating' (1=bad; 5=good). The Freshman seminar courses due their very nature typically receive scores that are higher than the overall engineering school average. For the fall of 2002 the course evaluation for this course was a 4.63 versus $4.24 \pm 0.29$ for the 11 sections of the freshman seminar and $3.76 \pm 0.57$ for the entire engineering school. The instructor rating showed a similar trend.

Various course-specific assessments were performed throughout the semester. On a scale where 1 is bad and 5 is good, students were asked how well the course objectives (see section II) were met. These data are shown in Figure 1.

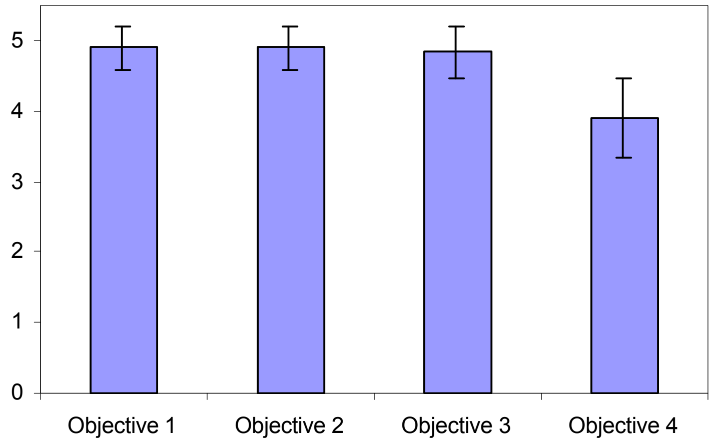


**Figure 1.** Student (n=19) evaluation of accomplishing course objectives (5 represents good and 1 represents bad). The explicitly stated course objectives were: 1) expose freshman (biomedical) engineering students to one area of biomedical engineering that includes various aspects of Biomedical Engineering (medical, design, regulatory, ethical) as well as convey excitement for this field; 2) teach how the eye works as an optical system and how it can fall short in this function; 3) teach how vision can be corrected, including concepts of laser vision correction; 4) introduce students to fundamental skills in engineering including problem solving, written and oral communication, library and patent searches.

In addition, students were asked to evaluate the use of laptops in the classroom. Interestingly the VSAS system itself was used for this evaluation. Using the multiple choice feature students were asked to indicated their level of agreement with several statements (where 1 is strongly disagree and 5 is strongly agree) The following questions were asked:

- "The use of the VSAS system enhanced the learning environment in the classroom" Score: 4.11 ± 0.47. (average ± standard deviation)
- "The questions we answered using the VSAS system helped me assess my understanding / knowledge of the topic". Score: 4.36 ± 0.59.
- "In this course, aside from VSAS, we made good/effective use of our laptops which helped in the learning process". Score: 4.63 ± 0.95.

The open-ended questions were used to get additional feedback from students on the use of the laptops and our VSAS system in particular. Overall students were satisfied and excited to use their laptops in the education process. The main negative comments reflected the less-than-perfect reliability of the wireless network and problems logging in. Some of these problems were indeed network and server issues while some could be traced to user error due to an (unexpected) deficiency of basic computer skills of some of the freshmen, particular early in the semester. A sample of positive comments included:

- "immediate feedback"
- "being able to figure out what I had learned and what I hadn't understood"
- "The VSAS system helped me figure out what I did and didn't know through a series of questions"
- "The real time evaluation of our answers to relevant questions allowed us to learn our mistakes quickly and gain enhanced understanding by our answers along with the answers of our peers"

- "I thought it was most useful for the teacher to be able to see exactly what his students knew or did not know. If there was something that clearly none of the students knew the right answer we were able to go over it again where in regular class situation it is usually skipped with the teacher thinking that all the students fully comprehended everything"

Lastly, an assessment quiz was developed that included two open-ended questions given to the students the last day of the course. The goal of this activity was to assess the students' understanding of the material covered in this course (explicitly) as well as assessing their ability to apply this knowledge to a new problem (treating a strange skin condition using laser light). Student understanding was assessed by again posing the initial grand challenge and asking the same questions asked on the first day of class (as well as once mid-semester). The second question asked was the same question developed for a senior BME course in Biomedical Optics (the data for which was collected during the same semester) [Jansen 2003]. A scoring rubric was devised by a team of domain experts and learning scientists, and student answers to the assessment questions will be blindly scored by three independent faculty in the biomedical optics field. Performance of the freshman students will be compared to performance of the seniors. At the time of writing this analysis is in progress.

## VI. Summary:

A new freshman seminar course "Laser Vision Correction" was developed in which students were exposed to biomedical applications of optics and to a growing subspecialityof Biomedical Engineering. This course was taught in the Fall of 2002, and was successful in meeting the course objectives of providing Freshman exposure to the field of engineering, as well as to their academic major. Students enjoyed this exposure and indicated that they feel more informed to make a final choice of major. Significant didactic use of laptops in the classroom was made which was perceived positively by students and the instructor and enhanced the learning environment.

## VII. Acknowledgements:

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