Board 21: Work-In-Progress: The Influence of Digital and In-Person Pedagogical Interventions on Undergraduate Biomedical Engineers

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Introduction

Undergraduate engineering programs are designed to be both rigorous and experiential, consisting of a curriculum aimed at helping students develop a strong foundation of fundamental engineering concepts while providing them with the tools to operate in complex real-world scenarios. The overall goal of engineering programs is to produce students who have the academic preparation needed to approach and navigate the diverse challenges they may encounter in the engineering field [7]. However, engineering graduates have been shown to often have difficulties when attempting to apply their knowledge from the classroom to the challenges they encounter in professional settings ('school-to-work transition') [8]. Moreover, there has been an inconsistency between academic achievement and workplace performance shown in prior research [4] that has raised concerns in the engineering field and caused a reevaluation of the approach of engineering education while suggesting a necessary departure from traditional lecture-based teaching methods. This WIP paper draws from the principle of critical reflexivity to argue that both digital and in-person socialization and dialogue are important pieces for students' professional development as they enter the workforce. We argue that the teaching of biomedical engineering can be strengthened by having students engage in critically reflexive practices (as demonstrated by students' responses to current curricular implementation) meant to analyze what is the purpose of engineering in *both digital and physical* engineering spaces.

Critical Reflexivity

Critical reflexivity has been recognized as an important piece of pedagogy, offering insights into the pedagogical impact of questioning issues of power while considering social, environmental, economic, and cultural factors in educational settings [5]. While critical reflexivity is often associated with acknowledging the individual's positionality, its integration into classroom settings extends beyond mere self-awareness. Critical reflexivity practices are vital in engineering as they foster a deeper understanding of the social, cultural, and ethical dimensions inherent within the discipline [6]. Engineering, traditionally perceived as a technical and objective field, is deeply embedded within broader societal contexts and power structures [2]. Through critical reflexivity, engineers can interrogate their assumptions, biases, and privileges, thereby challenging dominant narratives and fostering inclusive and equitable practices. By engaging in self-reflection and critical dialogue, engineers can better recognize the social implications of their work, identify potential sources of bias or discrimination, and strive towards more ethical and socially responsible solutions. Critical reflexivity, thus, encourages collaboration and interdisciplinary engagement, inviting engineering students to consider diverse perspectives and alternative approaches to problem-solving.

Pilot Study

The initial step in this pilot study entailed selecting a tissue mechanics course that is part of an undergraduate biomedical engineering program. The course consisted of a 'lecture-driven', traditional teaching environment with minimal collaboration opportunities. This course was also chosen because biomedical engineering is a rapidly growing and emergent field [10] that challenges educators to prepare students for its evolving landscape. Lastly, tissue mechanics was

selected because it consists of complex concepts that students have difficulty understanding such as mechanics of materials. The initial data collection consisted of a survey administered to undergraduate biomedical engineering students in the selected tissue mechanics class. The survey consisted of questions that inquired about the current conditions of the course. The survey instrument of questions included such items as: "Why do you think these topics have been difficult and what about them do you find the most challenging?" and "What are some improvements that you think would help you better learn these concepts?". We collected qualitative data that helped inform how the development of the future study and implementation will include critical reflexivity as the main pedagogical theoretical framework. The following statements are representative examples of students' comments regarding the current structure of the tissue mechanics course:

- "I found mostly the complexities about [tissue mechanics topics] to be difficult, not that they were very difficult to understand, but there were lots of complexities that are considered in the mechanical behavior of those tissues."
- "I think most of the time the application to engineering is what makes it smore difficult to understand."

As shown in the qualitative data, students mostly emphasized concern that it is not the content that is complex; instead, it is the amount of content relayed in the course and the limited opportunities to engage in dialogue. The response from this survey further demonstrates that there is difficulty in translating academic concepts into practical problem-solving approaches relevant to the complex challenges they may encounter in their future engineering careers if there is not ample opportunity to apply and discuss conceptual knowledge. These insights provided by the student comments highlight students' perceived need to receive additional opportunities to critically analyze the material being studied. Students' responses show that there is a lack of (1) time to process the information received, (2) debriefing of material content to prevent cognitive overload, (3) application to real-world scenarios, and (4) critical analysis of theoretical principles to practical implementation. We argue that argumentation in the classroom through a combination of in-person and digital critical reflexivity can allow students to achieve these objectives when learning about tissue mechanics. The implementation of pedagogical interventions that allow for socialization in person and virtually promises different avenues where critical reflexivity can happen. The digital platform Perusall, for example, has been proven to be a valuable annotation tool for students to make notes and collaborate on different research articles with scored responses that encourage social learning [3]. Perusall is also a tool that gives instructors an opportunity to identify students' mental models, and therefore appropriately address difficult concepts created by epistemic causes (i.e., patterns of how the learners construct concepts, knowledge and theory) [11]. In addition, the implemented case studies that will be used allow students to practice concepts learned in class as collaborative dialogue occurs in the classroom. In turn, these interventions may also provide better insight into the benefits of an interactive and dynamic learning environment, facilitated by both in-person and digital tools.

IRB Statement: No Institutional Review Board (IRB) approval was required for this study as it did not involve the collection of personally identifiable information.

Context of Intended Implementation for Critical Reflexivity

The predominant method utilized to educate engineers is often 'lecture-heavy' traditional-based teaching [4]. This method has been perceived to be the most effective when

relaying the content needed to produce a successful engineer but is often described as overwhelming by students due to the amount of information being taught [1]. This experience can be attributed to the limited opportunities forcollaboration and application of theoretical knowledge needed to prepare students for 'real-world' scenarios in traditional engineering classroom settings. Recognizing this limitation and building on the foundation that learning is a social process not solely cognitive [12], there has been a growing interest in diverting from traditional based teaching methods and exploring alternative pedagogies that promote collaboration and critical reflexivity. That said, we intend to analyze the influence of in-person and digital pedagogical interventions to determine how they contribute to the development of conceptual knowledge of current engineering students when critical reflexivity is considered at the front and center of the pedagogical approach. Digital interventions leverage technology to create interactive educational experiences through online simulations and collaborative tools, fostering virtual learning. In contrast, in-person interventions prioritize face-to-face communication, traditional lectures with facilitated group discussions, and hands-on activities such as case studies or projects. Both approaches, typically independently studied for their unique strengths and limitations, will be jointly implemented into an undergraduate biomedical engineering tissue mechanics course in this research to promote critical reflexivity through the added socialization. To determine the effectiveness of the applied interventions, assessments will include observations made of discussions on the virtual collaborative learning platform Perusall, in-person case studies, and student artifacts (surveys). Moreover, we anticipate that in-person and digital pedagogical interventions will expand the understanding of the social, cultural, and ethical dimensions inherent within the discipline [6] of the undergraduate biomedical engineering students in the tissue mechanics course. To not overwhelm the students at once, we will be introducing the in-person case studies at the beginning of class (student and class discourse), continue with traditional lecture, then assign the students an article to read for homework where they must make 3 significant posts on Perusall (1 individual post and 2 responding to peers). Authors will assess the discussions and Perusall posts based on the complexity of the discussion. We also intend to address concerns regarding the possible reduction of socialization among students in distance learning [9] environments (Perusall) by emphasizing the research's grounding in both digital and social purposes. This is grounded in the idea that socialization and discussion play an essential role in scientific argumentation and the professional development of future biomedical engineers.

Future Work

Based on the preliminary data, the students' survey responses demonstrate that there is a need to divert from the current usage of traditional pedagogical methods in engineering education. Future directions of this research indicate continuing to monitor the progression of conceptual understanding and scientific argumentation of tissue mechanics within the selected undergraduate course through the use of course exams and newly implemented pedagogical interventions. By leveraging digital (Perusall) and in-person (case studies) interventions, we intend to learn how to create dynamic learning environments while promoting the fundamental practices of critical reflexivity in engineering education. In turn, we expect to enhance critical thinking and collaborative engagement in the classroom, assisting students in applying conceptual knowledge developed from content and diverse perspectives, facilitated by the implemented digital and in-person interventions, to real-world situations.

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