Works in Progress: Development of a need-based BME design course focused on current NICU challenges

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Kyle Martin is a graduate student at the University of Virginia in Dr. Shayn Peirce-Cottler's laboratory. Kyle's research is focused on agent-based modeling of skeletal muscle function and fibrosis. He is equally interested in teaching and has been both a TA and co-teacher, as well as attends workshops and seminars concerning teaching methods and academic jobs.

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Pamela Norris is the Frederick Tracy Morse Professor of Mechanical and Aerospace Engineering at the University of Virginia and the Associate Dean of Research and Graduate Programs. A native Virginian, she received her Ph.D. from Georgia Institute of Technology in 1992 working in the area of heat transfer in diesel engine cylinder heads. She then served as a Visiting Scholar and a Visiting Lecturer at the University of California at Berkeley from 1993-1994, where she developed her interests in microscale heat transfer and aerogels while working in the laboratory of Chang-Lin Tien. In 1994 Pam joined the Mechanical and Aerospace Engineering Department at UVA where she received a National Science Foundation CAREER award in 1995, was promoted to Professor in 2004, was named the Frederick Tracy Morse endowed chair in 2010, and she accepted the Associate Dean position in early 2012.

Dr. Shayn M. Peirce, University of Virginia

Dr. Shayn Peirce-Cottler is an Associate Professor with her primary appointment in the Department of Biomedical Engineering and secondary appointments in the Department of Ophthalmology and Department of Plastic Surgery at the University of Virginia (UVa). She received her Bachelors of Science degrees in Biomedical Engineering and Engineering Mechanics from The Johns Hopkins University in 1997. She earned her Ph.D. in the Department of Biomedical Engineering at the UVa in 2002. A past recipient of the MIT Technology Review's "TR100 Young Innovator Award" and the National Biomedical Engineering Society's "Rita Schaffer Young Investigator Award", Dr. Peirce-Cottler researches how blood vessels grow and remodel in response to diseases, such as diabetes, heart disease, and cancer. She and her research team combine experimental and computational modeling approaches to understand the complex web of molecular signals and cellular behaviors that contribute to vascular adaptations in tissues. Her lab also investigates the roles of circulating immune and progenitor cells in microvascular growth, which informs their translational investigation of adult stem cell therapies for tissue regeneration. Dr. Peirce-Cottler teaches courses to undergraduate students, graduate students, and medical students on the topics of computational systems bioengineering and medical device design and commercialization.

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Extended Abstract

Design is a vital component to an undergraduate engineering education and a critical criteria for ABET accreditation[1]. At the University of Virginia, in addition to the fourth year final design course, we offer design courses each year of the undergraduate curriculum to teach the fundamentals of design (from needs identification and brainstorming to manufacturing and commercialization). In spring 2013 we introduced significant changes to our required second year level semester-long design course aimed at teaching the ambit of BME research as well as developing design principles and practices.

Background

Historically, this course has two main objectives: introducing new engineering students to the vast field of biomedical engineering and to developing designs with faculty and engineering/medical professionals. While looking for projects to assign our students in the spring of 2013, we took a tour of our hospital's Neonatal Intensive Care Unit (NICU) with a neonatologist who had mentored a team the previous year. While on this tour, we realized the NICU had numerous and diverse needs that could be addressed with our class. Instead of assigning projects, our goal was to challenge the students to address a current NICU need which would improve their communication skills, professionalism, and research abilities. To this end, we re-designed our course such that it focused exclusively on the real-world clinical needs in the NICU while maintaining our ambitious goal for the students: to create a working prototype of their project by the end of the semester.

Course elements

We invited our assisting neonatologist to give a lecture concerning the conditions and limitations associated with present technology used to support premature infants. This talk outlined both their medical conditions (e.g., skin sensitivity/susceptibility, breathing and oxygen regulation), as well as current methods to support and protect the infants (e.g., incubators, monitoring devices). The doctor also outlined numerous problems currently plaguing the NICU. Students were encouraged to ask questions and write follow-up emails to willing doctors, nurses, and families.

Additionally, we created a unique learning experience by organizing a visit to the NICU. Under the supervision of our collaborating neonatologist, each team was allowed to observe current conditions, watch procedures, analyze unoccupied equipment, and ask questions to consenting nurses, doctors, and parents. We focused on promoting the students' abilities to identify problems and determine the needs of the clients (staff, infants). Figure 1 shows a representative example of one of the observed problems and our design process from class. Students were free to choose any complication they observed to work on and many created solutions for sanitation, equipment securement, and staff monitoring.

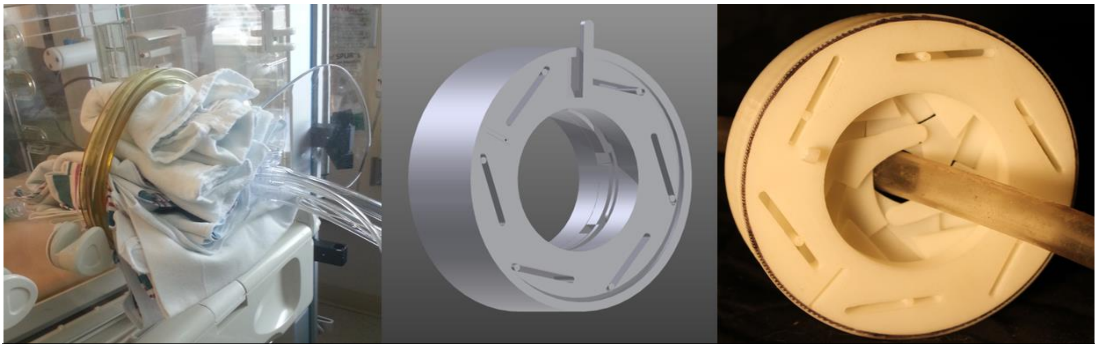

Figure 1. Students discovered high-frequency oscillatory ventilation tubing was difficult to secure, where the solution devised by the NICU nurses consisted of stuffing blankets in the port of the incubator (left). A design was created using a CAD program (middle) and rapid prototyped using a 3D printer (right).

Team organization

We decided to divide the class up randomly into eight teams of ten students. We felt justified doing this because groups of mixed GPAs preform as well as groups with all high GPAs[2]. However, studies have shown that large teams have more difficulty managing their time, agreeing on tasks, and dividing labor[3]. To mitigate this effect, we implemented a few policies. One lecture a week was dedicated to team meeting time. Each team was assigned a mentor/advisor who was either a graduate student or a volunteering senior undergraduate student. The mentors were instructed to guide their discussions and offer feedback throughout the design process. Weekly memos were assigned to keep the teams learning and working towards their prototype. Each memo was intended to accent a particular part of the engineering design process (identify a need, constraints identification, brainstorming, CAD design, market analysis, etc.). At the end of the semester, each team presented their designs to the class. The designs were judged by BME faculty based on innovation, marketability, and feasibility.

Biomedical engineering overview

We split the semester into blocks of material focused on specific BME disciplines. Due to our limited time, we decided to highlight topics that have active research at the University of Virginia. The sub-genres we chose to introduce included: electrical, computational, chemical and material engineering. Individual classes were dedicated to setting up engineering problems correctly and working through solutions in class. Each block was capped with a panel discussion. Faculty were invited to give small overviews of their current research. Afterwards the students were able to ask questions pertaining to current research in that field. Additionally, multiple lectures throughout the course were focused on design principles and tools, such as CAD, patent searching, market analysis, etc.

Another novel aspect of the course was the inclusion of a graduate teaching fellow to co-teach the course. Our engineering school offers graduate students the opportunity to gain teaching experience by applying for competitive teaching fellow positions. The teaching fellow must participate in all aspects of the course, including syllabus generation, grading, teaching, and student evaluation. This unique combination of teachers increased direct instructor/student interactions and offered multiple perspectives on topics and discussions.

Preliminary results

Our course changes were intended to immerse our students in a need-driven design course. And we had a lofty goal of creating working prototypes by the end of the semester. Of the ten design teams this year, every team was able to create a prototype. Additionally, three teams filed provisional patents by the end of the semester. This is a marked increase over the one patent filed from the two previous years combined (30% vs 12.5%). One of our teams also entered a pan-university design competition and managed to finish second place. Two teams have expressed interest in continuing their designs. The average grade for our renovated design course was a 90.6 ± 4.9. This was slightly lower than the previous two years (92.3 ± 2.8 and 92.9 ± 2.1). However, their patients and competition success provides evidence that the teams spent more time and effort on their designs than previous years.

Student evaluations indicated mixed feelings about the course. In the anonymous course evaluations, a few students reported wanting to visit the NICU sooner and more frequently (8 out of 51 responders) which will be difficult to accomplish since the NICU is a traffic sensitive area. Only 2 students expressed dislike for the NICU design. As for the course structure, students enjoyed the faculty panels (3.91 out of 5 rating, 81 responders) but wished they had more time to learn each engineering module. Additionally, many students felt the class was laborious and rushed (15 of 51 responders). We knew we had lofty goals for our students, a working prototype in 15 weeks, but all of the teams were able to fulfill this requirement. Many projects, as indicated by our provisional patents, well exceeded our expectations. In short, our design class has a lot of promise, but needs some refining in terms of work load and pacing.

Summary

Overall, the design course allowed the students to work on real-world engineering problems related to patient care in the NICU. Each student was given the opportunity to learn how to access challenges and constraints involved in design. Additionally, multiple groups filed provisional patents and entered design competitions in an effort to continue moving their designs toward commercialization. Since this was a pilot course, formal evaluations of the NICU design challenge would be conducted once this course is repeated.

Works Cited

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