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SHARE: A Constructivist Approach to Modular Course Design in an Undergraduate Biomedical Engineering Tissue Mechanics Course

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Challenge: The biomedical engineering field is continuously evolving to meet the growing demands of healthcare [1, 2]. Therefore, the education of biomedical engineering students needs to focus on equipping students with the conceptual foundation and tools needed to be immediately responsive when placed in commercial/industry roles [3]. However, undergraduate biomedical engineering students are often tasked with navigating multiple pedagogical approaches across their coursework, especially in advanced synthesis-intensive elective courses, such as tissue mechanics (which bridges concepts in classical mechanics/biomechanics, physiology, biomaterials, and tissue engineering), causing difficulty when translating knowledge and skillsets into real-world applications [4]. This tends to weaken academic performance and influence students' attitudes toward post-graduation professional pathways. This suggests that students need a better understanding of how content learned in the classroom can be applied to real-world scenarios, therefore gaining both foundational knowledge and applied learning pertinent to the field.

Learning Objectives: This implementation is guided by the following 3 learning objectives: (1) **Improve understanding of concepts in Tissue Mechanics through reflective learning** through the guidance of **Bloom's Taxonomy Levels, (2) Combine case-based and technology-enhanced learning using real-world applications. (3)** Understand potential limitations and problem-solving approaches by hands-on analysis.

Step-by-Step Details of Implementation:
This activity is designed **to be implemented in a higher-level 16-week semester course period** (is appropriate for junior/senior/graduate-level courses). S**tudents are expected to have prior knowledge of general physiology, biology, mechanics, and materials**. However, **functional context** is provided within the modules **to make** proper connections **to the course content.** Bloom's Taxonomy is a well-developed theoretical framework that has been used to guide the structure of many courses by categorizing learning objectives into different stages of complexity [5]. Therefore, this implementation aligns with Bloom's Taxonomy levels, beginning with remembering and understanding. Before the primary activity, s**tudents will begin with two weeks of guided** lecture-based **review of physiological functions and** mechanics principles as relevant to biological **tissues. This is followed by a** 15-minute **thi**nk-**p**air-**share.** An example of a prompt for the instructor to use would be: "What is the normal nature of loading this tissue experiences and how does it respond**?". Students are expected to ponder and discuss** tension/compression, torsional loading, d**eformation** (Ex: extension/compression, angular rotation), l**oss of energy** (Ex: viscoelasticity), and cyclic/fatigue in the tissue because of repeated loading. The purpose is t**o re**fresh prior knowledge **and prepare students** for **upcoming activities in** which they must apply content to example **real-world scenarios** (Ex: what happens to this tissue during growth/development and aging**)**. The implementation will begin to be applied during the 3rd week of the course, and is then applied weekly to consider the mechanics of 16 different tissues (Ex: Bone, cartilage, tendons and ligaments, skeletal muscle, dental tissues, skin, adipose tissue, central nervous system, peripheral nerves, vocal chords and upper airway, ocular tissue, tongue, the ear, cardiac muscle, pulmonary tissue and blood vessels). First, students are broken into teams of 3-4 students and are assigned a specific concept that is in correlation with that week's course

contentment leveraging Bloom's Taxonomy (**Appendix 1**). For instance, since each lecture includes mechanical testing of the tissue, the students are assigned a specific mechanical test data set (Ex: indentation measurements of cartilage) and are provided with a test protocol that 'generated' the set of data. The first 10 minutes of the lecture cover the basics of the tissues' properties (such as form, function, extracellular matrix composition, and primary mode of loading). The students then analyze the data/fit the model for the tissue for 15 minutes to use this dataset to extract the characteristic properties of the tissue from the test. This is followed by guided data analysis in which students are asked to interpret their "calculated" data in the context of pre-existing data for that tissue (Ex: properties for cartilage generated by indentation testing and reported in the literature across age/sex/species/pathology) for 15 minutes. Students are also introduced to a publicly available finite element analysis software: FEBio in week 3 of the course and are provided with a model for the tissue being discussed in the given lecture (Ex: a biphasic confined compression model for cartilage appropriate for indentation testing analyses). The students then use the finite element model to model the test using the material properties they derived, and then observe changes in mechanical behavior under varying loads with varying parameters for 15 minutes. This lecture is then concluded with a 20-minute discussion of available information from the literature regarding the mechanics of the tissue in question, in which students will reference published studies online to review their methods and results sections to decide how experimental data lead to scientific interpretation and decision-making. This would be followed by an open-notes/open-internet post-implementation quiz after each set of 2-3 tissue modules that are designed with questions that not only evaluate the conceptual understanding of the students, but also their understanding of how content can be used in real-world scenarios.

Situational Factors:

Factors that may affect this activity are the following:

- Class size and inclusion of team-based approaches
    - In the context of this implementation, this is designed for larger courses of 25-40 students enrolled. However, if there are smaller courses, this structure could be modified to give students more time for their activities or longer group discussions.
- Student classification level, credit hour total, and academic standing
    - As previously mentioned, this course is intended for upperclassmen/graduate students. In turn, if a student were of a lower classification level, had a low credit hour total, and/or poor academic standing, this may affect whether the student is able to make meaningful connections between course content and real-world scenarios. However, this structure could be adjusted to meet the needs of students by expanding on introductory content if most students lack some general physiology, biology, mechanics, and materials understanding.
- Student attitude towards group participation
    - If students have a negative attitude towards group participation or numerical models, it may be difficult to promote collaboration. However, this could be addressed through group rotation or incentivizing students with participation credit.

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Appendix 1:

Week	Bloom's Taxonomy Level	Activity
1-3	Remembering and Understanding	Students will take part in a guided lecture-based review of physiological tissue functions, outlining tissue structure to function and the structural components of a tissue, focusing on the extracellular matrix. Stu
4-5	Applying, Analyzing, and Creating Evaluating Understanding	Week 4-5 (bone, cartilage): • Protocol Demonstration- Students will be assigned a specific mechanical test (ex: flexural testing of bone) and will determine the properties of bone (E, ν) using a sample set of flexural testing data. • Data Analysis- Following the protocol demonstration, students will interpret the example 'generated' data sets. • Finite element model – students will use a (flexural loading) model of bone to input the (E, ν) parameters calculated and observe characteristic bending of the bone • Literature Report- Students will reference published studies online to review their methods and results sections to decide how experimental data leads to scientific interpretation and decision-making. • Students will be provided with a 'what-if' scenario (aging, pathology, traumatic injury regeneration) to simulate changes in the mechanical test/tissue properties to hypothesize a change/mechanistic understanding. Ideally, students will formulate different approaches and understand that there are different ways to approach challenging scenarios.
6		Open Note/ Open Book quiz
6-16	Applying, Analyzing, Creating, Evaluating, Understanding	Continue for other tissues: tendons and ligaments, skeletal muscle, dental tissues, skin, adipose tissue, central nervous system, peripheral nerves, vocal chords and upper airway, ocular tissue, tongue, the ear, cardiac muscle, pulmonary tissue and blood vessels