Abstract—Mechanical engineers often have limited understanding of current biomechanical engineering research areas and how they apply to biomedical technology. Through a National Science Foundation Transforming Undergraduate Education in STEM grant, we redesigned MEM 304: Introduction to Biomechanical Systems into a problem-based learning course focused on current biomechanical research challenges. Course modules included medical device design, cellular and tissue biomechanics, biomaterials, biomechanics, and bio-inspired robotics. Each module was inspired by a real-world task, and students completed hands-on laboratory projects as part of each module’s learning progression. Through this course, student co-operative education experiences, and biomechanical engineering senior design projects, we will improve education of biomechanical engineers who can translate laboratory discoveries into cutting-edge biomedical technology.

Index Terms—Biomechanics, Problem-Based Learning

I. INTRODUCTION

Biomedical engineering suffers from a significant lag between laboratory bench discovery and real world implementation. A primary challenge in engineering education is to create a new generation of engineers who can successfully link engineering research with practice. Drexel University already has a strong focus on hand-on experiences throughout the curriculum. Drexel students gain extensive practical engineering experience through the cooperative education program, one of the largest and oldest in the country. More recently, Drexel emerged as a leader in translational bioengineering. In April 2011, Drexel was awarded $10 million by the Wallace H. Coulter Foundation to endow the Coulter Translational Research Partnership with the goal of bringing life-saving solutions to clinical practice.

Despite these strengths, Drexel has not yet achieved its full potential. In the mechanical engineering department, a core group of successful faculty has diverse research expertise in biomechanical engineering. However, currently offered biomechanical engineering courses within the department do not leverage faculty research strengths or focus on translating research into consumer devices. Furthermore, while cooperative education provides students with real-world engineering knowledge, this knowledge is not effectively connected to classroom learning. Finally, Drexel students often miss out on high quality research experiences since they cannot participate in summer research programs or spend long continuous periods of time in university research labs due to the cooperative education schedule.

Problem-based learning (PBL) is ideal for integrating biomechanical engineering classroom, laboratory, and cooperative education. In PBL, the process is student-centered in small student groups with the professor serving as a facilitator or guide. Students encounter authentic problems which are then used as a tool through which the students direct their own learning. While many active and collaborative teaching strategies are more effective than traditional lecture formats in enhancing student knowledge and retention, studies suggest that PBL enhances students’ abilities to apply their knowledge both immediately and in the long term. Thus the PBL approach can help integrate classroom learning, research and design projects, and co-op, as well as improve student performance in these experiences.

We developed a new biomechanical engineering PBL course that builds upon Drexel’s strengths to effectively link the classroom, laboratory, and co-op in the Drexel undergraduate curriculum. We are currently evaluating how the PBL course impacts student performance in co-op jobs and senior design.

II. COURSE PREPARATION

The first step in course preparation was instructing the faculty involved in the course in how to create, teach, and assess a PBL module. We sponsored a PBL workshop run by the Institute for Transforming Undergraduate Education at the University of Delaware. Attendees learned about the fundamentals and advantages of PBL, what makes a good PBL problem, assisting teams with group dynamics, how to assess PBL problems, and flipping the classroom. In addition, ample time was provided to create PBL problems and receive feedback through poster presentations. All professors and teaching assistants associated with the new PBL course attended the workshop, along with 20 other engineering
facultv members and graduate students.
In the months prior to the course, several Skype information sessions were held to encourage mechanical engineering students to register for the new PBL course. 26 students expressed interest, and of these, 20 attended the Skype sessions. Course philosophy and syllabus were presented, and student questions were answered.

III. BIOMECHANICAL ENGINEERING PBL COURSE
The PBL course entitled Introduction to Biomechanical Engineering was co-taught by mechanical engineering faculty with expertise in three subject areas: Dr. Alisa Morss Clyne (cellular biomechanics and biomanufacturing), Dr. Hongseok Noh (microfluidics for biological applications), and Dr. James Tangorra (biorobotics). 25 students enrolled in the course (23 from mechanical engineering and 2 from electrical engineering), and all 25 completed and passed the course. The course included 5 PBL modules.

1. Medical Devices (Clyne): In this module, students listened to a short overview lecture on human physiology, and then were provided with anatomy and physiology online lectures. In the next class session, students visited the human anatomy lab at Drexel Medical School to provide a physical understanding of the human body. Student teams then received the PBL module, in which they were tasked with pitching a new medical device idea to their company’s CEO. Students delivered a practice elevator pitch to Dr. Clyne, and then a final pitch one week later. As part of this module, students recorded their elevator pitches and sent the videos to a biofabrication class in Spain through Drexel’s Global Classroom Initiative. The Spanish students then implemented the designs from the Drexel students’ elevator pitches.

2. Lung Biomechanics (Clyne): This module took a real life problem—a highly-publicized lung transplant in a pediatric patient with cystic fibrosis—and tasked students with determining how to measure lung function decline in patients with cystic fibrosis before and after lung transplantation. Students initially watched online videos about cystic fibrosis and lung biomechanics. A pulmonologist from Drexel College of Medicine taught students the basics of cystic fibrosis and lung function testing, allowing the students to practice reading real patient lung function tests. For the laboratory component, pig lungs from the slaughterhouse were treated in various ways to replicate obstructive and restrictive lung diseases. Students then inflated the lungs and measured pressures/volumes to determine which lung represented which disease. The students completed an executive summary describing which lung function test they selected, and the pig lung lab data analysis was included as supplementary material.

3. Lung Biomanufacturing (Clyne): This module continued the cystic fibrosis case, but now the students were tasked with developing a system to tissue engineer new lungs for transplantation. Students learned about tissue culture and tissue engineering from Professor Clyne. They then analyzed current journal articles on how cell migration changes on scaffolds of different stiffness as preparation for their lab experience. In the lab, students measured cell migration speed on polyacrylamide gels of varied stiffness. Since the lab time was not adequate to complete each section in series, we had one student from each team complete each section of the lab. Student teams then designed a lung tissue engineering system, using the lab data as supplemental material.

4. HIV Lab on a Chip (Noh): In this module, student teams created new microfluidic devices to either diagnose HIV or perform HIV monitoring. Students learned about microfluidics through a mini-lecture by Dr. Noh and through online videos. The students watched additional videos about HIV/AIDS detection and monitoring, followed by an excellent overview of HIV/AIDS and the state of the art in disease detection/monitoring from an infectious disease specialist from Drexel College of Medicine. In the laboratory components, students observed a microfabrication demonstration in Dr. Noh’s lab and discussed their own device goals. The students then designed a lab-on-a-chip device for HIV detection or monitoring, and their final deliverable was a Powerpoint presentation of their devices. An infectious disease specialist from Drexel College of Medicine observed and commented on their final designs.

5. Biologically derived prosthetics (Tangorra): In the final module, student teams designed a new athletic prosthetic leg. Students learned about animal locomotion and musculoskeletal modeling from Dr. Tangorra and online videos of human and animal motions. They then experimented with designing new locomotion systems using Animatlab (a free computational dynamics program). The student team deliverable was a Powerpoint presentation of their new prosthetic design.

Throughout the entire course, students completed weekly journal entries through Drexel’s Blackboard Learn program. There were three assigned questions each week. The first question asked about how the students felt about the particular module (what they enjoyed, what was frustrating). The second question asked them to identify something they learned that was interesting in the module. And the third question asked them to apply knowledge gained in the module to a new situation. The first question helped the faculty respond quickly to student frustrations—either individually or to the entire class. The second question enabled students to reflect on their own experiences. The third question tested student depth of knowledge, and showed that only a few students could relate concepts learned in the module to a new situation.

IV. ASSESSMENT
We are currently evaluating the success of the PBL course as well as its impact on student performance in co-op assignments and senior design. An end of course survey was used to assess student opinions about the course. Additional information (e.g., academic achievement data) will be drawn from standard University assessment procedures, but this will be buttressed by several customized evaluation activities, including:

- Analysis of student journals/logs; interpreting participants’ responses to written, open-ended questions;
- and surveying participants to garner their perceptions of
how they have changed in their knowledge/skills regarding science/engineering understanding;
• Individual interviews and/or focus groups with students and project staff to assess learning and programmatic components;
• Student product analysis (e.g., final projects) by the evaluators and the Drexel faculty/program staff using criterion-referenced rubrics to investigate student learning/competence; and
• Document analysis by Drexel University faculty and program staff, using formal, pre-established protocols such as the employer co-op survey by the SCDC, to interpret the quality and usefulness of curriculum, project description materials, and other written artifacts produced in project delivery.

The project will be evaluated through an assessment of student participant attitudes, learning outcomes, skill development, faculty and student engagement, and the effectiveness of project activities designed to achieve stated program goals. Formative and summative assessment and evaluation activities will be advised, developed, and implemented by an external evaluator. The major research question guiding the evaluation process is: What are participants’ learning outcomes (cognitive, affective, social, and professional) and skill gains?

V. CONCLUSIONS

The course was well received by both faculty and students, and we expect students will apply skills learned through PBL in co-op and senior design. 1/3 of students who went on co-op in the spring-summer cycle took a biomechanical engineering position. Faculty did not feel that the PBL format significantly increased their workload once problem formulation was completed, and engineering students especially enjoyed the hands-on nature of the course. In addition, medical doctors enjoyed interacting with engineering students. While initial student deliverables often did not meet quality and depth expectations, likely due to the novelty of the PBL format and the course speed, deliverables improved dramatically with faculty critique followed by student revision.