On Track: Seeing Engineering as Sociotechnical using Fitness Trackers

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***Abstract*—In this innovative practice paper, we describe a project related to fitness trackers designed to cultivate sociotechnical awareness and practice among second-year undergraduate engineering students in Spring 2020. We identified four topics related to fitness trackers that intersected with broader sociotechnical themes including data privacy, the workplace, health insurance companies, and sustainability. In teams, students researched the social and environmental impacts of fitness trackers for their topic and gave a presentation to the class including leading a discussion. This project was designed to scaffold learning, encourage class participation, and enhance the quality of presentation. Survey responses revealed that all student respondents found the practice presentation with the instructors held over Zoom as helpful in completing their assignments and presentations. Other aspects that students rated as helpful included providing a list of resources to start their research and an example presentation to clarify expectations about depth required. The global COVID-19 pandemic necessitated the project presentations being conducted remotely, which gave students the opportunity to practice facilitating using Zoom, a skill that is directly relevant to current industrial practice. Students were creative in how they encouraged their classmates to participate including using Zoom polls, Kahoot, and breakout rooms. Students' responses to survey questions demonstrate that they learned about the sociotechnical nature of engineering, believed the project topics mattered to them as engineers, and these topics were relevant to their majors. Students cited the environmental, social, and legal aspects of the project as most interesting to them as engineers. Thus this can serve as an example for other engineering educators for how to approach teaching sociotechnical content in engineering.**

Keywords—socio-technical thinking, communication skills, project based learning, virtual teams, social responsibility

Introduction

Leaders and researchers in engineering education have argued for decades that it is important for students to see engineering as a sociotechnical endeavor to become effective practicing engineers [1, 2]. For example, the National Academy of Engineering (NAE) recognized this in a 1991 symposium entitled *"Engineering as a Social Enterprise"* explaining that this title "was chosen to imply that engineering functions inseparably from the society of which it is a part [1, p. 2]." More recent research emphasizes students' ability to work effectively with diverse communities, pursue intellectual and personal development, and engage in social justice efforts [3, 4, 5, 6]. ABET accreditation requires students to develop "an ability to apply engineering design to produce solutions that meet specified needs with consideration of... global, cultural, social, environmental, and economic factors" [7]. Most important challenges facing humanity today, such as those outlined in the UN Sustainable Development goals [8], involve multiple dimensions including, but not limited, to the technical.

Thus it is important to integrate sociotechnical approaches into engineering curricula so that students have opportunities to practice navigating complex sociotechnical problems. As part of a project funded by the USA National Science Foundation, our engineering school is exploring ways to do this in undergraduate engineering courses. Curricular efforts have focused on entire classes such as Engineering and Social Justice [9] and Drones for Good [10] as well as modules within required engineering classes including topics such as conflict minerals, material life cycle and social responsibility, single-use plastic straws and disability access, social context in heat transfer, and ethics in robotics [11] –[18].

In this innovative practice paper, we describe the "'On Track': The Social and Environmental Impact of Fitness Trackers" project implemented in a second-year undergraduate engineering course designed to help students see engineering as sociotechnical by integrating social and environmental contexts. This work builds directly on a project implemented in the Spring 2019 offering of this course [19]. We begin by describing the context of the course, the Spring 2019 offering, and some lessons learned from that project. Then we describe the 2020 offering including details of the project logistics and assignments. We conclude by discussing student response and instructor reflection.

I. Background

A. Course Content

The "'On Track': The Social and Environmental Impact of Fitness Trackers" project was incorporated into "An Integrated Approach to Electrical Engineering," which is a required course for second-year Integrated Engineering students. Industrial and Systems Engineering (ISYE) majors may choose to take it as an engineering science breadth course. The course provides a broad introduction to electrical engineering concepts and topics including components such as resistors, capacitors, diodes, light emitting diodes (LEDs), solar cells, switches, and amplifiers. Analysis, simulation, design, and frequency

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response are explored in lecture and laboratory. The course also includes social context. For example, in their first homework, students identified and researched something related to electrical engineering that they find interesting and presented to the class about what it is, why they think it is interesting, and how this is relevant to their life. Later in the semester, a legislative advocate with the U. S. Public Interest Research Group who is a graduate of our university gave a presentation and led a discussion about the Right to Repair movement [20]. The instructors guided the students in an exploration of conflict minerals and electronics [15]. A project is incorporated into the class to specifically address two of the course learning objectives that relate to social context:

1) Describe two examples of how electrical engineering topics from this course relate to their everyday lives.
2) Describe an example of how engineers might consider social context in electrical engineering applications and why this is important.

B. *First Iteration: Spring 2019*

In Spring 2019, we designed and implemented a "Design for the Future" module which aimed to develop the capacity among engineering students to address broad considerations that support values such as sustainability and social justice [19]. Students chose a technology of interest (TOI) to them that relates to electrical engineering, (e.g. Tesla batteries, solar cells, radio-frequency transmitters in football helmets, and tidal-powered turbines). The module included a student proposal; lectures and discussions interrogating how to determine and define sustainable technologies and how these can be improved; an in-class worksheet exercise designed to help students consider the design implications of who benefits, who pays, and who is excluded in relation to their TOI; and, finally, student presentations and written reports on their TOI. Student performance and feedback showed that the module enabled students to think more deeply about the broader implications of technologies and their electrical components.

For that project, we observed that students were highly engaged in relation to their chosen TOI. Some students who were typically quiet in class discussion eagerly contributed when discussing their TOI. Their excitement for their TOI manifested in their presentations, drawing other students in so that they actively asked questions. This excitement, however, also produced a tension for some students who found it difficult to move beyond their enthusiasm for a technology to critically evaluate and identify potentially negative implications involved in the sourcing, manufacturing, using, and disposing of their TOI. Others focused only on negative aspects without mentioning any positive implications. Students struggled with providing depth on the social and environmental implications. We wanted to help students better describe and engage with the integrated complexities of a sociotechnical topic within electrical engineering so that they are prepared for their future careers.

C. *Ideas for Improvement for Second Offering*

Based on our observations and evaluation of that project in Spring 2019, we decided to make improvements to the project for the next offering of the course. Specifically, we endeavored to maintain student enthusiasm for their topics while also arranging students in teams to accommodate our larger class size and provide more scaffolding for the social and environmental aspects. The previous module was offered for only six students, which allowed for us to engage with each individual student about their TOI. Having students work in groups is more practical for larger classes and can help to overcome some of the difficulties we experienced, such as students' over-enthusiasm about their TOI. We hoped that students within a group could challenge one another and explore multiple perspectives. To address the previous issue with lack of depth, we provided examples of relevant research in the social and environmental sciences to give them a starting point for their projects. We believed that identifying some examples would help students to have a deeper understanding of what is required, expected, and possible. In addition to providing these references, we also showed them an example of what a finished product should look like by having one of the instructors prepare and deliver an example presentation.

II. Methods: Project Design and Implementation

A. *"On Track" Project*

"'On Track': The Social and Environmental Impact of Fitness Trackers" was designed and implemented in Spring 2020. Sixteen second-year engineering students were enrolled in the class including fifteen Integrated Engineering majors and one ISYE major. The project was designed by an interdisciplinary team of instructors, including the instructor for the class, a tenured professor in engineering with expertise in electrical engineering, materials science, and engineering education, and a postdoctoral scholar with expertise in environmental engineering and engineering education.

To enhance the learning in this project, the instructors carefully considered team formation, logistics, and scaffolding. Each team researched the social and environmental impacts of fitness trackers for a specific assigned topic and gave a presentation to the class including leading a discussion. Students were instructed to look deeper into the topic and make a personal connection with it. This project spanned two homework assignments and was designed to scaffold learning and enhance participation and the quality of presentation.

Our initial planning for this project began before the transition to emergency remote teaching (ERT) necessitated by the global COVID-19 pandemic. This added challenge meant that we needed to carefully consider how to conduct this project in a remote environment. We thought it was important for students to still have an opportunity to work in teams on a project to combat some of the isolation they felt during this time. As our university moved to using Zoom, we decided it was important for students to have a practice session where they had the opportunity to get feedback on their content and work through the technological and logistical issues of presenting to

their classmates over Zoom. Having it on Zoom made it easier to schedule a time when both instructors and all student team members could attend.

B. Project Assignment and Team Formation

We wanted students to see the complexity of sociotechnical issues for a single piece of technology so we chose to have them all engage with the same topic of fitness trackers. We identified four topics related to fitness trackers that would intersect with technical, social, environmental and other aspects of engineering and would be of interest to students to enhance their motivation and hopefully maintain the enthusiasm we had observed in the projects in 2019. We chose the topics of data privacy, the workplace, health insurance companies, and sustainability. These topics are highly interconnected, which necessitated the careful selection of the order and grouping of presentations. Students were assigned to teams of four. We were selective about team formation and tried to connect students' academic interests (e.g. concentrations) to the topic they were assigned. Table 1 shows the concentrations of the students assigned to each topic. For example, several students with concentrations in sustainability were assigned to the sustainability team, several students with concentrations in embedded software were assigned to the data privacy team, a student with a concentration in law was assigned to the health insurance team, and a student with interest in policy was assigned to the workplace team. These concentrations are bolded in Table I. Given the distribution of concentrations in the class and to offer some diversity of thought, each team included students from at least two different concentrations.

TABLE I. INFORMATION ON STUDENT PRESENTATIONS

Presentation Date	Topic	Concentrations of students*
Friday May 8th	Fitness trackers and data privacy	**ESW**, SUST
Friday May 8th	Fitness trackers in the workplace	ESW, **IPS**, SUST
Monday May 11th	Fitness trackers and health insurance companies	IPS, **LAW**, SUST
Monday May 11th	Fitness trackers and sustainability	IPS, **SUST**

*IPS = Independent Plan of Study, SUST = sustainability, ESW = embedded software, LAW = Engineering and the Law. One Industrial and Systems Engineering student (ISYE) also took the class

Based on previous experience that students often struggle to find relevant resources with appropriate depth, the instructors prepared a list of resources to help start students' research that were distributed to all students when the project was assigned. These resources included multiple sources for each topic and ranged from easily readable items such as blogs or popular magazines to more academic sources such as conference proceedings or journal articles. A list of the provided references for each topic is given in Table II. Some key issues for each topic are also included. For example, for the topic of data privacy, we provided the students with an article describing an issue where the locations of classified U.S. military bases, patterns of movement between military bases, and patrol routes were unintentionally revealed through the social media fitness application Strava which produces a global heat map of user activity such as running and cycling routes [21]. This is an example of a larger issue where individual users reveal more information than they intend when they agree to provide personal information to companies in exchange for a service.

TABLE II. PROJECT TOPICS, KEY ISSUES, AND REFERENCES PROVIDED

Topic	Key issues	References
Fitness trackers and data privacy	The main issues of data privacy for fitness trackers is who has access to personal health data and how this data is being used by the companies who manufacture these devices, connected phone applications which show data visualizations and summaries, and also potentially third parties the data is being sold to. For example, Google bought Fitbit in 2019. Many users see this as an enhancement of technology and correspondingly user experience. They assume that a larger company has systems in place to protect the data. However, providing additional personal health and location data to a company which already has access to data on web searches, social media activity, purchases, etc. scares people. Some customers fear that there are many ways for those companies to manipulate people's data to their own benefit and that customers of fitness trackers are unaware of this.	• Blog. 2018 [21] • Wired. 2019 [22] • International Conference on Information. 2018 [23] • IEEE. 2017 [24]
Fitness trackers in the workplace	In an attempt to increase employee health and productivity, many employers incentivize using a fitness tracker through means such as bonuses. The employee opts in to letting their employer recieve their personal health data which is not protected from disclosure like health records are. In workplaces where employees are constantly sitting, this is supposed to help reduce the health problems associated with a sedentary lifestyle. Some people are suspicious of this because of the amount of data given to employers about employees' lives and how this could influence promotions or layoffs. Sharing data is up to the employee but it comes with many consequences that an employee needs to fully consider.	• Washington Post. 2019 [25] • New York Times. 2018 [26] • 2017 CHI conference on human factors in computing systems. [27]
Fitness trackers and health insurance companies	Health insurance companies and employers are working together to lower premiums for people who exercise regularly and exhibit healthy habits which are recorded by a fitness tracker. In theory, healthier employees should have lower premiums and many employees are excited about the idea. However, people must be aware of the possible repercussions associated with sharing personal health data.	• NPR. 2018 [28] • BBC. 2018 [29] • JAMA. 2016 [30]

Fitness trackers and sustainability	The main issues associated with fitness trackers and sustainability are where and how materials are sourced to manufacture fitness trackers, how long they are designed to last (i.e., planned obsolescence), how to dispose of them, and who has access to them. Some people use them briefly before abandoning them while others notice how the battery life steeply declines within five years. Companies will not repair the battery issue and require you to purchase another device instead. Thus, fitness trackers end up in drawers or landfills. There are organizations such as Recycle Health that recycle old or unused devices and distribute them to vulnerable populations such as the homeless or elderly. It is also important to consider designing these devices to last longer and for customers to understand that some communities do not even have access to fitness trackers and recognize their privilege.	• CNBC. 2020 [31] • GreenBiz. 2017 [32] • IFixIt. 2014 [33] • *The True Cost of Waste* 2018. Ch 7. [34] • Planet Money 2019 [35]

C. Introduction of the Project

During a class period one month before the first student presentation, the instructors introduced the project in class via Zoom using PowerPoint slides. These slides and a version of the content in word were also made available to the students. The instructor began with highlighting the relevant course learning objectives and connecting the project to them. We briefly reviewed previous course activities and topics that also addressed these objectives.

Then students were given an overview of the project's steps:

- Start by reading about 4 issues related to fitness trackers. Summarize each issue and prepare at least 1 question.
- Conduct research about a specific issue (pros and cons)
- Prepare a presentation (as a team)
- Lead a discussion (as a team)
- Propose a solution (as a team)

The schedule for which days which teams would present was shared along with a selected article on that topic that all students would read. They were instructed that they needed to do three things by April 29 as their Homework 8 (3 weeks from the assignment date and about 2 weeks before their presentations on May 8 and 11).

1) Draft PowerPoint slides
2) Sign up on a google doc for a time to meet with instructors to do a practice run of the presentation
3) Submit summaries and questions

Engineering students are not typically asked to explore social aspects of technology. Thus we provided a lot of detail on what our expectations were for the content of the presentation:

- Title slide including names, group number, title of project, GENG 288, date (1 slide)
- Brief outline of the topic issue (at least 2 slides)
  - How are fitness trackers being used in this way?
    - Outline the important issues involved with your topic. Which sensors or fitness tracker features are being utilized and how?
  - What are the benefits of using fitness trackers this way?
  - What are the problematic aspects of using fitness trackers this way?
- Who benefits, who pays? (at least 2 slides)
  - Who benefits from using fitness trackers in this way? Why?
  - Who pays or is excluded from using fitness trackers in this way? Why?

Note: Consider multiple points of view along the lifespan of the fitness tracker and intended and unintended consequences. For example, where do the materials to make fitness trackers come from? Who gets to use them? How are they disposed of?

- How does this issue connect with you personally? (1 slide per person)
  - *For example: a personal interest, this class, your current major or integrated engineering concentration, or career goals*
  - Each student must briefly describe their connection to the topic.
- Questions and discussion (1 slide)
  - Consider how to get your classmates involved and discussing your issue.
  - You can ask your classmates to work in breakout rooms or use the chat feature in Zoom or …
- Using what you learned in GENG 288 and other sources, propose at least one sociotechnical solution that considers technical and social, legal, ethical aspects of the issue (at least 1 slide)
- Cited sources (Include a minimum of four references)

Students were encouraged not to "divide and conquer" but to work together as a team.

After this introduction, one of the instructors prepared and delivered a presentation on background on fitness trackers that included all of the required sections and an issue of personal interest to her - safety and fitness trackers for runners. Students were encouraged to pay attention to the different sections of her presentation and consider how they would do them in their own presentations. This presentation was also an opportunity to give more details on how fitness trackers work since this was not a class topic. Seeing this example helped students understand the depth required while introducing them to technical aspects of fitness trackers that tied to other course content.

D. Assignment 1 (Homework 8)

In the first assignment, to facilitate discussions, each student individually read about the other three topics and submitted a summary and questions about each topic. The required

discussion questions helped all students engage in the four topics, and were given to the student groups to help their presentations and prepare for the discussion they would lead. When students have to teach, they learn more deeply. Students were also encouraged to connect what they have learned in this class about conflict minerals, "The Right to Repair" movement, and any other topic relevant to their presentation.

To help students develop an effective presentation, students were required to prepare draft PowerPoint slides based on their research and sign up for a time to meet with the instructors to do a practice presentation. During the practice presentations, students met with both instructors and ran through their presentations on Zoom. Instructors gave verbal feedback during the session and discussed the biggest ideas with students after the presentation. After the session, instructors emailed written feedback summarizing the instructors' comments and a list of their classmates' questions about their topic. Each group received about one page of feedback and one page of questions.

All groups made substantial changes to their presentation based on the feedback from the instructors during the practice sessions. This included updates to slides' format, adding more details, reorganizing the presentation and careful consideration of the discussion. Instructors' feedback was divided into slides, content, and plan for interaction. Instructors highlighted things that they liked and things that could be improved. Common items for slides included typos, too much text, size of text, contrast of text and background, and encouraging use of pictures and images. Content comments included encouragement to focus on the most important issues, reconsider organization, provide more details especially in areas that were unclear, and items specifically related to their topics. Some of these were discussed during the meeting. For example, one team mentioned "HIPAA" (Health Insurance Portability and Accountability Act) but did not describe or define the term during their practice. Instructors commented on how effectively students made their personal connections to their topics. We also made sure to comment on their sociotechnical solutions since this was a challenging area for students. For the plan for interaction, instructors provided practical advice such as considering time management, using classmates' questions for activities such as Kahoot, being explicit with directions for classmates, and deciding on logistics for items such as polls.

E. Assignment 2 (Homework 9)

As this was a scaffolded assignment, most of the work was done before this final homework assignment that required students to submit their slides and deliver their presentations. Detailed information was given about the content of the slides in the project assignment. Final slides for all teams were due on the date of the first presentations. This was designed so that all teams had the same amount of time to work on the slides regardless of their presentation date.

III. RESULTS

A. Student Performance

For Homework 8, the grading was half for the individual summaries and questions (6 points out of 12) and half for the PowerPoint draft and meeting signup (6 points out of 12). All teams submitted a reasonable draft of their slides by the due date and signed up for a time to meet with the instructors for a run-through and thus received full credit. Of the 16 students, 13 submitted their summaries and questions on time and with sufficient detail to earn full credit. Two students did not submit and one student provided three summaries but only questions for two topics so received 5/6 or 83% for that portion of the homework.

For Homework 9, overall the students did a great job on the presentations. All students attended all of the presentations and presented as part of their own team's presentation. All teams had all required elements including some class discussion. One student did not update his personal slide in response to instructor comments. The instructors specifically told his teammates not to do this for him. He received an 11/12 (92%) as a grade while all others received full credit for the assignment. Students were creative in how they encouraged their classmates to participate in discussion including using Zoom polls, Kahoot, and breakout rooms. One team chose to start with their Kahoot poll to raise student interest that worked really well.

B. Student Response

After the project was completed, students were invited to fill out an anonymous survey via Google forms. Thirteen out of the sixteen students (81%) completed the survey. As seen in Table III, all students reported that the topics in this project mattered to them as engineers. This supports that students see the value of viewing engineering as sociotechnical. Most students reported that the project tied well to their concentrations. These results support our decision to choose topics that would relate to most concentrations.

TABLE III. STUDENT RESPONSE (N = 13)

	5 Very Well	**4**	**3**	**2**	**1 Not at all**
I think that topics we covered in the Social and Environmental Impacts of Fitness Trackers assignment matter to me as an engineer.	9	2	2	0	0
How well did the Social and Environmental Impacts of Fitness Trackers assignment connect to your major or concentration?	5	5	1	2	0

We were pleased to see that students were interested in a variety of aspects of the project. In fact, as shown in Table IV, environmental was of the most interest followed by social and legal. In other work, we have seen that technical and environmental are given top priority [2, 16, 36]. This result is

encouraging suggesting that this project integrated these aspects effectively and was interesting to the students.

TABLE IV. RESPONSES TO "WHAT ASPECT(S) OF YOUR ASSIGNED TOPIC WERE YOU MOST INTERESTED IN AS AN ENGINEER?" (N = 13)

Aspect	Number
Environmental (e.g., sustainability)	10
Legal (e.g., data privacy laws)	7
Social (e.g., who benefits, who pays)	7
Technical (e.g., sensors, coding)	6
Economic (e.g., profit)	5

Student feedback on the most helpful aspects of the project is shown in Table V. These results demonstrate that the instructors' strategies of providing an opportunity for practice and feedback, resources to start research, and an example presentation were considered particularly helpful by the students. We were pleased that all student respondents chose the feedback session underscoring its value.

TABLE V. RESPONSES TO "SELECT WHAT ASPECTS YOU FOUND MOST HELPFUL TO COMPETING YOUR ASSIGNMENTS AND PRESENTING YOUR TOPIC." (N = 13)

Aspect	Number
Feedback session on the rough draft of your presentation	13
Resources provided to you about your topic	10
Example presentation by Dr. Gelles	7
Reading articles on the other topics	6
List of student questions about your topic	4
Additional feedback by Dr. Lord	4

When asked "What was the most interesting part of this assignment?", students had a variety of responses. Three students mentioned reading the articles. Other comments included:

- *Looking at the companies and the real issues they face with sustainability, data privacy, and more*
- *To see how technology that was made to help people can actually hurt people.*
- *Learning about the internal functions of watches*
- *The most interesting part was seeing how it connected to my concentration*
- *I appreciated that the topics was relevant in our lives even though we might not have had fitness trackers because the issues relate to other devices in our lives, mainly smartphones.*
- *Seeing all the different types of engineering that can analyze a product/their perspectives*

When asked "What was the most challenging part of this assignment?," students had a variety of responses. Seven students cited doing the research and organizing what they learned for presentation. For example, one said "*The most challenging part of this assignment was summarizing what we learned into bullet points that weren't sentences.*" Another said "*Finding reliable information because there was usually a source that contradicted another. For example, one test of security might not yield the same results as another third party's test*." Given the students' limited prior experience with research, this is not surprising. Two students mentioned the challenge of making the presentation engaging and interesting with one specifically mentioning Zoom and one student mentioned teamwork. Other responses included "*getting a big picture of fitness trackers with our individual topic and the other three topics*," and "*thinking about solutions to these issues and how as engineers what we can do to change these issues around*."

Students' responses to the question of "what was the most important takeaway from this assignment" demonstrated that they were able to connect various aspects of engineering including technical, social, environmental, economic, and legal. For example, "*As engineers, we always have to look at larger perspective and outcomes of new technology."* and "*Fitness trackers have implications in various fields such as social, economic, technical, and legal."* Issues related to data privacy and environmental impact came up several times. For example, one student said "*Fitness trackers can be counted towards our ewaste problem and that our data can be used in ways we are unaware of."* Connections to data privacy were specifically mentioned several times. For example, "*how fitness trackers can actually be an invasion of our privacy" and "being aware of the kind of information we let people access about us".* Some students made connections between the project and their personal lives. "*Think about how I can use my apple watch more effectively in my daily life, and also to think as I buy new tech."* and "*being aware of what's happening in the real world with techonology [sic] we use almost everyday."* One student bluntly stated "*I do not want a fitness tracker*" which echoed the discussion in several presentations.

When students were asked to directly respond to the course learning objective of "describe an example of how engineers might consider social context in electrical engineering applications," they demonstrated their learning. Several students referred to overarching themes of social impact. For example, *"Who does it impact and how? Then who does this product marginalize? What are the pros and cons of putting out said product?"* Some students commented on end of use environmental impact of electronic devices. "*When designing new technologies, being conscious of where they may end up after use is as important as how the user interacts with the tech originally."* Some students commented on data privacy beyond fitness trackers.

> *Other electrical engineering applications also have to consider people's privacy as so many things have become digital now a days so cell phones are very big in that perspective as most people have one.*

Some students commented on various aspects of the course including the conflict minerals and right to repair discussions. Some students' comments particularly related to this project.

For example, "*creating things such as a Fitbit can lead to wearing fitness trackers in the workplace, which can affect peoples' performance and status within their workplace*." One student commented on a topic that had been included in the presentation on fitness trackers and insurance companies critiquing the accuracy of the sensors within the fitness trackers, "*the readings for heart rate varied based on skin color so this is one thing that should have been further considered.*"

IV. Instructor Reflection

Even during ERT, students participated actively in this project. Some students told the instructors that they appreciated having an opportunity to work with classmates on a project to combat the isolation and loneliness of ERT. Our campus was closed during this time so no students were living on campus. Some had moved out of the state.

The connection to personal experience worked well. Some students needed help with this as their initial slides and thoughts lacked depth. The instructors were particularly interested in how the embedded software students were able to relate to the data privacy issues and appreciated the discussions in the run-through and presentation about how users give consent on software applications. The opportunity to connect to personal experience such as their own or their parents' experience with fitness trackers generated enthusiasm from some students who were otherwise quieter in class discussions.

Overall, the main instructor evaluated the quality of the presentations to be much better than last year [19]. The scaffolding was beneficial. Having designated readings, questions posed before the presentation, the practice session, and the example presentation really helped to raise the level and depth of the presentations.

The instructors were pleased that the students were able to demonstrate knowledge of engineering beyond just the technical in these projects. In prior work, students have often focused primarily on the technical [2, 16, 36, 37] or prioritized the environmental over the social [38]. This finding from this project demonstrates the effectiveness of the module's design.

Because this project occurred during the transition to ERT during Spring 2020 due to the COVID-19 pandemic, it was all facilitated remotely. Their presentations gave students the opportunity to practice facilitating using Zoom, a skill that is directly relevant to current industrial practice. Students were creative in how they encouraged their classmates to participate in discussion including using Zoom polls, Kahoot, and breakout rooms. A particularly interesting aspect was the enthusiastic response to the instructor practice sessions held over Zoom. Note that all respondents chose the feedback session as being helpful for completing this assignment (see Table V) demonstrating that this was of the most value for the students and is a practice that other instructors might want to adopt, particularly for online teaching. Zoom may have lowered the barrier for attendance and made it feel more like the actual presentation. Students were motivated to practice and could experience what it would be like to do their presentation. Having students teach on Zoom and work through the challenges of engaging the class is a good way to refine the two-way compassion/empathy for each other between students and faculty during this difficult time [39]. As student explore ways to facilitate participation by their peers, they may examine the ways that they themselves participate in remote learning.

V. Future Directions

On the survey, students provided some good suggestions for other topics related to fitness trackers that they would be interested in. Several students were interested in exploring how other groups interacted with fitness trackers including medical professionals, the elderly, or the homeless. Some students suggested exploring more technical aspects such as the materials used, how the sensors work together, or how the fitness trackers interact with GPS satellites. One student provided a more detailed and thoughtful response

> *Is there a future where companies start to use less and less of our data, or is that inevitable? In other words, I think two aspects of data privacy (2 different presentations) could be "ethics vs. economics", and the general trend toward losing all data privacy, regardless of profits.*

For future offerings of this course and project, the instructors also had some ideas for enhancing the project's effectiveness. We would like to connect this project more directly to the laboratory component of the class to connect the technical and social aspects more explicitly to emphasize the sociotechnical approach. For example, students could experimentally investigate some of the sensors used in the fitness trackers. We initially planned to do this in Spring 2020 but due to moving to ERT, the laboratory became focused on simulation. The last laboratory assignment did have students explore the design of a circuit using an infrared photodiode as a temperature measurement device for COVID-19. However, this would be more meaningful if done physically in the lab. We would also like to expand the sociotechnical solutions part of the presentation since that is arguably the most important. It would be good to have some class discussion about these.

VI. Conclusions

The "'On Track': The Social and Environmental Impact of Fitness Trackers" project cultivated sociotechnical awareness for undergraduate engineering students. In teams, students researched fitness trackers and data privacy, the workplace, health insurance companies, and sustainability. This project was designed to scaffold learning, encourage class participation, and enhance the quality of presentation. Pedagogical design factors that students reported as helpful included a practice presentation with the instructors held over Zoom, providing a list of resources to start their research, and an example presentation to clarify expectations about depth required.

Students appreciated the sociotechnical nature of the project. They reported that the project topics mattered to them as engineers and that they were most interested in the environmental aspects followed by social and legal aspects. This suggests this project was effective at helping students see engineering beyond the strictly technical.

Because this project occurred during the transition to emergency remote teaching (ERT) during Spring 2020 due to COVID-19, it was all facilitated remotely. Students were creative in how they encouraged their classmates to participate in discussion including using Zoom polls, Kahoot, and breakout rooms. A particularly interesting aspect was the enthusiastic response to the instructor practice sessions. All students who responded to a survey after the project listed this practice session as helpful. This aspect could be adopted to other projects, particularly for online environments.

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