Board 2: Work in Progress: Development of a Biomedical Engineering Concentration Area within an Integrated Engineering Major Emphasizing Sociotechnical Thinking

Prof. Mark A Chapman, University of San Diego

Mark Chapman is an assistant professor at the University of San Diego in the Department of Integrated Engineering. His interests lie in the fields of skeletal muscle mechanics, muscle disease, exercise physiology, international education and engineering education. He earned his MS and PhD in bioengineering from the University of California, San Diego and a B.S. in biomedical engineering from the University of Minnesota.

Prof. Gordon D Hoople, University of San Diego

Dr. Gordon D. Hoople is an assistant professor and one of the founding faculty members of integrated engineering at the University of San Diego. He is passionate about creating engaging experiences for his students. His work is primarily focused on two areas: engineering education and design. Professor Hoople's engineering education research examines the ways in which novel approaches can lead to better student outcomes. He is the principal investigator on the National Science Foundation Grant "Reimagining Energy: Exploring Inclusive Practices for Teaching Energy Concepts to Undergraduate Engineering Majors." He has also co-developed a unique interdisciplinary course, Drones for Good, where engineering students partner with peace studies students to design a quadcopter that will have a positive impact on society.

Dr. G. Bryan Cornwall PhD P.E., Shiley-Marcos School of Engineering, University of San Diego

G. Bryan Cornwall, PhD, MBA, PEng is an adjunct faculty member at the University of San Diego (USD) Shiley-Marcos School of Engineering.Dr. Cornwall's academic background includes a Bachelor of Applied Science in mechanical engineering, a Master of Applied Science in material science, and a PhD in mechanical engineering, specializing in Orthopaedic Biomechanics from Queen's University in Kingston, Ontario, Canada. He is registered as a Professional Engineer.

Dr. Cornwall spent twenty years in the medical device industry with fourteen years as an executive in publicly traded companies. He has also completed a MBA at the Rady School of Management at the University of California, San Diego and was named a Rady fellow. He has published over 24 peer-reviewed publications, eight book chapters, and 24 US patents.

Dr. Cornwall's academic interests include: biomechanics, biomaterials, mechanical design, entrepreneurship, and innovation in medical devices and music. He has an active and long-standing interest in not-for-profit volunteering and service. Bryan is also an active runner completing more than 20 marathons around the world. He is a member of the "7 Continent Club" completing marathons on 7 of 7 continents including Comrades (the Ultimate Human Race) in South Africa.

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Introduction. In this 'Work in Progress' paper, we present our efforts to develop a new concentration area in biomedical engineering (BME) within a newly created Integrated Engineering major at The University of San Diego (USD), which has been a "Changemaker"-designated campus since 2011. The goal with the development of our BME concentration area is to provide students with an engineering curriculum that is explicitly sociotechnical in nature. By sociotechnical we mean that our students should understand engineering is not simply technical problem solving but requires an understanding of how engineering solutions must integrate both social and technical elements. This is a theme across our entire Integrated Engineering major and is of particular relevance for students interested in biomedical applications.

Background. The department of Integrated Engineering at our institution was founded in the Fall of 2016. Our mission as a department is to approach engineering education from a non-disciplinary holistic perspective that aims to fuse social and technical thinking together to create well-rounded engineers. To accomplish this mission, we have created unique courses that challenge the traditional engineering cannon by explicitly addressing social justice topics. For example, we offer an upper division course entitled *Engineering and Social Justice* that is required for all students graduating from our department. In this class, students consider the historical and contemporary contexts and impacts of the designs, systems, processes and products surrounding and involving engineering and engineers. With all five full-time faculty members in our department committed to our mission, we believe that a sustainable model for sociotechnical engineering education has been created at USD.

The first two years of our curriculum are focused around providing a broad foundation in mathematics, physics and engineering principles. To complement this foundation, our major also includes a concentration area that students begin in their third year. These concentrations consist of approximately 8-9 courses where students can achieve a deeper understanding of a particular topic. This paper reports on the creation of a new BME concentration. Similar to the other courses in our major, social and technical skills are woven together in our BME concentration to educate "Changemaking" engineers creating a foundation that aims to facilitate their future leadership and service to the BME field.

Prior to discussing the particular features of our concentration area, it is useful to review the existing models of BME education. Although BME is a relatively new engineering field, over 6,000 bachelor degrees are awarded in BME/BioE every year. Due to the broad nature of the discipline, there is a large variability in BME curricula [1]. Despite this variability, there *are* common features that are shared within BME education. Specifically, it is common to see core topics in materials science, mechanics, fluid mechanics, transport, thermodynamics, signals and systems analysis, instrumentation/electronics, and imaging [2,3]. Thus, the goal with our BME concentration area is to expand our current integrated engineering curricular offerings to produce well-rounded engineering graduates that are exposed to these topics in a biomedical context.

Our Biomedical Engineering Concentration Overview. Our BME concentration uses a multi-scale approach to give students the opportunity to apply engineering principles at the smallest scales of BME (*Bioinformatics*), at the tissue level (*Biomaterials Design and Quantitative*

Human Physiology), at the macroscale (*Biomechanics*) and, finally, to integrate principles from all scales into the design of medical devices (*Medical Devices)* [4]. The objective of this curriculum is to provide students with a toolkit of important BME skills to make them competitive for industry careers as well as graduate school. An emphasis on design and project-based learning will help our students develop their communication skills, critical thinking, and their ability to work in teams. We plan to weave in issues of social responsibility and ethics into our BME curriculum to provide for rich classroom discussions and allow students to reflect on important topics they will likely face in their careers with the advent of new biomedical technologies. Topics such as equal access to healthcare, ethical issues surrounding gene editing, and understanding how a user's background or culture can affect their healthcare needs/desires will all be discussed and considered throughout our curriculum directly alongside technical topics. This approach will allow us to more specifically address the new ABET outcomes (particularly Outcome 2) that call for more integration between social and technical elements.

Our first students will not officially begin the BME track until the fall of 2020, but we are piloting our biomechanics and biomaterials courses during the 2019 January intersession and 2019 spring semester, respectively.

In *Biomechanics,* the topics covered include physics and math themes applied to the human musculoskeletal system, orthopedic trauma, bioethics, global outreach and medical device design are considered. Typical anatomical, free body diagram, and other biophysical problems are addressed in homework, quizzes, and tests. An exploration of sociotechnical topics is integrated throughout the course through a daily reflection journal with prompted questions and a final independent review paper with instructions to explore diversity and the inclusion of vulnerable populations. The daily reflection journal includes prompted questions concerning various topics and consideration of vulnerable populations including age, gender, and race. The individual review paper considers a biomechanics topic with a minimum of three peer-reviewed publications and with further consideration of a selected vulnerable population. Finally, a team project uses OpenSim, a 3D biomechanics simulation software, to model a complex biomechanical movement [5].

Biomaterials Design is a new course offered at USD that was launched in the spring semester of 2019. The objective of this course is to introduce students to the fundamentals of implantable biomaterials. Course time is divided between lectures and discussions of scientific articles related to biomaterials. During course lectures, the fundamental principles of biomaterials are presented as well as ethical issues surrounding biomaterials design. Since biomaterial science is a relatively new field, a recently published scientific article is discussed each week. Journal club discussions at the undergraduate level have been demonstrated to improve student development and are useful tools to reinforce lecture material and build critical thinking skills [6]. Additionally, journal clubs provide a venue for the discussion of ethical issues such as equal access to scientific advances, scientific misconduct, and animal research. These discussions provide opportunities for our students to understand the bigger picture and prepare them for work in biomedical fields where ethical issues are of paramount importance.

A large portion of student grades in this course are determined by an open-ended design project. The goal of this project is to teach students how to design a medical device that addresses an unmet user need. Unmet user needs were sourced from a 2018 FDA/NIH report entitled, 'Unmet

Medical Device Needs for Patients with Rare Diseases', that highlights the overwhelming need for new or improved medical devices that diagnose/treat individuals with rare diseases [7]. This extensive report provides students with real world context for their projects and allows them the freedom to define how they would solve their chosen need. Over the semester, students work in teams of three to choose an unmet need and design a solution to this need. A final report and presentation are due at the end of the semester. A large motivation behind having the students develop a device for a rare disease is to have them reflect on why existing treatment options are limited. In the final report, students are asked to reflect on this and discuss their responsibilities as engineers when developing medical devices. At the time of writing this manuscript, student projects were not completed, so a detailed discussion will take place at the ASEE conference.

In addition to *Biomechanics* and *Biomaterials Design*, we plan to develop other BME courses. As alluded to previously, one of these courses will be focused on bioinformatics. The purpose of this course will be to introduce students to genomic and transcriptomic sequencing techniques, sequencing data analysis, and gene editing. This course also aims to address perceived gaps in knowledge that can exist following graduation from BME programs that have not adapted to new technologies [8]. This course will address ethical issues surrounding genomics using case studies. Specifically, topics centered around equal access to personalized medicine, CRISPR gene editing and scientific misconduct will be discussed. We will also develop a quantitative human physiology course aimed at providing students with a concrete foundation in biology and physiology. Finally, we will develop a medical device course that integrates all of the topics covered within our BME curriculum. Using user-centered design, this senior level course will focus on demonstrating the integration of theory and practice into a commercial application by leveraging local companies. Partnerships with local industry will provide students with valuable 'real-world' experience as well as potential avenues for future employment. In addition to these BME courses, students will select 3 additional courses from a list of approved engineering electives. The courses our students can choose from aim to provide them with knowledge in the 'core' topics of BME mentioned previously [2].

Instead of seeking accreditation for each of our five concentrations separately, we will pursue ABET accreditation for our entire major under the Engineering (general) category. The core curriculum of our major satisfies a majority of ABET requirements. To satisfy all requirements, the BME concentration includes a certain number of math/science units (3) and upper division engineering units (6). Beyond these unit requirements, material from our concentration courses will not be used as primary evidence to show ABET evaluators we are meeting the required learning outcomes. However, an internal assessment will take place to ensure we are meeting BME specific learning outcomes and that our students find employment following graduation. We are in the process of developing these concentration-level BME outcomes and hope this paper will facilitate a conversation at ASEE about appropriate outcomes for our concentration.

Conclusions. Overall, our BME concentration area aims to produce engineers with the breadth of knowledge necessary for successful careers in BME or other related fields. With a foundation in both the technical and social aspects of engineering, our hope is that the engineers graduating from our integrated engineering program will approach biomedical engineering with a consideration for the necessary engineering principles *as well as* the end user of the product, service or diagnostic they develop. We strive to give our students a "Changemakers" mindset to positively impact communities, companies, and society when they graduate.

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