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Work in Progress: Assessing Biomedical Engineering Student Engagement in Asynchronous and Synchronous Virtual Physiology Laboratory Experiences

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Introduction

The unprecedented effects of the COVID-19 pandemic have further pushed online learning development and have made distance learning an integral component of undergraduate education [1]-[3]. Although standard lectures have transitioned to virtual space in a relatively seamless manner, laboratory components have presented a greater challenge [2]. Maintaining dynamic yet relevant practical, hands-on learning experiences within a virtual platform has demonstrated mixed success [4]. Since laboratory experiences remain a keystone to biomedical engineering (BME) education, it is critical to design curricular experiences that provide active, sensory, visual learning experiences to maintain student engagement in the virtual space to promote cognitive development and enhanced student success [5], [6]. The BME curriculum at the University of Toronto is rich in hands-on laboratory experiences, giving students a heuristic experience to explore relevant biological and physiological concepts through translation of captured biosignals. In this paper, we explored BME student engagement during online physiology lab experiences to discern possible approaches in optimizing the active distance-learning experience. Our strategy in re-designing physiology labs was to develop an expanded curriculum around commercially available laboratory simulations (Labster ApS, Copenhagen DK). To explore the effectiveness of virtual lab engagement, students completed scaffolded lab activities independently (asynchronous; completed on student's own time) or collectively (synchronous; completed as a class cohort during scheduled time with the teaching assistant instructor). While several studies have presented various ways to manifest the laboratory experience in an online space, we have yet to explore and understand whether synchronous or asynchronous physiology experiences best promote BME undergraduate engagement.

Methods

Students participating in the current study (n=13) were enrolled in a third-year physiology course in the BME program at the University of Toronto during the fall semester of 2020. The course included biweekly online laboratory activities managed through the Canvas Learning Management System (LMS). The two labs chosen for this comparative study commonly focused on electrophysiological and required using MATLAB software to preprocess biosignals and assess physiological reactions to different scenarios. This study was approved by the University of Toronto Research Ethics Board (Protocol #40392).

The 'asynchronous' lab focused on skeletal muscle physiology, reflex arcs, and EMG signals. Students independently completed the virtual simulation "*Skeletal Muscle: Learn About the Muscles We Use to Walk and Run*" (Labster; runtime 48 minutes) and subsequently used MATLAB to process previously recorded EMG signals [7] and complete a series of questions. The goal of data analysis was to use a peak detecting function in MATLAB to calculate the temporal distance between the stimulus and the muscle contraction reflex to understand response latency and amplitude. Students were allowed 9 days to complete the lab; the TA provided support with two optional 3-hour Zoom office hours (Days 1 and 6) and oversight of a designated Canvas Discussion Board. Upon completion, students submitted their responses to the MATLAB activity through a Canvas Assignment site.

The ‘synchronous’ lab focused on cardiac muscle response and the electrocardiogram (ECG) signal. During the regularly scheduled 3-hour timeslot, the TA used Zoom screen sharing to lead the class through the virtual lab. The first hour was devoted to completing the Labster simulation “*Cardio-respiratory Physiology*: *How can Seals Dive so Deep for so Long?”* (runtime 36 minutes) as a group. Using the Zoom polling feature, the class completed the lab according to audio instructions, making group decisions as required and answering embedded multiple-choice questions (anonymous; independent). The TA led a brief discussion regarding the theory behind each answer allowing for connections to be made between simulation content and course concepts. Post-simulation completion, the TA gave a 20-minute ECG lecture including the physiology, acquisition, and digital processing of the signal. Students were randomly assigned to online breakout rooms (3-4 per room) to use MATLAB to process ECG data previously collected by the TA (i.e., dive-reflex, cold-pressor response, holding one’s breath, etc.). Processing involved using a peak-detecting function in MATLAB to determine heartrate changes relative to baseline measurements. After 1 hour each group presented their findings to the class with the TA supporting more holistic discussions relating to the physiology of observed effects.

At course completion, all participants wrote a one-page reflection essay on their perceptions of ‘asynchronous’ and ‘synchronous’ online lab experiences. Sentences contextually relevant to either experience or providing feedback on lab development, were manually separated into two large text files and MATLAB R2021b Text Analytics Toolbox was used to analyze the distinct categories of student responses for determination of keywords and student sentiment [8]. Text was preprocessed as per the toolbox’s documentation and word frequency for each category was counted with most frequent words being identified [9]. Identified words were compared to anonymous responses from an end-of-term survey designed to discern variation in student engagement. This included experience with lab tools (i.e., interactive simulations and MATLAB) as well as the perception that lab experiences reinforced relevant physiological concepts (i.e., muscle function; signal interpretation). The survey included: 1) Likert-scale questions wherein responses were coded according to scale of response (1- very poor, 2- poor, 3-okay, 4-good, 5-very good) for averaging purposes, and 2) true/false questions that were quantified based on percent class response. Finally, the number of times online files were accessed was measured using the Canvas LMS “New Analytics” function as an indicator of student engagement.

Results and Discussion

In this pilot study, we aimed to understand whether ‘asynchronous’ or ‘synchronous’ experiences led to greater overall BME student engagement in the context of online lab delivery. Our observations to date suggest our 3rd year BME students prefer to engage on their own: 8 of 12 students indicated that “*working through the laboratory exercise in my own time was better than working as a class during a scheduled time*” (1 student did not complete the survey). This likely reflects the need for focused time to navigate lab components, and preference for independent engagement and decision-making. Seven of 12 students indicated better comprehension of theoretical content when completing the simulation independently. Essay responses supported survey findings that students were more engaged with the simulation material and had a better understanding of concepts when allowed independent access. Students expressed different learning styles when approaching the simulation with one student explaining that they would prefer to "*read quickly and skip the voiceovers*" while another took an alternative approach and preferred to "*take notes during the simulation … for future reference in the course*". Half of the essay responses (n=6) indicated that 'time' was a critical factor when completing the simulations and further expressed that completing the exercise as a group was either "too slow", leading to decreased engagement, or moved "too quickly" for students to absorb the questions.

Synchronous lab activities were favored among our BME students due to increased peer interaction and engagement with the TA. Students discussed 'group' work as creating a less isolating environment (n=6) and a platform to share ideas or receive instantaneous feedback (n=11). Students reflected that real-time support was more beneficial to their experience because group work encouraged peer interactions and a range of perspectives. Interestingly, and in contrast to this sentiment, Canvas analytics showed only 4 of 13 students interacted during the optional 3-hour live Zoom session at the start of the 'asynchronous' lab suggesting that the real-time discussion and interaction is preferred when most amenable to students' schedules. Student sentiment was less favorable with regards to completion of a lab simulation as a group with sentiments echoing the idea of variable learning styles. Similarly, more than half of the responders (58.3%) indicated reduced focus when completing the simulation as a group. There was no difference in student perception of the overall value of using MATLAB in a group setting compared to individual engagement. Although code could be implemented efficiently with the support of peers and the TA, the experience was minimized because students were not able to exhibit independent decision making in a group setting. Therefore, guiding the coding experience with time for independent engagement should be supported by iterative group discussion.

Although virtual simulations were just one activity scaffolded within our online labs, most of our students (11/13) indicated this to be a 'very good' experience (4.4 ± 0.3) that helped them understand real-world applications (4.3 ± 0.3). However, students indicated that the simulations were 'okay' at providing a motivating experience (3.9 ± 0.3) and were moderately positive about gained translatable lab skills (4.0 ± 0.3), revealing the limitations that virtual laboratories present. While realistic environments can be envisioned, lab simulations lack real-life consequences that can prove to be additional learning experiences for students. Nevertheless, the value of this component within our scaffolded online lab framework is clear. As one student expressed "*[the Labster simulation] will never be as ideal as the real thing, but I get a chance to expose myself to different equipment and protocols I might use in the future*".

Conclusion

Due to small sample size (n=13), we were unable to apply robust statistical analysis to determine significant differences between our 'online laboratory frameworks; however, we were able to identify elements with each framework that best align with BME student learning preferences. Student response confirmed that a blend of asynchronous and synchronous activities would be optimal for reviewing concepts, applying tools, and engaging with peers when engaging in online curriculum. We recommend that simulations are fruitful tools as pre-laboratory preparation for the in-person experience. Additionally, isolation brought on by the pandemic has increased psychological stress and vulnerability among students, regardless of mental health conditions [10], [11]. Researchers have suggested that this can be mitigated by adjusting academic expectations [11]. For physiology lab experiences, and perhaps lab experiences in general, this could mean integrating synchronous experiences into the curriculum to improve social connection among students to intermittently support independent student work.

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