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Board 11: Work in Progress: Development and Assessment of an Innovative, Student-Centered Biomechanics Course

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Introduction

Biomechanics is an essential course in a biomedical engineering curriculum studying the structure, function and motion of the mechanical aspects of biological systems. In developing a biomechanics course for our new biomedical engineering program, I investigated the methods that previous educators have used to teach biomechanics concepts.

Some previous studies have been done looking at different learning modalities on understanding and retaining biomechanics concepts. Teaching that involves high amounts of active student participation in their own learning appears to be of particular interest. Active learning techniques have been shown to improve student learning compared to lecture alone.[1] Problem-based learning in biomechanics has also been shown to motivate student learning, increase knowledge retention and help develop problem solving, communication and teamwork skills. [2] Because of the effectiveness of these hands-on techniques, there have even been studies evaluating the design of biomechanics labs that could be done in an online or hybrid class format.[3]

The inclusion of numerical techniques in solving the complex mechanics problems inherent in biomechanics problems has also been of interest in studies on biomechanics classes. One such study effectively incorporated finite element analysis (FEA) into a design project in an introductory biomechanics course.[4]

In developing my own new Biomechanics course, I aimed to incorporate multiple learning modalities for interacting with the course material which incorporated hands-on labs, exposure to scientific literature and inquiry-based projects. Inclusion of diversified learning strategies may increase student motivation,[5] while diversity of assessment increases student engagement and empowerment.[6] This newly developed course focuses on this diversity of teaching strategies with an aim towards effective teaching and retention of Biomechanics concepts. This study describes the development of an innovative, student-centered Biomechanics course within the framework of our new Biomedical Engineering program.

Methods

Developing the course

The biomechanics course was developed as a class for biomedical engineering students to take in their sophomore year concurrently or after differential equations. This class is also taken subsequently to an engineering statics class. This course will include instruction on basic biomechanics and engineering principles including uniaxial tension, compression, bending, and torsion applied to orthopedic biomechanics, as well as rigid body planar kinematics and dynamics and numerical methods including finite element techniques. These mechanics techniques will be given proper context within a biomedical framework by interweaving the mechanics with information on the physiological reactions of the musculoskeletal systems that experience these forces. Specifically, the class covers the topics of force and moments, static equilibrium, joints and degrees of freedom, rigid body dynamics, mechanics of fibers, elastic stress and strain, viscoelastic behavior, continuum mechanics, stress tensors and principal stresses, deformation and rotation, constitutive modeling of solids, solution strategies for biomechanics problems, finite element techniques and biological responses to mechanical forces. This class has 6 major learning objectives shown in Table 1.

Table 1: Course Learning Objectives

1	Describe the basic structure and mechanical properties of various human body parts.
2	Understand force and moment vector operations and the center/axis of resistance concept when applied to the human body.
3	Understand the concept of axis/center of rotation and how to plan the correct axis/center for a specific biomechanics problem.
4	Describe how different body regions respond to static and transient loads: biomechanical and physiological response.
5	Use numerical methods to obtain solutions to complex biomechanics problems.
6	Use measurement techniques to obtain and analyze data on mechanical reactions of living and non-living systems.

Finding a textbook that both comprehensively covered the topics needed for a biomechanics class, while also remaining at an undergraduate level proved difficult, but the primary text used in developing the class was *Biomechanics: Concepts and Computation* by C. Oomens et al. This text was used to provide the basic framework for introducing the mechanics and computational fundamentals within the biomechanics curriculum. The book also came with access to MATLAB code which will be used to introduce the concept of FEA. The textbook is also supplemented with other resources to round out the material with more physiological information as well as examples of real research data and articles which show the real-world applications of the information that the students will be learning.

The students will be instructed on these concepts in several diverse ways. Concepts are first introduced through lectures that involve interactive learning components and reinforced through homework assignments. Further contextualization of these concepts and scientific literacy will be taught by including analysis of scientific journal articles. The students will be expected to both read and evaluate the merit of these journal articles. This will help empower the students to be self-sufficient in acquiring new knowledge from original research. Labs will expose the students to real-world applications of the biomechanical concepts that they are learning. Three labs will expose students to mechanical testing through tensile testing, compression testing and three-point bend testing of biological tissues. A fourth lab will expose students to a MATLAB based FEA model that will allow the students a better understanding how numerical methods can be used to help solve complex biomechanical problems.

40% of the students' final grade will be based on exams, with 10% each coming from midterm exams and 20% coming from a comprehensive final. 35% will be due to assignments including homework problem sets, journal article responses and lab reports based on in-class experiments. 10% of the grade will be based on a final project where a student selects a biomechanics-based journal article to evaluate and then present to the class. The final 5% of the students' grade will be due to participation and attendance.

Evaluating the course

Student success within the course will be evaluated in multiple ways including exams, lab reports, journal article discussions, and a final project. Student understanding of engineering mechanics and biomechanical responses will be evaluated through questions on three midterm exams and one comprehensive final exam. The first exam covers the topics of force and moments, static equilibrium, and rigid body dynamics. The second exam covers the topics of mechanics of fibers, elastic stress-strain, viscoelastic behavior, and continuum mechanics. The third exam covers the topics of stress tensors, principal stresses, deformation, and rotation. The final exam covers all topics taught within the class including all above topics plus the addition of solution strategies for biomechanics problems and finite element techniques as well as biological responses to mechanical forces. This comprehensive final helps ensure long-term retention of biomechanics concepts as well as evaluates the ability of students to integrate topics from multiple sections of the course. Data collected as the exams are given will be evaluated by topic to evaluate the effectiveness of the teaching strategies on instruction of various biomechanics concepts.

The ability to conduct experimentation and analyze experimental data will be assessed by having students conduct mechanical testing experiments or running a FEA model. The students will then be asked to complete a lab report in which they will demonstrate their understanding of the experiment. Students will be asked to formulate a hypothesis about the experiments based on previous knowledge acquired in the course. They will be expected to obtain data through the experimental protocol and then analyze it for statistical significance. Finally, students will be expected to draw appropriate conclusions based on the results obtained.

The ability of students to acquire and apply new knowledge will be assessed through journal article analysis culminating in a final project in which each student will choose a biomechanics-related journal article which the student will present to the class. The student will be evaluated on the ability to identify the motivation behind the article, identify the main hypothesis of the paper, evaluate the effectiveness of the methods chosen, describe the significance and relevance of the results, and assess the relevance of the results to answering the hypothesis.

Finally, end of semester student evaluations administered by the university will be used to reflect on the effectiveness of these teaching strategies and further iterate the course development process as well as evaluate student confidence in the material that they have learned. The collection of the student data has been evaluated by the university's IRB and the research protocol was considered exempt.

Results and Discussion

As this class is being offered for the first time in the Spring 2024 semester, initial data on the effectiveness of the proposed teaching methods is still being collected. This data will include performance on representative exam questions for key biomechanical concepts, lab reports from in class hands on experiments, discussion questions from journal articles read and discussed in class, final presentations on journal articles of the students' choosing and student evaluations given by the university. This year's class consists of only two students, so further data will need to be collected on next year's class, which is expected to increase to 4 to 6 students. However, this year's data will be used to inform the initial round of reflection and changes in the design of the biomechanics class. The data obtained through this methodology will be used to improve the instruction of biomechanics for our biomedical engineering students.

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