Teaching Tips

Development and Implementation of a Biometrics Device Design Project in an Introductory BME Course to Support Student Wellness

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(Received 14 August 2021; accepted 4 December 2021; published online 3 January 2022)

Abstract—Mental health challenges have been rising across college campuses. To destigmatize wellness practices and promote student mental health, we present a novel technical project in an introductory bioengineering course that explores stress management techniques through physiology, biosensors, and design. We hypothesize that if students measure objective, physiologic impacts of stress management techniques on themselves, they may be more likely to realize the benefits and use those techniques when needed. Additionally, through this data-driven project, we aim to appeal to engineers’ critical thinking nature. To support students in selecting stress management techniques for themselves, mindfulness is introduced and practiced in the course. Initial student feedback on the introduction of mindfulness into the classroom is positive. The COVID-19 pandemic has emphasized the need to focus on student wellbeing in addition to physical health. Integration of wellness into the core curriculum can normalize the use of these resources within engineering departments and colleges and equip students with stress management tools for their careers. Ultimately, this curricular development lays the groundwork for institutional enhancement of undergraduate STEM education by supporting student wellness through the engineering curriculum.

Keywords—Undergraduate education, Experiential learning, Mental health and wellness, Medical device design, Design courses, Biomedical engineering.

CHALLENGE STATEMENT

Engineering culture is dominated by perceptions of difficult and heavy workloads. This challenging environment creates a culture described as one of “suffering and shared hardship”. Students are expected to accept demanding workloads to be successful at the expense of their mental health. Undergraduate mental health challenges have been increasing in prevalence in recent years. From 2007 to 2017, student mental health services utilization increased by 15% across US college campuses. Some studies have indicated that rates of mental health issues have been found to be higher among engineering students than non-engineering students. Additionally, some studies also found help-seeking to be lower for engineering students. These challenges create a need for colleges to provide more targeted mental health resources for students. We identified an opportunity to use data analysis and engineering design in a manner that allows faculty to promote inclusion within technical courses and students to find healthy coping methods for themselves while learning the importance of diversity in design courses.

Design courses provide an opportunity to teach engineering students the importance of achieving inclusive environments within engineering. As an engineer it is important to be able to design products that serve all populations. One need not look far to find instances of bias in engineering design. For example, the pulse-oximeter, a medical device used in the project described here, does not accurately measure blood-oxygen levels for People of Color because of the absorption-based optical measurement. Previous
Design heuristics cards are a set of 77 designs. Design heuristics cards can help students think from more perspectives. In one first-year engineering course, students tended to revise their first design multiple times rather than try different designs. Design heuristics cards displayed with applications of the research-based heuristic on everyday products. Students can use the cards to think about features of the existing devices or their own ideas that can be improved. The goal of using the cards is to expand the design space within which the student team works by allowing them to ideate from multiple perspectives. Another study found that undergraduate students using design heuristics when analyzing and critiquing existing patient designs had more “unique” and “feasible” solutions than students who did not use design heuristics. Studies have found that students working in teams gain professional and technical skills and adapt and advance more quickly in future industry careers. Another study found that students’ ideas of identity were based on performance of a task, while their sense of belongingness was based on peer comparison. First year engineering courses can utilize group projects to help students gain valuable team and social skills. Previous work suggests that engaging first-year bioengineering students in a team-based, data-driven design project with an emphasis in DEI provides an opportunity to enhance student engagement when wellness is practiced in a group, to strengthen students’ engineering identity through technical data analysis, and improve team skills and quality of student’s designs through the use of DEI principles.

**NOVEL INITIATIVE**

To meet these challenges, we propose a design project that asks teams of students to practice wellness techniques over a 6-week period and use stress tracking devices to monitor biometrics while testing their own hypothesis related to how the techniques impact cardiovascular physiology. In addition to analyzing data collected before and after wellness activities, student teams look specifically at the functionality of the stress tracking devices used. Teams evaluate the functionality of the biometric measurement devices and share ideas as to how the device could be redesigned for a more accessible and enjoyable experience for users. To aid students in their development of a wellness practice, mindfulness is introduced and practiced in class, led by audio recordings or the course instructor.

Previous efforts to teach mindfulness-focused activities to engineering students included lectures, journaling, reflections, guided meditations, and guest research presentations. Other studies used physical education courses, such as Gyrokinesis or deep breathing exercises to teach wellness. A recent study by Huerta et al. developed four mindfulness workshops for students and found that students completing the workshops had improvements in mindfulness, and interpersonal and intrapersonal competencies. This course project aims to teach wellness topics and mindfulness techniques to students, through data collection and analysis. On the first day of class, each student receives a pulse oximeter to measure pulse rate and oxygen saturation data. Students use data to analyze the relationship between engaging in wellness practices and the physiological effect on their own person. Fingertip pulse oximeters were chosen because they are compact, can be carried throughout the day, and are more affordable than other devices.

**CURRICULUM**

Bioengineering Freshman Seminar (BIOE100) is a required course for all first-year bioengineering students at University of Illinois Urbana–Champaign in which peer mentors guide students through bioengineering projects. The learning objectives of the project are (1) become familiar with the cardiovascular system, hypothesis testing, statistics, and software useful for data analysis and visualization, (2) understand and apply technologies central to the field, (3) begin independent explorations into technologies in the field, and (4) practice teamwork, technical writing, and presentations. For 5 years, the first half of the course has centered on a biometrics design project through which students explore physiology, hypothesis development, data collection and data analysis (Fig. 1). From 2016 to 2018, after learning about cardiovascular physiology, students proposed everyday activities they hypothesized significantly impact heart rate and oxygen saturation. In a 2019 offering, ~28% of students elected to study stressors (homework, or classes) or stress management techniques (meditation) within their hypothesis. The course instructor saw this as an opportunity to redesign the project and focus on studying physiological impacts of stress management techniques and use data analysis to reveal physical benefits to engineering students. In the revised offering,
students used mindfulness meditation or a stress management technique of their choosing (e.g., yoga, exercise, listening to calming music) to collect and analyze biometric data before and after practicing that technique. Benefits of mindfulness were introduced to students by reviewing literature on the impacts of mindfulness for students.9,16,21 Using data visualization (MATLAB) and statistical analysis (Microsoft Excel) scripts (slides used to introduce the project, data collection and analysis instructions, scripts and instructional videos provided in Supplemental Materials), students look for statistically significant changes in pulse rate and oxygen saturation as a result of the wellness techniques. Practices chosen by students are summarized in Table 1.

Teaching Remotely

Due to the COVID-19 pandemic, BIOE100 was offered fully online in Fall 2020. The class met synchronously for lecture with the instructor and in breakout rooms with peer teammates and upperclassmen mentors. Devices were mailed to students’ homes and collected at the end of the semester. In Fall 2021 the course resumed in-person offerings.

In addition to focusing the project on wellness, the revised offering also included a design evaluation of existing commercially available stress tracking devices (Fig. 2). The “need” was developed through the lens of the bioengineering student: bioengineering students need a method to track changes in physiology while practicing wellness. In this case, the students themselves were the users of pulse oximeters for 6 weeks of data collection. At the end of the project, the course instructor tasked student groups with designing an improved pulse oximeter device. First, teams developed a list of features, based on their own user experience, that they would keep in a new device and features to improve. Results from this exercise are displayed in Table 2.

Within the biometrics design project, the instructor discusses engineering ethics and bias in engineering design with students. The pulse oximeter device provides an opportunity for a discussion of encoded sexism7 and racism in design.4,11 Given the optical measurement, hemoglobin levels, and finger clip design, students use the literature probing bias in these instruments11 to discuss possible calibration methods or device redesign. The discussion focuses on design methods to correct this error, ethical responsibilities of engineers, and the benefits of a diverse engineering workforce in combatting bias in design.

Students were encouraged to use information about other commercially available stress tracking devices (examples in Fig. 2) in their analysis. Due to online learning necessitated by the COVID-19 pandemic, in Fall 2020, students learned about the devices in class but were not able to physically interact with all devices. In-person, each team of students had the opportunity to experiment with a commercially available device and report out to the class on its features and func-

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**TABLE 1. Summary of wellness practices selected by students in course (n = 185).**

| Wellness practice | % of teams |
|-------------------|-----------|
| Exercise          | 17        |
| Music             | 33        |
| Yoga              | 7         |
| Meditation        | 43        |

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![FIGURE 1. Overview of physiology and biometrics wellness project.](image-url)
tionality. Students analyzed devices through usability heuristics and propose improved device design through use of design heuristics cards. Table 3 shows the results of a 30 min brainstorming session facilitated by use of design heuristics cards. Students were tasked with identifying three cards and specifically enumerating how the team would apply the card to redesign of the pulse oximeter.

SURVEYS

We obtained Institutional Review Board approval to administer two online surveys, a pre- and post-survey, to students enrolled in the course. Both surveys were optional to students and anonymous. To link pre- and post-surveys, students were asked to create a unique code. In Fall 2020, students were entered into a raffle for a $50 gift card for each survey completed. The pre-surveys (administered at the start of the project) had a response rate of 37.9%. Post-surveys (administered at the end of the semester) had a lower response rate of 17.2%. The pre-survey asked questions about students’ perception of, practice of, and willingness to try mindfulness. Students were asked again about their perception and practice of mindfulness on the post-survey to gauge changes after the project. The post-survey included additional questions about the quality of the project and devices, and usefulness of the devices in helping students to identify stress, and effectiveness of the devices in gaining a better understanding of design heuristics. In Fall 2021, the survey was offered in person during class time and compensation was changed to incentivize participation. Participants were paid $10 per survey completed. These changes resulted in a pre-survey response rate of 97% and a post-survey response rate of 60%.

PILOT ASSESSMENT

A pilot of the new project was first implemented in Fall 2020 with approximately 90 first-year engineering students. The pilot offering (1) introduced students to new biometric devices that capture additional physiological data including electrodermal activity and EEG (Fig. 2) for design comparison, (2) introduced students to the concept of wellness, and (3) collected general student feedback on the project implementation to improve future offerings. The pilot project was suc-
cessful as measured by qualitative measures and course feedback surveys. Students noted that collecting their own biometric data was convincing of the effectiveness of wellness practices (Table 4). Students noted that the project applied engineering principles while also providing students valuable life skills. Students also indicated that the project was useful in learning about engineering design.

Students also provided suggestions for improvements to the project. Some of the pulse oximeters used by students were unreliable, so students suggested getting better or newer devices for the class. One student suggested that more wellness practices “that aren’t just mindfulness activities or light exercise” could be introduced. We also gathered feedback on the usefulness of pulse oximeters during the wellness project. Eight students reported that using the pulse oximeters helped them become more aware of stress, five students said they did not, and one student did not use the device in this way. After Fall 2020 and Fall 2021 offerings, 68 students reported that pulse oximeters were useful in improving their understanding of design features (Table 5). One student reported they did not gain a better understanding of design from using the pulse oximeters but did not further elaborate in a comment.

**REFLECTION**

Overall receptiveness to the wellness project, as identified from the post survey, was positive. Students noted enjoying designing their own experiment related...
to wellness and using biometric devices. A difficulty that arose during the project concerned the quality of the pulse oximeter devices. In future offerings we plan to improve the project by supplying students with higher quality pulse oximeters that give more consistent readings, as well as allowing students to check-out other devices shown in Fig. 2. In teams, students can further compare the design and functionality of different devices, identify needs, and posit solutions for improvement. In Fall 2021, the instructor led live in-person mindfulness meditations. At the end of the 6-week project, 88% of students in the course voted to continue meditating daily at the start of class. We plan to collect data and assess changes in help-seeking, perceived barriers to care, and use of university wellness resources in future offerings, ultimately to shift the engineering culture from one of “suffering and shared hardship”\textsuperscript{14} to a culture of wellness.\textsuperscript{17}

**ACKNOWLEDGMENTS**

The authors thank Professor Andrew Smith for the resources originally developed for the BIOE100 course and the students for their feedback.

**FUNDING**

This work was supported by the Department of Bioengineering at the University of Illinois Urbana-Champaign and the University of Illinois Urbana-Champaign Faculty Retreat Grant.

**DATA AVAILABILITY**

All materials are available on our website, https://www.hollygolecki.com/teaching or upon request.

**CODE AVAILABILITY**

MATLAB code for this project is available for download on, https://www.hollygolecki.com/teaching or upon request. Scripts and instructional videos for this project are available for download on https://www.hollygolecki.com/teaching and upon request.

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### TABLE 4. Themes from student responses about what they enjoyed about the wellness project (Year 1).

| Theme                              | Number of responses | Example student comments |
|------------------------------------|---------------------|--------------------------|
| Analyzing own data                 | 2                   | “I enjoyed how we could analyze data from our own experiences, which also led to some benefits of our own.” |
|                                    |                     | “I liked that I was able to see a measurable change in my data, because it reinforced to me that mindfulness does in fact work.” |
| Way to de-stress                    | 5                   | “It made me take time out of my day to slow down.” |
|                                    |                     | “I liked that it forced me to take some time out of my day to just relax.” |
| Applicable outside of academics     | 2                   | “I liked how useful and applicable it was to my life.” |
| Freedom to create own project       | 3                   | “I liked the freedom of choosing what to incorporate as a wellness practice.” |
|                                    |                     | “The freedom aspect of being able to choose what mindfulness activity to engage in.” |

### TABLE 5. Student feedback on usefulness of pulse oximeters in gaining a better understanding of design features (Years 1 and 2).

| Response | Number of responses |
|----------|---------------------|
| Yes      | 68                  |
| No       | 5                   |
| Example student comments | |
| “Yes, being able to have a medical device and use it personally gave me a lot of insight into the design and use processes.” | |
| “Yes, it gave me a better sense of the features such as pulse rate and oxygen levels that can help track stress levels for people.” | |
| “Using the biometric devices and talking with my group about the issues we encountered when using them gave us a better sense of how to improve these devices.” | |
| “I realized we need to better diversify the biometric devices we use since they did have bias within their design.” |
CONSENT FOR PUBLICATION
Not applicable.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

ETHICAL APPROVAL
This work is approved by UIUC IRB #21171 and 21782.

INFORMED CONSENT
Not applicable.

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