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Work in Progress: Problem-based Learning in a Flipped Classroom Applied to Biomedical Instrumentation Teaching

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Introduction

Biomedical instrumentation is a required course in our Biomedical Engineering (BME) program for all concentrations: electrical, mechanical, pre-med and tissue engineering. The course has been part of the curriculum since its inception and it is part of a larger set of courses related with medical devices, as shown in Figure 1. In the early years of the program, the required courses included other courses taught by the Electrical and Computer Engineering (ECE) Department; it included courses such as electronics and linear circuits. With the evolution of the BME profession, the department decided to teach the ECE concepts in the existing courses: measurements, instrumentation and signal analysis. This decision was motivated by student feedback and by a curriculum reform that required the expansion of the biomaterials and tissue engineering courses. The Department made a pedagogical effort to add a significant amount of knowledge to these core courses without diluting the fundamental scientific and engineering principles. The present work in progress shows the first iteration of the most recent pedagogical effort applied to the Biomedical Instrumentation course.

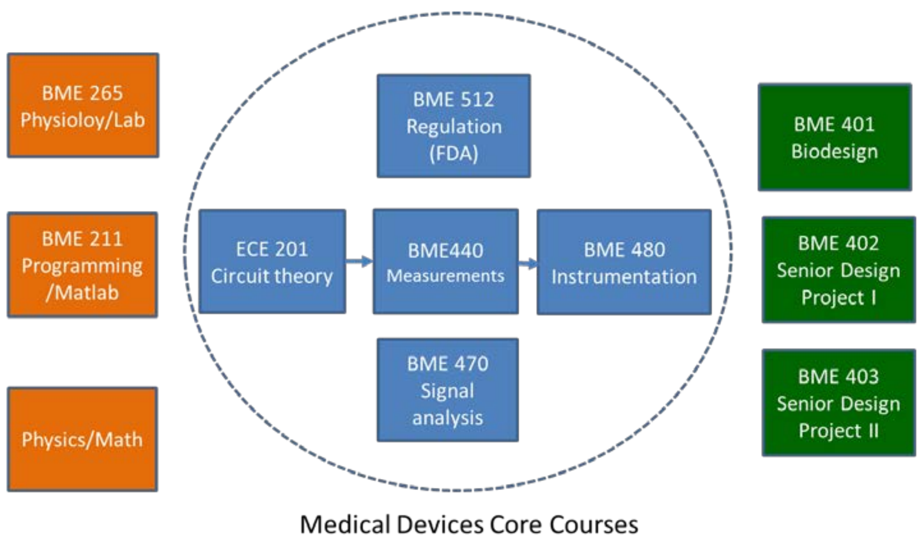

Figure 1. Sequence of required courses related to medical devices

Course design challenges

The BME student motivation: The class of 2017 placement of BME's shows that around 50% pursue BME master and doctoral levels; 25% went to BME industry; 17% went to medical school; 5.6% MS in health-care related programs and the remaining 2.8% follow other paths. The student body, as the discipline itself, has diverse motivations and professional pathways. Therefore, there is a need to deliver the course content in a way that promotes intrinsic motivation for this diverse population. The problem based methodology motivates the pre-medical students [1] because they see the usefulness of the theory in realistic medical problems while the students aiming to go to industry appreciate the technical aspects and the explicit connections with the regulatory world.

Industry Expectations: In addition to the technical knowledge and problem solving skills, the BME industry expect BME graduates to understand how the instruments affect the patient's treatment, exhibit a "system engineering" mentality and understand the standards and the regulatory processes. Graduates must also be effective team workers with good communication skills.

These expectations were obtained by the author after attending multiple industry round tables at the BME-IDEA meeting.

Pedagogic Strategy

Progressively, the teaching “flipped” from the conventional approach of teaching the building blocks first (circuits, electronics, linear systems, etc) before addressing the medical device application to a new approach, where we start with the medical need. We use the analysis and design of some medical devices as the conducting thread and progressively introduce the engineering tools and standards as necessary skills required solving it. The medical devices we use to teach liner systems are the invasive blood pressure system (signal, hydraulic system, analog filters), the thermometer and electrocardiograph (Instrumentation amplifiers, common mode and differential, standards). The course revolves around the concept of medicine as a close loop system where the medical device provides the patient’s information to a classifier (diagnostic) and decision-making entity that will apply a therapy to the patient. For the classifier and decision-making entity we assume, most of the time, it is the health care professional but, we also analyze the case of a full automatic system such as the Automatic External Defibrillator AED.

This proposed strategy, where we see the instrument as affecting the well-being of the patient, makes the course material very attractive to the diverse population of students. Working with open realistic problems with the patient as center, makes the connections between this course with physiology, signal analysis, regulation, measurements natural and easy. The course works as a glue to the many other courses relating with medical devices and helps to fulfill the industry expectations of BME graduates understanding the medical devices beyond the mere technical aspects.

The Flipped Classroom

It was shown [2] that students found the flipped classroom to be effective and satisfactory. Recently, the College of Engineering of the University of Miami has promoted the use of active learning. Several classrooms were equipped with tables and multimedia equipment to implement flipped classrooms. The classrooms consist of tables (~6), each one holding two teams (3 students) and a big TV where any student can easily share their computer screen. During the first minutes of the lecture, the instructor gives a brief explanation of the topic/problem of the day; the remaining time is dedicated to active learning activities, such as problem solving. The students are instructed to prepare material ahead of the lecture.

Normally one or two TAs (advanced undergrads) attend the lecture. To select the TAs, we approach students having performed very well in the class and that exhibited very good interaction with their team mates. The instructor trains the TAs and has periodic meetings with them. The instructor and TAs interact with individual students without disrupting the lecture flow. The TAs are instructed not only to help the students solving the problems but also inquiring the students about the way they interpret the problem and their solution strategy.

The recent use of the flipped classroom setup has significantly boosted the implementation of the pedagogic strategy of the Instrumentation course by providing the natural inclusion of cooperative learning elements [3] and boosting the student instructor interactions.

In the flipped classroom, we emphasize a problem-based learning strategy. We use the well-being of a patient undergoing physiological recordings as the ultimate goal. Every problem requires the students writing a discussion addressing the likelihood of having a diagnostic error and its clinical consequences. The students are required to support their argumentation using quantitative predictions, the applicable device standards and the medical practice recommendations issued by the medical societies. The instructor provides handouts with "extracts" and interpretations from the standards that have been either purchased by the University or obtained trough the American National Standards Institute (ANSI) University Outreach Program. For example, the American Heart Association recommendations along with the International Electrotechnical Commission (IEC) and the Association for the Advancement of Medical Instrumentation (AAMI) standards are regularly used in the case of blood pressure and electrocardiography. The use of modern computational tools enables the students to effectively solve medium-complexity problems and deeply explore the concepts without the cost of tedious manual mathematical developments.

Preliminary evaluation of the flipped pilot

Testimonials from students

- I felt **engaged** during class, and was able to **work on solving real, applied problems with a group of my peers**. This classroom setup provided us with the opportunity to bounce ideas off of each other, which ultimately **helped us learn from each other and grow as engineers**.
- It is important to **diversify how we learn** and I truly appreciated the hands-on experience in the flipped classroom.
- The ability to work within a group and **discuss the programming activities during class with the professor** helped immensely with my understanding of the material.
- This environment **allowed our professor to give us individualized feedback**, which was especially helpful when learning how to use MATLAB for instrumentation applications.
- I loved having the opportunity to work on a team and be able to **rely on each other's strengths** to create well-balanced projects.
- Both the **theoretical, as well as applied knowledge** were able to be combined in an **exciting way**.

- The interactive classroom was a good concept, but too many students and there **wasn't much interaction with the groups**.
- Personally **did not like the open classroom experience** for the class. I felt the class would've been better suited in a traditional classroom experience like all of the other classes taken previously.

In general, the students and faculty have appreciated the pedagogical changes, as shown by end-of-class surveys and testimonials. The students are more engaged in the class as they feel they are solving real/important problems; they learn from each other and they feel they grow as engineers. They appreciate the individualized feedback provided by the instructor. By inquiring the students during the solution of the problems, the instructor better understand any possible misconception that the students may have.

We identify the student team management as one aspect with high improvement need: there is still great variability in the effectivity of the student teams. In the most recent pilot we start using the Comprehensive Assessment of Team Member Effectiveness (CATME) to create and assess team effectivity.

In our case we feel that active learning has been a successful pilot experiment to teach bioinstrumentation because it enhances problem-solving skills along with other important traits of modern engineers such as teamwork and communication skills. After applying some refinements to the method we plan to perform an formal assessment of the methodology and preset it as a full paper.

Works Cited

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