Work in Progress: Direct incorporation of research articles into undergraduate biomedical engineering courses to contextualize complex topics

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Abstract. This work-in-progress paper presents our introduction of a journal club activity directly into undergraduate biomedical engineering (BME) courses. This activity is aimed at contextualizing complex topics in BME through peer-reviewed articles. Our journal club activity is composed of a written assignment focused on summarizing and evaluating the assigned article and an in-class discussion of the article. In this paper, we present how we structured the written assignment and classroom discussion. Additionally, a skill that we aimed to develop in our students with this assignment was their ability to critically evaluate journal articles. As such, we examined student critical thinking skills through an analysis of written assignments. Although we found that students valued this activity, we found that students did not develop their abilities to critically evaluate scientific articles. Future work is needed to develop structured feedback that can assist in developing these critical analysis skills.

Introduction. Engineering curricula have a tendency of being strongly rooted in theoretical concepts that do not provide students with real-world examples of course topics [1], [2]. This can lead to student disengagement and may ultimately lead to decreases in student persistence in engineering programs [3]. Contextualizing course topics is a strategy to combat student disengagement by providing real-world examples related to course topics allowing students to see the applications of abstract theoretical concepts [3]. Providing real-world context for technical topics covered in engineering courses is typically accomplished through case studies [4], [5]. While case studies can be useful in practice as an intellectual exercise, the skills of analyzing a case study are not necessarily drawn upon during an engineer's career following graduation. More commonly, engineers working in industry, government or academia use primary research literature to inform the engineering decisions made in their work. As such, learning how to read and interpret scientific articles is important for the future success of engineers. In-class discussions of scientific literature, more commonly known as 'journal club', is an existing strategy used to contextualize course content and teach experimental design [6]. Previous work has shown that exposing undergraduate students to journal club activities is a useful pedagogical tool, but this has been primarily performed in biological/medical fields, outside of structured courses, in elective courses, and/or at the graduate level [6]–[11]. Given this, we propose that incorporating the discussion of research articles in courses required in our undergraduate biomedical engineering (BME) curriculum will not only expand what the students are learning, but will build a skill necessary for their success as future engineers. As such, in this 'Work in Progress' paper, we present our efforts to contextualize complex topics in BME by incorporating scientific research article discussions *directly* into required BME courses.

Methods. All work presented has been reviewed by our university's institutional review board and was approved as a category 1 exempted study. We have incorporated a journal club discussion into the first offerings of three of our required BME courses: biomaterials design (n=19 students), orthopedic biomechanics (n=23 students) and bioinformatics (n=9 students). Our BME program was created in 2019 and is housed within an engineering major at our university [12]. This 'concentration' in BME consists of 5 required courses that are taken during the 3rd and 4th years of our program. At the date of publication, we have developed 3 of these 5 classes, all of which include this journal club activity. Below, we outline journal article selection, the written assignment, in-class discussion, grading strategy and an analysis of the written assignments.

Journal article selection. In each of these BME courses, at numerous points in the semester, students are provided with a research article directly related to recent lecture material. Selection of an appropriate journal article is critical for the success of this assignment. Since this is the first time many of the students will be reading a scientific paper, it is important to select articles that will not completely confuse students. Furthermore, in order to properly contextualize course topics, it is critical that the articles be directly related to lecture topics. We screen all articles prior to assigning them and only choose articles deemed to be appropriate for junior/senior level students. Seven articles were discussed in Biomaterials Design related to metallic biomaterials [13], ceramic biomaterials [14], polymeric biomaterials [15], biomaterial evaluation [16], viscoelasticity [17], foreign body response [18] and biomaterial surface properties/inflammation [19]. Two articles were discussed in Bioinformatics related to DNA sequencing [20] and RNA sequencing [21]. Three articles were discussed in Orthopaedic Biomechanics related to free body diagrams [22], biomechanics data capture [23] and fracture fixation devices [24].
Written assignment. Students are given a week to read the article and turn in a 1-2 page written assignment detailing a summary of the article, an evaluation of the article, and a list of defined terms. In the summary section, students summarize the introduction, materials/methods, results and discussion sections of the paper. In the evaluation section, students are asked to reflect on how the authors have interpreted the data, how the data are presented and the appropriateness of the experimental design chosen by the researchers. Furthermore, the students are asked to evaluate whether the authors' claims are supported by the data as well as if there are any missing experiments that they would recommend to strengthen the article. Lastly, given that many of the terms students come across in these are articles are new, students are asked to define 10 new terms they encounter in the paper. This written assignment is due before the article is discussed.
In-class discussion. During the class discussion, students are split into groups of two and are assigned a figure, table, and/or section from the article. Students are then given ten minutes to review their assigned portions. The instructor then leads the students through a discussion by calling on each group in the order of the sections. The discussion of each figure always ends with defining a 'take-home' message to ensure students have fully synthesized the data.
Assessment. A large motivation for the written assignment is to prepare students for the in-class discussion. As such, the written assignments were graded based on completion. If the instructor deemed that the student had written an accurate summary of the article and has attempted to reflect on the article's content, then full credit was awarded to the student.
Analysis of written assignments. A skill that we aimed to develop in our students with this assignment was their ability to critically evaluate journal articles. As such, we assessed the reflection portion of the written assignment to gauge student attainment of critical thinking. The presence of critical thinking was assessed using the *WSU Guide to Rating Critical Thinking* [25]. The WSU guide has instructors assign an achievement level for a particular skill from 1-6, with 1 representing 'not evident' and 6 representing 'substantially developed; considered in full complexity; nuanced and sophisticated'. Since we were interested in students' ability to critically reflect on findings from a research article, we chose to focus on dimension 7 of the WSU guide, which assesses how students, '*identify and assess conclusions, implications and consequences*'.
Results and Discussion. Overall, an analysis of student ability to identify and assess conclusions, implications and consequences of research articles showed that students remained at an achievement level of 2, corresponding with 'discernable, but not developed', in all three courses (Figure 1). From this we can see that the content of student reflections did not include the depth or critical perspectives that a more experienced reader would have included. For

example, it was typical for students to comment on the paper/figure layout or just provide a superficial evaluation of the science contained in the article. Statements such as, "…I also enjoyed that most of the images shown were relatively clear and easy to decipher", "they presented their data very clearly and explained each image", and "overall, I think this article was written well" demonstrate common reflections corresponding with an attainment level of 2. Although these types of reflections were most common, we did observe reflections that were indicative of critical thinking, such as, "…it would have been better to use current osteoconductive materials to show that β-TCP/PLA-DX-PEG/rhBMP-2 is truly a superior alternative" and "…it would be better to move beyond pure speculation that TNF-α production was higher in the days following implantation and conduct another study".

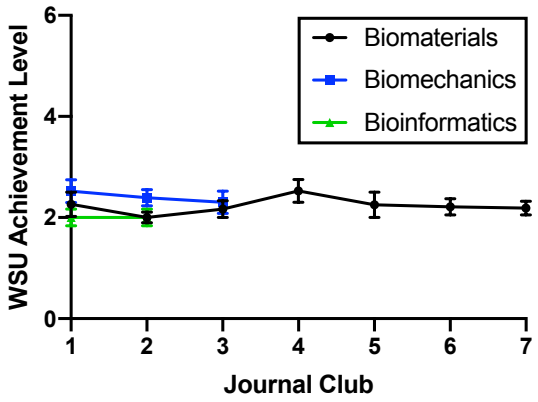

Figure 1: Achievement level to identify and assess conclusions, implications and consequences in the assigned journal articles over a semester in BME

Student self-efficacy. When analyzing students' written assignments, we qualitatively observed an increase in student self-efficacy as the semester progressed and they gained more practice in reading and analyzing scientific articles. This was particularly prominent in the biomaterials course where students read 7 articles. Specifically, following the first article, we found that 21% of student reflections contained statements that indicated a lack of confidence in their ability to understand and evaluate the articles. This was indicated with quotes such as, 'the summary of these figures was too high of a level for me to understand what was going on in these figures' and, 'the language was hard to decipher at times and took re-reading a sentence three or four times to somewhat grasp what it was trying to say'. At the end of the semester, statements such as these decreased to just 5% of reflections in the biomaterials course. These statements also decreased throughout the semester in our other courses.

Conclusion. Overall, our work to incorporate scientific articles into three of our BME courses has been successful as indicated by an increase in student self-efficacy as well as numerous positive comments about this activity in our class evaluations. In the biomechanics course evaluation, 27% of students indicated that journal club was their favorite part of the course. Additionally, student comments such as, "journal clubs allow us to go into our field with real world knowledge and give us the tools to continue to learn", and "the journal clubs were an amazing way to explore different journals and current information in the field" demonstrate that students found value in this activity. However, an analysis of students' written work showed that written reflections generally lacked a serious and critical reflection of the material. Given this, future work is needed to provide students with more constructive feedback and guidance on the written assignments in an effort to increase their critical analysis skills. Specifically, we will work to explicitly guide students through what they should be looking for as they read journal articles, such as through the use of dialectical notes [10], [26], [27]. Furthermore, as we have qualitatively observed changes in student self-efficacy, we will move to quantify these observations through surveys administered before and after each course. Finally, we realize that this work can and should be translated to other engineering fields outside of BME. When translating this activity to other engineering fields, care should be given to select articles that are *directly* related to lecture topics and are at an appropriate difficulty level.

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