A Case Study of Student-Community Interaction through an Education-First Assistive Device Design Class

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Abstract

Assistive device design classes are popular and often incorporate local community members in projects as stakeholders, or need-knowers. It remains important to generate best practices to improve student-stakeholder interactions in these service-based classes, particularly those that focus on the early product design stages like need-finding and feels-like prototyping. This study is performed across two offerings of the new class "Augmenting Human Dexterity" at the University of California at Berkeley; it serves as a case study of the lessons presented, and resulting perceptions of its instructors and students. In the class project, students participate in need-knower identification and recruitment processes. In this preliminary study, we ask: *what can students learn through this process?* Given only a small handful of student groups produce a physical device that can be given to the need-knower at the end of the term for daily use, we ask: *how do students portray this expectation?* With the lessons provided, students expand their understanding of disability and accurately communicate expected deliverables to the need-knower at the time of recruitment and interview. This preliminary work must be followed by further studies in order to establish generalizable results. Regardless, we present potential methods for managing projects in assistive device classrooms that focus on early product design stages.

Introduction

Mechanical engineering is a discipline that encourages invention in the service of individuals and society, a motivating factor for many students to pursue this discipline.[1] Naturally, assistive device design classes enjoy popularity; they also interact with ableism and cultural tensions between disability and technology.[2] As instructors seek to expose students to real-world design scenarios, many community members with disabilities are invited to present challenges they face as design motivation, contributing to student learning as need-knowers. Here, we use the term "need-knower" to mean any stakeholder whether an end-user, family member, attendant, or

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clinician with expert knowledge. But, what is the benefit received by the need-knower for sharing their expertise? While some students may produce a usable artifact and deliver it to the need-knower, others may not. In some assistive device design classes, there may be no instructional requirement for producing a working artifact delivered to the need-knower at the end of term at all – we call this an education-first approach. While some need-knowers may be aware of this potential outcome, others may be disappointed by the lack of follow-through. Unfortunately, in talking with various need-knowers and instructors across different educational activities, this anecdote regarding a lack of product follow-through appears to be somewhat common; such negative sentiments are also common in academic settings.[3] Expectations can be managed by fully informing need-knowers of the potential benefits and risks before they agree to participate. Thus, students should consistently and accurately represent expectations to need-knowers during their interactions. This presents opportunities to teach students ethical practices, self-reflection, disability awareness, and empathetic design.

The authors developed the course "Augmenting Human Dexterity" in 2020 at the University of California at Berkeley. This class has been offered four times in total, and the present study relates to the two most recent offerings in 2022 and 2023. It is open to both upper-division undergraduate students and lower-division graduate students across the College of Engineering, but it primarily serves Mechanical Engineering students. To make the class accessible to a large number of students, there are no human-centered design prerequisites. Yet this one-semester elective course involves a term project during which student teams interview a need-knower to motivate an invention concept around upper-limb dexterity. Our goal is to introduce students – who are drawn to assistive technology design, but do not yet have critically relevant skills – to interact with individuals in this space. Students mechanically or electromechanically realize a feels-like prototype for a public showcase, guided by their needs analysis of the interview and subsequent feedback sessions.[*] To support this process, lessons range broadly from interview and need-finding to ideation and low-fidelity prototype realization in the space of human assistive wearables. These are common elements of assistive device design classes.[4]

In this class, there is no instructional expectation that the prototype will be high-fidelity or delivered to the need-knower for daily use. As cited as a best practice by Goldberg and Pearlman,[5] it is possible for students to achieve a functional device within the context of an engineering classroom when designing for a specific individual, and this can be quite motivating to students.[6] While we recognize that creating a well-functioning prototype for a need-knower is important, the scale and logistics of doing this in one semester can make it challenging. We elect to run an assistive device class with an education-first model, allowing us to spend more time on core skills for the early stages of the design process. For example, assistive design classes sometimes solicit project prompts through the teaching team,[7] but this means students are disconnected from the recruitment process. Studies show that students have better outcomes when they interact more with need-knowers.[5] Therefore, we include students in an intensive need-knower identification and recruitment process. We use these lessons to instill more

[*]Students are encouraged to access prototyping materials, tools, knowledgeable support staff, and even project funding awards through the Jacobs Institute for Design Innovation makerspace. Mechanical Engineering students additionally have access to their department's student machine shop. Resources like these enhance the ability for students to make more functional artifacts. Without access to these resources, the class could instead be run without requiring such feels-like prototypes.

awareness. For example, we observe that students enter the class with strong preconceived notions of disability-related challenges, and do not necessarily recognize diversity of needs, i.e., they may assume they must work with someone with severe visible limb differences. Through the need-knower identification process, we can discuss limiting assumptions regarding disability and the role of technology.

Four lessons offered in "Augmenting Human Dexterity" align with the selected education-first class model. Lessons 1 and 2 ask students to critically understand their own assumptions regarding disability and assistive technology. Lessons 3 and 4 then ask students to consider the benefits received by the need-knower by participating in a project. These activities may initially feel uncomfortable for students, but ideally this format generates competence and confidence in students *before* they first contact a prospective need-knower or conduct their interview.

Lesson 1: Broadening definitions of disability and assistive technology. The first lecture is dedicated to providing a broad set of definitions for the terms "disability" and "assistive technology." [*] The goal is to introduce students to definitions they have not yet considered. We introduce the idea that disability is defined relative to the norms of society – introducing the term "normative"[†] as an alternative to "healthy" or "able-bodied," etc.– and the idea that assistive technology can be any intervention that enables someone to achieve their potential – i.e., not just for people who self-identify as disabled. Thus, everyone can benefit from assistive devices, and anyone could be a need-knower for this class. To critically assess how perception of these concepts change, we use self-reflections at the middle and end of this lecture, an important exercise when engaging with need-knowers.[8]

Lesson 2: Employing definitions of disability and assistive technology to identify need-knowers. Students identify potential project need-knowers from their own communities; the instructors do not facilitate these connections. Through this activity, students are provided guidance about different types of people who may want to participate, including people who are traditionally approached for such classes (e.g., someone with visible limb-differences), people who do not have a visible disability (e.g., rheumatoid arthritis, etc.), and people who may not identify as disabled (e.g., an elite athlete or gamer, an older adult, etc.). All teams meet with the instructor to discuss their approach. Commonly, a student might say they do not know anyone with a disability and therefore do not have anyone to ask; this presents an opportunity to discuss again how anyone can benefit from assistive technology and the diversity of disability. The goal of this exercise is to reinforce the broad definitions of disability and assistive technology.

Lesson 3: Practicing beneficence and respect for persons through need-knower recruitment. When at least one potential need-knower is identified by a team, the students draft a script email for how they will request an interview. Students receive guidelines regarding what information must be provided. Many of these elements align with the consent process typical of recruiting human subjects, e.g., fully describing the parameters of participation, the potential risks (e.g., data privacy), a statement that need-knowers are welcomed to decline to participate and can stop the interview at any time, etc. Students are required to include one specific element related to device delivery: "Clarify that there is no direct benefit to the person for participating." Even with these

[*] This is inspired by how David L. Jaffe begins "Perspectives in Assistive Technology" at Stanford University.
[†] Normative was offered as a preferred term by Professor Karen Nakamura in the Department of Anthropology.

guidelines, many teams initially propose language that mentions that they will make the need-knower a functional device. Here, the instructor intervenes and uses it as an opportunity to reiterate the educational motivation for being in the class. Students must revise their script for instructor approval before the email is sent. Despite best efforts, it is difficult to ensure that students do not prematurely approach potential need-knowers.

Lesson 4: Preparing for the interview through laboratory practice. One laboratory section is dedicated to introducing and practicing interview methods that promote respectful interactions, such as the master-apprentice model for contextual inquiry, the consent to record process, reminding interviewees that they can stop the interview at any time, etc. We intersperse activities with reflections regarding the effectiveness and experiences of both student interviewers and student interviewees, with the goal of increasing empathy while gaining comfort with the interview process. Ideally, this activity illuminates potential benefits received by the interviewee as an alternative to a physical product, e.g., personal insights, a transcript, etc.

In this paper, we present data to:

- analyze student vocabulary use regarding their written definitions of “disability” at the start and end of the class, related to lessons 1 and 2,
- support instructor observations of device prototype fidelity in this class, and compare this to student self-reported end-of-semester prototype function,
- characterize student perception of the benefit received by the need-knower for participating in their project, and perceived effectiveness at communicating these benefits during the recruitment process, related to lessons 3 and 4, and
- document the self-reported end-of-semester perceived experiences and learning outcomes of students engaging with need-knowers in this class.

These outcomes are the first step in understanding this class design and will serve to motivate and focus future quantitative study design.

Methods

We collected data in Spring 2022 (41 consenting students) and Spring 2023 (39 consenting students), under IRB Social-Behavioral-Educational Exempt Protocol ID #2022-01-14977 “Educational Practices in the Assistive Device Design Classroom.” In these two years, 85% of students enrolled in the Mechanical Engineering department’s undergraduate (29%, MEC ENG 179) and Master of Engineering (56%, MEC ENG 270) offerings. Data and artifacts were collected during each semester, and students were given the option to opt-out of the study after final grades were assigned to have their data omitted. We wish to emphasize that this is an elective course, and therefore the cohort have opted into this coursework, thus are not necessarily representative of the average engineering student. Only a minority of students reported that they self-identified as disabled. Of students who reported age, the average was 23.5. For gender identity, 38 students were male, 30 were female, 11 did not respond, and 1 was non-binary.

At the very start of the first class, students submitted their definitions of “disability” and “assistive technology.” In the last class of the semester, students repeat this activity. Students also completed a required non-anonymous survey, graded by completion only. This survey asks questions regarding student perceived skill development and sentiments/anecdotes regarding execution of the project and interactions with the need-knower. The complete end of semester survey is in the Appendix; in this work, we analyze a subset of these questions. Final project reports were also collected, which include documentation of the final project artifacts.

Written entries are pre-processed using the spaCy library and CountVectorizer from the package sklearn. To obtain important words per student entry we use Term Frequency–Inverse Document Frequency (TF-IDF) using sklearn's TfidfVectorizer. TF-IDF increases proportionally to the number of times a word appears in an entry and is offset by the number of responses in the data that contain the word. Sentiment analysis is performed on written entries using Valence Aware Dictionary and sEntiment Reasoner (VADER). VADER separately provides measures of positive, neutral, and negative sentiment as well as a compound score which synthesizes all three into a single measure of sentiment. A compound score of greater than or equal to 0.5 is seen as a positive sentiment, a score of -0.5 to 0.5 as a neutral sentiment, and a score of less than or equal to -0.5 as a negative sentiment.

Results

Related to lessons 1 and 2, we find a positive learning outcome in the analysis of language use when defining "Disability." A TF-IDF analysis shows that when defining disability at the conclusion of the class, the word "normative" becomes salient in student textual entries. Whereas this term is absent from entries of students entering the class. This represents a direct influence of student perspective, as an entire lesson is dedicated to best practices in language around those with disabilities and specifically offers "normative" as an alternative to terms like "healthy," etc. We do not see a notable change in vocabulary use regarding definitions of "assistive technology."

Figure 1(a-h) shows examples of the final products generated by student project teams. These demonstrate thoughtful embodiments informed by unique needs expressed by the individuals in interviews, thus fully satisfying the project requirements. We note the broad set of applications represented, reflecting the diversity of need-knowers recruited – consistent with lesson 2. Often, these prototypes use short-lifetime fabrication methods and materials, such as 3D printed materials, laser-cut wood, duct tape, hot glue, etc. Wires are typically loose and electronic components remain tabletop or tethered. This is acceptable for the project objectives for this course that focus most on the need-finding process and design space exploration. This largely results in prototypes not ready for daily wear and tear. Many would require iteration or regular mending in real-world use, limiting practicality in their current forms. As evidence, to the knowledge of the teaching team, only a small handful (approximately 3) of the total 33 devices constructed over these two offerings of the course were given to the need-knower for daily home use. In these cases, the team went far beyond fabrication expectations.

Interestingly, many students appear to perceive that the devices they built could be used daily by the need-knower. As in Figure 1(i), almost half of the students responded "Yes" to the question: "Did you physically realize a product that the need-knower can take home and use on a daily basis?" This demonstrates that over half of the class recognized at least minor limitations of the device, which shows an important level of honest reflection. At the same time, many students may

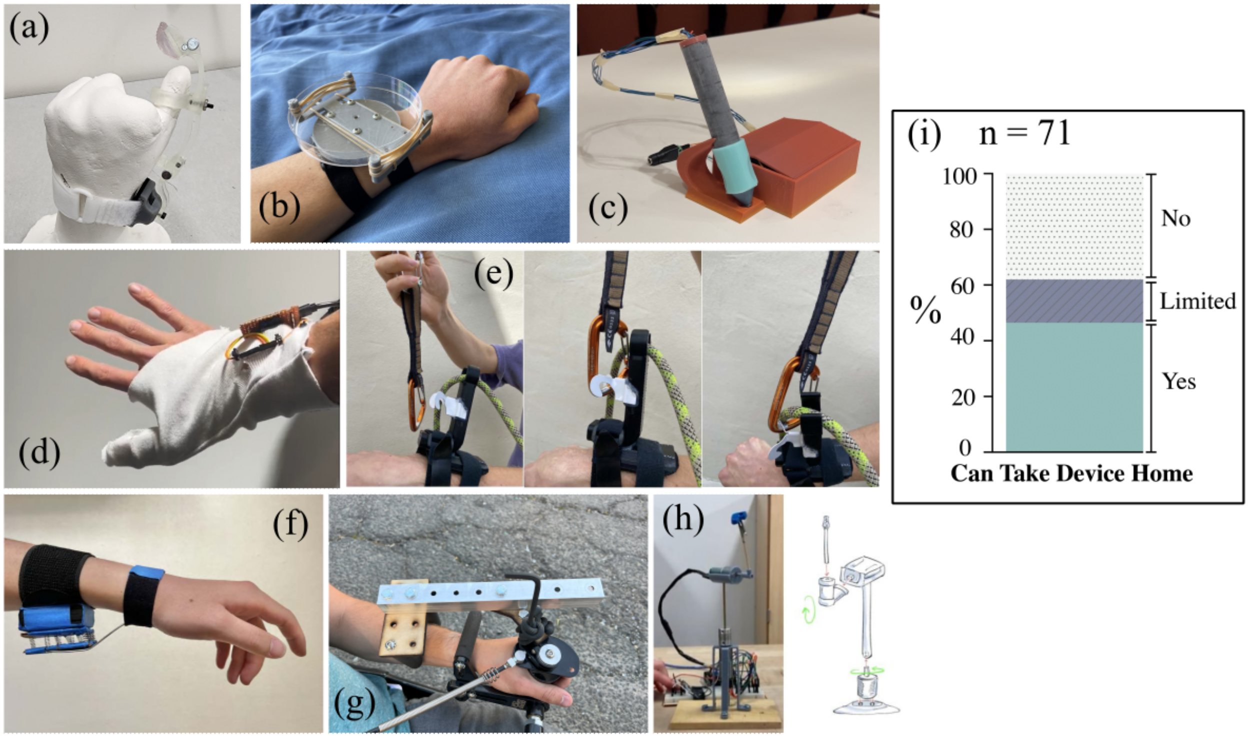

Figure 1: (Left) Example end-of-semester devices from the 2023 offering of the course. (a) a body-powered prosthetic thumb distal phalanx; (b) a wearable petri dish fixture; (c) a heated pen; (d) a vibrotactile feedback system with thumb shield; (e) a belay hook prosthetic for adaptive climbing; (f) a spring-loaded wrist brace; (g) a wrist- and shoulder-driven adaptive bike braker and shifter; (h) a motorized stand for detailed model painting. (Right)(i) Student response to the question: “Did you physically realize a product that the need-knower can take home and use on a daily basis in its current realization stage?”

still overestimate the immediate utility of what they generated. This outcome was so contradictory to the instructors’ perceptions in 2022 that we added the following language to the end of this question in 2023: “...in its current realization stage? i.e. as shown in the showcase.” However, the outcome in 2023 remained similar to that in 2022.

To gain further insight into this apparent contradiction, we observe student responses to the question at the end of the semester: “What do you perceive as the benefit(s) received by the need-knower by participating as a volunteer for your project?” Responses fall into these common categories (with examples):

1. Volunteering time for student education or advocacy:
    - “Giving back to cal [UC Berkeley] students”
    - “Passing on information about their disability and its needs, making people more perceptive and well rounded individuals regarding disabilities.”
2. Supporting the field of assistive device design:
    - “I believe that they felt a benefit from helping to expand this space.”
    - “As a need-knower, I really like the way that we designed something that could

potentially be produced in the future (I can see it come to the market in the future)."

3. Social connection:
   - "She was... able to just share her struggles and know that there are people who care and are interested to help."
   - "Have someone to talk with..."
4. Personal insights:
   - "... him realizing new facts about himself, or opening his mind to the possibility of trying new prosthetics that he didn't consider before."
   - "She described the process as being therapeutic in allowing her to reflect on the process, so we hope that it allowed her to process her emotions regarding the injury."
5. Device delivery and usability, or lack thereof:
   - "They're actually going to receive a working prototype and gain the ability to ride their bike again which they're thrilled about."
   - "It could be used on a daily basis but might need some adjustments to be more user-friendly when things go wrong."

Categories (1) through (4) were all common. Category (5) which specifically deals with the delivery of a working device was the least common; this infrequency matches with instructor expectations, where few need-knowers received the device prototype. While a promising indication that students develop a realistic perception of beneficence to the need-knower, this outcome does not explain why so many students said "Yes" to the question "Did you physically realize a product that the need-knower can take home and use on a daily basis?"

We also asked students to "Reflect on whether you effectively communicated with the need-knower at the beginning of the class whether they would receive a working device or not this semester." Many students, to varying degrees of detail, stated that they clearly communicated that the need-knower would not receive a device. For example, "In the email and interview, we were very clear about the project only being for educational purposes and to not expect a well developed product in the end. The need knower seemed receptive to this and has not expressed any sign of discontent." Another substantial number of students said that they simply omitted the promise to provide a functional device: "We did not communicate an intention of providing him a working device by the end of class." Others explicitly expressed a hope to make a working device without guaranteeing it: "We said it was a possibility but not definite at all and should not be expected." A small handful of comments reflected that they could have improved their communication: "I think our wording was a bit unclear at first, but we ammended our statements and I hope that was enough to effectively communicate our intentions." A minority of students indicate they did not follow the instructions of the course, nor did they acknowledge that this may have been an issue: "We said that we want to give him something functional, that he could try." Overall, most students express positive or neutral statements about early communication of device delivery expectations, without shortcomings. While most students indicate they followed assignment instructions, there is variation in the interpretation of this activity.

Students perceive their understanding, skill, and confidence in topics taught in the class positively. All the learning objectives surveyed show improvement from before to after the class. This includes topics not traditionally in mechanical engineering classes, such as "Disability in society" or "Contextual inquiry interviews," as well as more technology-focused topics like "mechatronics for robotic grasping." Specifically for project interactions, student sentiments skew positive when describing their "experience working with need-knowers for this project," as seen in Figure 2(a). When reading the narrative data associated with this sentiment plot, a couple common topics emerge (examples provided):

1. Observation of the interview interaction:
   - "He was friendly and open to share his stories."
   - "...Very good overall, one downside is that he seemed a bit reserved."
2. Observations on the data gained during the interview:
   - "We spent lots of time observing the real scenario, it helped us see the opportunity more clearly."
   - "...we were exposed to a lot of information and ideas that would've slipped through the cracks otherwise."
3. Comments relating the interview with other project tasks:
   - "It was helpful to have some template as a reference for what to do when contacting them."
   - "... identifying a need was difficult at first."

Most comments – over 85% – fall into (1) and (2) above, which focus on the act of conducting the interview itself. Fewer students focus on what came before or after the interview. This indicates that the experience of the live interview may be most memorable or influential on student sentiment regarding need-knower interactions. When specifically asked to reflect on the process preparing for the interview, students largely view their preparedness to perform these tasks positively, seen in the Likert-scale data in Figure 2(b). While most students skew towards "Very easy"(5), some students still report some skills as "very challenging"(0). This spread is consistent with instructor observations, where the majority of students move through each task with relative ease by using the structured lessons provided. However, some students need additional support while identifying multiple prospective need-knowers to successfully confirm an interviewee. This is in part why so much of the early class is dedicated to the process of broadening the pool of prospective need-knowers. On the other hand, students resoundingly rate their perception of need-knowers' experiences very highly, except for a couple of individuals, Figure 2(c). In fact the median for most categories is "Outstanding"(5), while no one selected "Poor or not at all"(0) for any category. It may be meaningful that, despite the overall high ratings, the perceived "Interest in volunteering again" is lower than the rest, which may indicate a slight contradiction. We want to remind the reader that this data represents the *student* perception of the need-knower experience, thus the true need-knower experience would likely differ.

Discussion and Conclusion

This work presents a case study of a service-learning class that engages students with need-knowers in the early product need-finding process. It offers support through lessons to expand vocabulary and normalize and increase respect for individuals with disabilities providing their time and expertise. This class is meant to reshape the narrative of assistive device design classes towards one that focuses outcomes on student education when high-fidelity operational devices are an unlikely result. Specifically, we explore opportunities for including students in the early identification and recruitment of need-knowers while addressing observed issues regarding

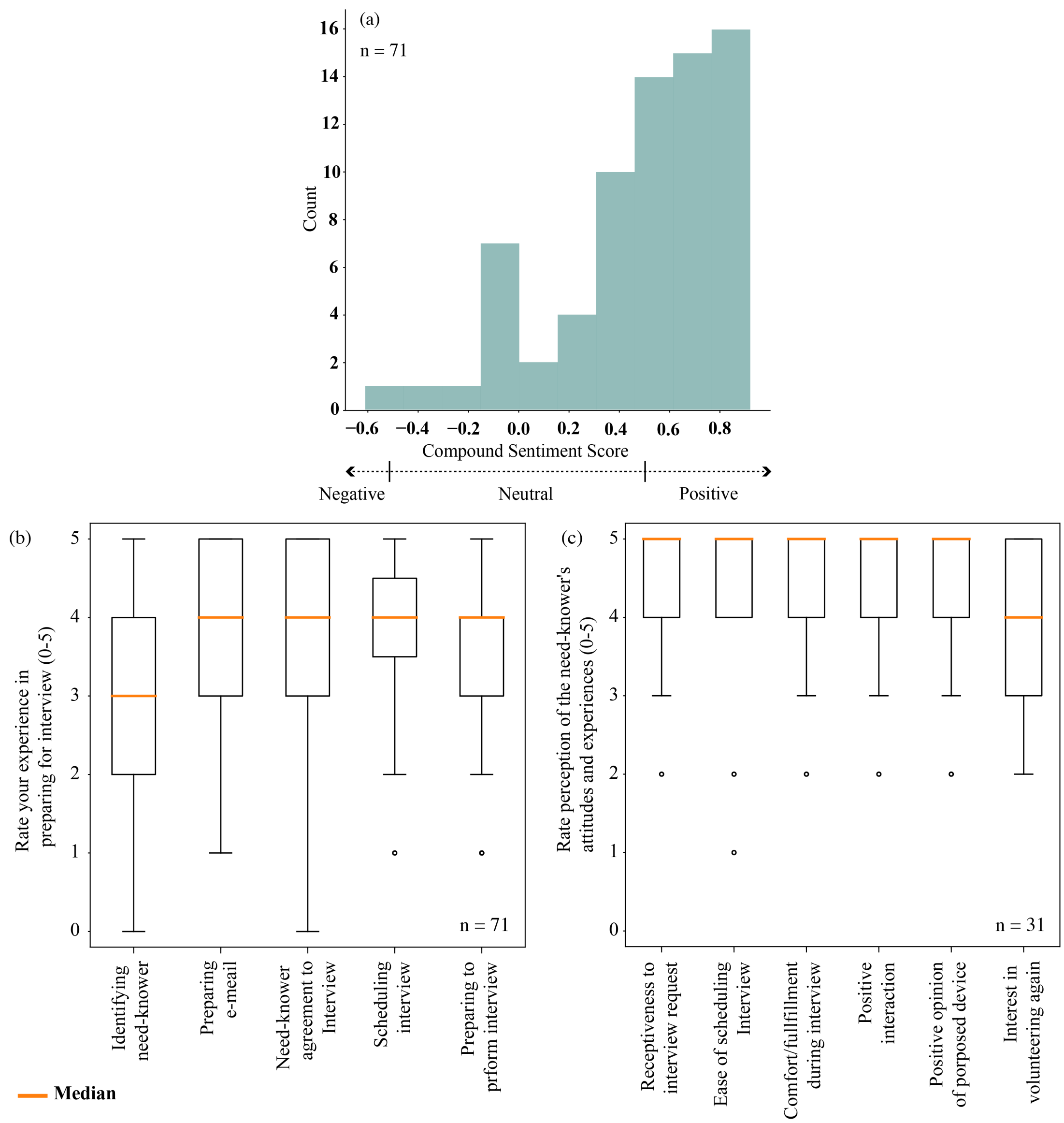

Figure 2: (a) Sentiment analysis for the prompt: "Describe your experience working with a need-knower for this project." (b) Likert-scale for: "Rate your experience in preparing for interview." (c) Likert-scale for: "Rate your perception of the need-knower's attitudes and experiences when working with your team."

device delivery expectations in the project. While the need-knowers may not use the resulting prototypes, there are positive learning outcomes associated with lessons 1 through 4.
Students:

- alter their vocabulary regarding "disability" to include the term "normative," which is relative to societal norms of the day,
- identify a wide diversity of disabilities and assistive device needs through need-knower recruitment from their own communities,

- accurately represent expectations regarding project deliverables to the need-knower at time of recruitment, practicing respect for persons, and
- articulate a diversity of benefits received by the need-knower, beyond the device itself.

We observe that some students initially find the interaction with need-knowers challenging, especially when identifying and recruiting a need-knower, as seen through student quotes and Figure 2(b). However, students speak about their interview interactions with a positive sentiment, Figure 2(a), and rate the need-knower's perceptions as positive, Figure 2(c). This finding shows that the tested student-need-knower interactions result in positive perspectives from students despite initial task difficulty.

The current work has substantial limitations. The end-of-semester survey utilized in this study to gather student perspectives contains non-ideal practices, such as double-barreling and leading questions. In addition, much of the data is collected at the end of the semester, as opposed to gathering incoming student perspectives at the start of the semester. Further surveying students at both the beginning and end of the semester, as well as intermittently after specific activities, would capture more accurate representations of change. Most importantly, we solely look at student perspective in the student-stakeholder interaction; it is essential to collect data from the need-knowers participating in the class in the future. Future work should directly test hypotheses that emerge from this work regarding the correlation of student vocabulary use – in both recruitment and interview interactions – on the need-knower's real expectations, perspectives, and experiences. Future work must also validate that the lessons proposed consistently produce an effect on student learning and behavior when interacting with the need-knower.

Regardless of these limitations, this case study provides insights from the perspective of an assistive device design class that focuses on the early stages of design synthesis, and less so on the delivery of a working product to need-knowers. By engaging students in multiple lessons during the early need-knower identification and recruitment phases of the need-finding process, they are invited to confront and discuss their preconceived beliefs related to disability and the role of assistive technology.

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Appendix

Question	Response type
Identity information	
Age	Round number
Gender	Fill in the blank
Do you identify as having a physical disability?	Y/N
Perception of learning	
Rank you understanding, skill or confidence in these categories[1] right now, near the end of the semester.	0-5 ranking
Rank you understanding, skill or confidence in these categories[1] before taking this class.	0-5 ranking
What activities contributed significantly to...	
... your perception of disability and the role of assistive devices in society?	Activity checklist[2]
... your understanding of ethical considerations and conduct in the design and testing of assistive devices?	Activity checklist[2]
... your confidence and skill in the process of initiating and conducting interviews to inform the design of assistive devices?	Activity checklist[2]
... effective realization of functional mechatronic devices to support human dexterity?	Activity checklist[2]
Comment on your particular experience and perspective of completing CITI Training in the context of this class.	Long answer text
Perception of need-knower experience	
Rate your experiences in preparing for interview. Across these factors.[3]	0-5 ranking
In what capacity did you interact with the need-knower?	Options checklist[4]
Describe yoru expirience working with a need-knower for this project.	Long answer text
Rate your perception of the need-knower's attitudes and experiences when working with your team. Across these factors.[5]	0-5 ranking
Support your perception of the need-knower's experience above by describing specific interactions or events as evidence.	Long answer text
What do you perceive as the benefit(s) received by the need-knower by participating as a volunteer for your project?	Long answer text
Did you physically realize a product that the need-knower can take home and use on a daily basis?	Y/N

[†1]Disability in society, the role of assistive devices in society, human hand function, mechatronics for robotic grasping, contextual inquiry interviews, realizing wearable technologies, ethics of human subjects research, hypothesis formulation and proposing a validation study, the benefit of designing for one individual as opposed to a large group of customers.

[†2]Lecture lessons and in-class reflextions, Assigned readings, CITI Training, Anatomy quiz, Lab 1: How to email a need-knower, Lab 2: Interview techniques and practice, Lab 3: Fabrication for wearables (rapid prototypes and body casting), Lab 4: Ethical invention workshop, Lab 5: Tendon-driven finger assembly, Lab 6: Decoding the interview exercise, Lab 7: Mechatronic actuation and state machine practice, Lab 8: Project presentations, Lab 9: Tactile sensing, Lab 10: EMG control, Project: submit an email script for review, Project: perform a literature search, Project: interview a need-knower, Project: conceptualize a product to address primary needs, Project: realize a physical prototype, Project: writing the report.

[†3]Identifying potential need-knowers to contact, Preparing an email for the initial request, Getting a need-knower to respond or agree to an interview, Scheduling the interview time and location, Preparing to perform the interview.

[†4]Emails/text messages, In-person interview, In-person meeting (Not the interview), Video or phone call interview, Video or phone meeting (Not the interview), Sending or testing physical prototypes, Perform body casting, Other.

[†5]Receptiveness to the interview request, Ease of scheduling and coordinating the interview, Comfort or fulfillment during the interview, Positive interacts with students, Positive opinion of the device proposed or built by your team, Interest in volunteering again.