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Expansion of Biomedical Devices in an Engineering Design Project to Promote Student Wellness

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Introduction

Mental health issues are prevalent on college campuses. Self-reported mental illness [1], utilization of mental health services [1,2], and treatment rates [1,2] have all increased in the past two decades, with the COVID-19 pandemic causing further stress [3,4,5], anxiety [3,5], and depression [4,5] in students. Further, some research suggests engineering students face more severe mental health challenges than students in other disciplines [6]. Unfortunately, not all students dealing with a mental health challenge receive support or reach out for professional care. Students face many barriers to help-seeking, such as personal stigma [7,8] or believing stress to be the norm [7,9]. Our work seeks to change the state of mental health awareness among engineering students specifically by approaching the concept of wellness through a data-driven design project to reduce stigma surrounding mental health, promote the use of campus services, and encourage students to learn healthy coping skills. The project described here used biomedical devices and individually collected data to appeal to bioengineering students in an introductory course. Building upon the previous wellness project offered in Fall 2020 described previously [10], the most recent implementation consisted of additional biomedical devices that collected more physiological measurements like electroencephalography (EEG) and photoplethysmography (PPG). Additional devices were added to account for the bias in optical measurements from the pulse oximeter [11] and allow students to investigate design and functionality by exploring various commercially available products.

Methods

Class Organization

The six-week wellness project has been offered for two years in an Introduction to Bioengineering course required for first year bioengineering undergraduate students. The learning objectives of the wellness 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. In Fall 2020, due to courses being online, students learned about multiple devices but were only given a pulse oximeter for testing [12]. In the Fall 2021 offering of the course, student groups were provided with multiple other biomedical devices that measured at least one physiological marker that could be related to stress in addition to the pulse oximeter. The additional devices provided in the Fall 2021 offering included the Pip device (One Gateway Ltd., Dublin, Ireland), Muse headband (InteraXon Inc., Toronto, ON, Canada), SleepU (Viatom Technology Co., Ltd., Shenzhen, Guangdong, China), Ōura ring (Ōura Health Ltd. Oulu, Finland), Garmin vivosmart 4 watch (Garmin Ltd., Olathe, KS, United States), or a health tracking device of their own. Students could borrow the additional devices based on availability if they wanted. Due to limited number of devices purchased, not every student was able to test every device. Twenty students were able to try the Muse 2, twelve the MuseS (gen 1), twelve the Ōura ring, eight the SleepU,

eight students the Pip, and four used the Garmin watch. Sixteen students used fitness trackers of their own. Our rationale for choosing these devices and the corresponding student feedback is summarized in Table 1. In general, we wanted students to have more hands-on opportunities to test different devices and devices that measured more physiological measurements. As in previous project offerings [12], students used the devices to test a wellness technique of their choosing. Examples of student techniques selected included listening to music and meditation.

During the weekly in-class meetings, students were introduced to mindfulness activities, practiced five minute guided breathing meditations as a class with activities led by the instructor, and met with their project groups and former students serving as mentors to work on the project. Students used design heuristics [13] to analyze their chosen device's functionality and generate ideas for improved designs. Students were also introduced to bias in design with papers on pulse oximeters giving improper readings for people of color [11], with the intention of helping students learn about the importance of diversity and inclusion in engineering and design and motivating the exploration of additional devices without encoded bias.

Survey

Institutional Review Board approval was obtained to administer two anonymous surveys at the beginning and end of the project. All students (n=95) completed the design activity and were invited to take the surveys. Students were offered a $10 gift card for completing each survey. Analyzed here are data from the survey concerning student reception to the project (Appendix). The open-response questions analyzed in this paper consisted of questions about the usefulness of the biomedical devices in monitoring stress and understanding design, their motivation to participate in the class project, and their suggestions for improvements to the course. Pre-survey response rate was 96.8% (n = 92) and post-survey response rate was 60% (n =57).

Results

Student Reception to Devices

Overall, students were excited in class to test different devices, but preferred certain designs more than others (Table 1). Student opinion towards the Pip device was generally negative. They found the device confusing to use and found the data, shown as a stress percentage, difficult to analyze and interpret. The Ōura ring was easy for some students to use, but because it was one-size and non-adjustable only certain students were able to wear it comfortably without the device falling off. In comparison, the Muse headbands, SleepU, and Garmin wristband all had adjustable components that allowed more students to test the device. Takeaways and lessons learned gathered from each group tended to focus on user comfort and quality of data.

Table 1. Rationale for choosing additional biomedical devices compared to student opinions.

Device	Measurement	Team's rationale	Student opinions	Student quotes
Pip ($149) 	• electrodermal activity	• easy to use • portable	Pros: • tracks progress Cons: • confusing data	"The PIP measured EDA but no actual data is shown on the companion apps we used. The app just showed a percentage of stressful events experienced... You can track your stress over a long period of time for personal comfort, not so much medical or scientific ..."
Ōura ring ($299) 	• blood oxygen • heart rate • steps • sleep analysis	• expected to be novel for students	Pros: • easy to use Cons: • hard to retrieve data real time • Non-adjustable	"Ōura does not provide an easy or obvious way to retrieve heart-rate data in real time, and sometimes, it does not fit correctly and would slip off our finger. It also doesn't give much usable data."
Muse Headband (2 and S) ($250-$350) 	• EEG • heart rate • PPG • movement	• two versions to compare • Muse S can be worn while sleeping • adjustable	Pros: • collects multiple types of data • easy to use Cons: • uncomfortable • limited free app use	"Trying to add a plethora of features to a device makes it more complicated and uncomfortable for the consumer."
SleepU ($168) 	• blood oxygen • heart rate	• can be worn while sleeping • adjustable	Pros: • can collect data overnight Cons: • uncomfortable	"This device showed more in depth data about your oxygen levels than the pulse oximeter."
Garmin Wristband ($90) 	• blood oxygen • heart rate • sleep analysis • "stress level"	• can be worn while sleeping • adjustable	Pros: • easy to use • collects multiple types of data Cons: • Must be worn regularly for accurate values	"This kind of device is great for everyday use and provides really interesting data concerning stress and sleep…"

Monitoring Stress

Student comments about the helpfulness of the devices in monitoring stress are summarized in Table 2. Students commonly cited seeing changes in their measurments as a reason for perceiving the devices as useful for monitoring stress, while students who found the devices not to be useful said they were already aware of their stress without the device or that the data was not meaningful to them. One student indicated that seeing the data made them more stressed.

Table 2. Post-survey themes from students on usefulness of biomedical devices in monitoring stress.

Perception of Usefulness	Example Comments	Themes
Useful	"Seeing changes in my pulse depending on how I was feeling made it very apparent that stress was affecting me, but also that there were easy ways like meditation to manage it"	Saw changes (n = 14) Learned about stressors (n = 3) Allowed for reflection (n = 2)
Not Useful	"… I only ever saw heart rate and pulse oxygen data which was not direct enough for me to feel it was showing the stress in my life."	Data was not meaningful (n = 8) Already aware without device (n = 6) Data was inconsistent (n = 4)

Understanding Design Features

A majority of students (n = 55) found the devices to be helpful in gaining a better understanding of design features, with multiple students mentioning having a better understanding of bias in design specifically and the importance of diversity. Students also commonly mentioned the need for small and comfortable devices. The student comments below illustrate what students learned:

> There is sometimes unintentional bias within medical devices, and using the devices showed me that small and comfortable models are highly desirable. Therefore, I have a better idea of how I would design devices to mitigate these issues.

> I would make biomedical devices smaller and more comfortable to wear. I would also make sure that there is no bias in the accuracies of the algorithms of biomedical devices towards any particular groups of people.

Comparing multiple devices allowed students to identify both effective and not-so-effective design features related to the physical device itself and the inner-working processes. Students were also able to identify possible improvements from a commercial standpoint (making the device more comfortable) and medical standpoint (reducing bias).

Motivation

Student motivation to participate in the wellness project is summarized in Table 3. Most students appreciated the opportunity to learn coping skills (*n*=11), such as mindfulness and the ability to interact with their own biomedical data (*n*=10). Some students reported participating in the project due to outside expectations, such as grades (*n*=8) or expectations from group members (*n*=3). Students were also interested in learning about different devices (*n*=4) and wellness topics (*n*=5). One student commented that they enjoyed "the opportunity to work closely with upperclassmen mentors."

Table 3. Post-survey themes from student feedback on the aspects of the class wellness project that motivated them to participate.

Theme	Responses	Example comments
Engaging with own data	11	"I thought it was interesting to get actual data to evaluate our stress and perform analysis on that."
Opportunity to learn coping skills	10	"I wanted to find ways in order to destress in my academic and social life especially with starting at a new scene such as college."
Grades/course expectations	8	"My grade/feeling of obligation to doing what I'm supposed to…"
Interest in learning more about mental health/wellness	5	"Mental health is something that we haven't learned too much about, and I was motivated by the chance to learn more about it."
Learning about devices	4	"The extra device motivated me to participate because I would never get the chance to use something like it ever again."
Class activities	4	"Having time to meditate/practice wellness in class…"
Not wanting to disappoint group	3	"Making sure that I had enough data points for my group motivated me to participate in the project because I did not want to let them down."

Discussion and Future Work

Overall, student response to the project was positive. Students enjoyed the opportunity to explore various biomedical devices, even if some did not work as well as others, and appreciated the mindfulness activities in class. 88% of students voted to continue doing mindfulness activities in class for the rest of the semester. Multiple students voiced their wanting of more devices available so every person in the group can test at the same time, and to allow them to test more devices. One student indicated their wish for the project to have more connection to bioengineering. Explaining how the skills they are learning for the project will help them in

future courses and careers could possibly strengthen the connection to the field. An opportunity could also be given for mentors to share their experiences in the program.

Though this work was designed for bioengineering students, it highlights the opportunity for implementing similar design courses beyond bioengineering. For example, in an electrical engineering course, students could build a circuit to measure heart rate or even a wearable device, testing their design with different activities to show how heart rate can be related to stress. Many of the devices had accompanying apps. Students in computer science can design applications that help people visualize and track their data, which helps people be able to identify and monitor stress.

The work described here has some limitations. The project was implemented in one course at one institution, with only bioengineering students, so the general engineering student population is not represented. Cost of devices is a major limitation for implementing a project like this. The commercial devices purchased ranged from $149 to $250. We could not afford buying each device for every student, so we purchased only a few devices and used a check-in/check-out system. Thus, not all students were able to engage with all the devices because of limited availability, resulting in a narrow scope for gauging student opinion about the devices. Additionally, there was a lower response rate for the post survey than the pre survey, so we have limited inference about student reflections after the completion of the project.

Future Work

In the future, we aim to study student perceptions of seeking help by analyzing other facets of the survey data related to barriers to care and student use of wellness resources. In future course offerings, we hope to have more devices available for students, so more groups can test the same device simultaneously instead of waiting for their turn or not getting the chance to use the device at all.

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Appendix

Open Ended Survey Questions analyzed in this paper

7. Did the use of biometric devices, such as the Pulse Ox and Pip, help you monitor of become more aware of stress in your life?

- ○ No (1)
- ○ Yes (2)

Explain your answer above:

9. Did using biometrics devices give you a better sense of design features to include for improved biometric devices?

- ○ No (1)
- ○ Yes (2)

Explain your answer above:

What aspects of the class wellness project motivated you to participate?