How Designing for People With and Without Disabilities Shapes Student Design Thinking

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ABSTRACT
Despite practices addressing disability in design and advocating user-centered design (UCD) approaches, popular mainstream technologies remain largely inaccessible for people with disabilities. We conducted a design course study investigating how student designers regard disability and explored how designing for both disabled and non-disabled users encouraged students to think about accessibility throughout the design process. Students focused on a design project while learning UCD concepts and techniques, working with people with and without disabilities throughout the project. We found that designing for both disabled and non-disabled users surfaced challenges and tensions in finding solutions to satisfy both groups, influencing students' attitudes toward accessible design. In addressing these tensions, non-functional aspects of accessible design emerged as important complements to functional aspects for users with and without disabilities.

CCS Concepts
• Human-centered computing~Accessibility theory, concepts and paradigms • Human-centered computing~Accessibility design and evaluation methods • Social and professional topics~People with disabilities

Keywords
Accessibility; Assistive Technology; Design; Design Thinking.

1. INTRODUCTION
User-Centered Design (UCD) approaches emphasize the user experience in the design of technologies such as laptops, mobile phones and wearables [16]. In UCD, including people with disabilities is considered part of addressing the user experience, where stakeholders are involved in the design process [29]. Some variations of UCD specifically advocate that people with disabilities should be included in the design process to create technologies that are accessible [18,24,35]. Nevertheless, current mainstream personal technologies are often inaccessible; people who create mainstream technologies do not regularly incorporate accessible design except perhaps to satisfy legal requirements [8]. Thus, despite research espousing the benefits of working with people with disabilities in the design process [18,24,29,35], the lack of accessible mainstream technologies indicates that few designers effectively do so. Promoting inclusion in the design process has not been enough to motivate a sweeping change in making technologies accessible. Instead, accessibility is often approached as "someone else's job," and the responsibility of accessible design is relegated to a niche group of designers [6,7].

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Figure 1. A student designer works through a design sketch with a blind "expert user."

Although prior work has demonstrated that designing directly with people with disabilities can improve accessible technology outcomes [1,20,33], we focused our research on which elements of inclusive design influenced student designers to incorporate accessibility in their design process and thinking, not just as a "special topic," or an afterthought of heuristics or guidelines for legal requirements. We conducted a design course study focused on how working with disabled *and* non-disabled users influenced student designers' perspectives on accessibility and design (Figure 1). Although it is well known and accepted that people benefit in awareness and empathy from exposure to people not like themselves [20,33], a specific account of how novice student designers come to think about accessibility (and people with disabilities) during the formative stages of their design thinking has not, to date, been provided. Our account here adds insight into the evolving thinking of students as they address users with and without disabilities and become aware of the need for accessibility in their design thinking. Our study demonstrates how expanding accessible design to include a broader, diverse view of users can positively influence the design process.

We found that designing for both disabled and non-disabled users surfaced unique tensions between non-functional and functional needs across both user groups. We use the term "non-functional" to refer to aspects of the design that are not related to how the technology works, *per se*, but other factors influencing the use and perception of the technology, like social appropriateness, professional presentation, adherence to decorum (is it loud during a work meeting when people should be quiet?), and so on. Addressing functional/non-functional tensions challenged students to re-assess their view of disability and accessibility, and stretched their capacity as designers of accessible solutions. Overall, engaging tensions that emerged from designing for two user populations challenged students to balance requirements from both sides, encouraging them to shift from ableist perspectives of disability toward a more inclusive approach to design overall. This work offers implications for accessible design based on improving ways users with disabilities can be included in the design process and the likely beneficial effects that has on how designers think.

2. BACKGROUND AND RELATED WORK

People choose from a variety of technologies to help them do more. However, most mainstream technologies are not accessible, and people with disabilities instead use assistive technologies. Inaccessible technologies are indicative of a shortcoming in most current approaches to technology design. We therefore see an opportunity to encourage technology designers to incorporate accessibility into their design thinking and work [10]. We separate related work into two categories, disability-specific design approaches and accessibility as taught in design courses.

2.1 Disability-Specific Design

User-Centered Design (UCD) emphasizes inclusion by focusing on users and the user experience in the design process [29]. UCD relies on inclusion—inviting others to participate in the process— also to address issues of disability. In theory, emphasizing the user at the center of the design process *should* provide opportunities for designers to seek out users with disabilities and become familiar with accessibility issues [29]. But in practice, the dearth of mainstream technologies that are accessible out-of-the-box without added accommodation suggests that most designers tend to assume an audience without disabilities.

Research has shown that rather than expecting disability to fall under the umbrella of "user experience," specifically encouraging accessibility and working with users with disabilities can help designers create more accessible technologies [1,20,24,33]. In contrast with design approaches like UCD, where designers tend to assume a non-disabled target user population, disability-specific approaches explicitly emphasize that to make design accessible, designers should include people with disabilities in the design process itself. Popular approaches include: *Universal Design (UD)* [1,21], which focuses on principles like equitable use, flexibility in use, and simple and intuitive use; *User-Sensitive Inclusive Design (USID)* [24], which emphasizes getting to know disabled users and focusing on specific needs; *Design for User Empowerment (DUE)* [18], which includes people with disabilities as the designers and engineers creating accessible technologies; and *Ability-Based Design (ABD)* [35], which emphasizes ability, and tries to design systems aware of and responsive to those abilities. Such disability-centric focus is a lingering aspect of assistive technology's relationship with rehabilitation engineering [6,17], the result of which is a "special" category of technologies specific to people with disabilities [4,19,27].

Assistive technologies may bridge the need that people with disabilities have for technical access. But it is increasingly common for assistive technologies, created exclusively for disabled users, to have mainstream counterparts with the same capabilities. An example is a refreshable Braille note taker, which has similar functionality as a laptop. Disability-specific design approaches help create technologies that people with disabilities can use, but the specificity of the approach often results in technologies *only* disabled people can use. In comparison, mainstream technologies are typically only usable by *non-disabled* people. Unfortunately, disability-only devices perpetuate an ableist view; mainstream devices remain inaccessible because "special" accommodations are available for those who cannot use them [19]. Ableism is a tendency to consider non-disabled people as superior to disabled people; the consequences of ableism have far-reaching historical and socially detrimental effects [4,9,19]. These topics are outside the scope of this study, but we highlight ableism to raise awareness of implications of design that assumes non-disabled users [34].

Including people with disabilities in the design process has been studied as a way to help designers create accessible technologies, but focusing solely on disability results in a schism: separate technologies for people with disabilities and for people without disabilities, regardless of whether the capability exists to make a holistic solution accessible to all. Despite positive outcomes when designers work with disabled users, more must be done to raise awareness of who benefits from accessibility and how. One way to address gaps in research and practice has been to focus on what designers do and why [15,26,36], and how to effect change. We studied novice designers to understand specific characteristics of inclusion that shaped their design thinking when required to create solutions for both disabled and non-disabled users.

2.2 Accessibility in Design Courses

Previous research in post-secondary design courses examined how college students address disability in requirements gathering, brainstorming, and prototyping solutions [1,20,33]. These courses introduced engineering and computer science students to accessibility, highlighting the benefits of working with users with disabilities. Ludi and Waller et al. [20,33] focused primarily on requirements gathering and the engineering process. Bigelow [1] incorporated UD principles in engineering courses to get students into a more human-centered mindset in design. In these studies, students worked directly with people with disabilities in at least one instance throughout the design process. In our study, we expanded opportunities for students and users with disabilities to interact by facilitating multiple feedback sessions throughout the course. Further research in UD in education facilitates ways to increase awareness of accessibility in teaching and learning [2]. Such research confirms that prioritizing accessibility and including people with disabilities improves understanding about disabled technology users' needs. Yet, while UD in education promises to increase student exposure to diverse abilities, strategies for inclusive design tend to remain disability-specific. Training engineering and computer science students to include disability in design may result only in functional disability-specific solutions, it may not translate into accessible *mainstream* technologies. To avoid creating this bias, we expanded our course project to challenge students to design for both disabled and non-disabled users in an effort to promote the view that disability is just one part of diversity among technology users. We purposefully structured the course to engage disability not as separate from design, but as part of a greater socio-technical community of users.

3. METHOD

To investigate how inclusion increases designer awareness of accessible design, we built on disability-specific design approaches with some modifications. We conducted a design course study with student designers as they learned UCD, focusing our investigation on how students engaged users with disabilities, and on student reactions and reflections throughout the design process. We built on inclusive design approaches by staying close to the UCD process, which also minimized cost and resource requirements. We modified inclusive design approaches by having student designers work with *both* disabled and non-disabled users to facilitate awareness from different perspectives. We prompted students to reflect on their experiences, specifically how they viewed and interacted with disability and design.

The curriculum of our undergraduate-level course on design thinking—a course utilizing Norman's and Buxton's popular texts

[3,25]—focused primarily on needs assessment, ideation, low- and high-fidelity prototyping, and user-testing. Students conducted interviews, created personas and scenarios, generated conceptual models, sketched and ideated, created paper-based and interactive prototypes, applied usability heuristics, and tested their designs with users. We set an expectation that accessible design was part of design overall and a requirement to design both for users with and without disabilities. The rationale for tasking students to design for both user groups was that rather than designing a "specialized" technology specifically for people with disabilities, students were to design an accessible technology usable and appealing to anyone. Students worked in groups and each group was paired with a person with a disability. They were largely left on their own to find non-disabled users, although we facilitated in-class paired feedback sessions, heuristic evaluations, and usability testing to assess non-disabled user interactions. Each week, students were introduced to a new concept and participated in activities to gain experience working with different techniques around that concept. Students applied this new knowledge in a term-long project to develop a usable prototype by the end of the course.

Table 1. "Project A" groups and expert users.

Project A: Real-Time Augmented Reality Navigation		
Grp.	**Student Designers**	**Expert User**
G1	S12 (M), S22 (M), S41 (M), S31 (F)	E1 (M), Blind
G2	S1 (F), S26 (M), S28 (F), S36 (M)	E2 (M), Blind
G3	S19 (M), S21 (M), S33 (M), S35 (F)	E3 (F), Low Vision
G4	S6 (F), S8 (M), S23 (M), S34 (M)	E4 (F) Low Vision
G5	S2 (F), S9 (M), S15 (F)	E5 (F), Blind
G6	S11 (M), S13 (M), S25 (F), S42 (M)	E6 (F), Blind

Table 2. "Project B" groups and expert users.

Project B: Real-Time Live Captioning		
Grp.	**Student Designers**	**Expert User**
G7	S14 (M), S30 (M), S38 (M), S39 (M)	E7 (F), Deaf
G8	S3 (M), S5 (F), S20 (M), S32 (M)	E8 (F) Hard of Hearing
G9	S10 (F), S16 (F), S29 (M), S37 (M)	E9 (M), Deaf
G10	S4 (M), S7 (M), S27 (M)	E10 (F) Hard of Hearing
G11	S17 (M), S18 (M), S24 (F), S40 (M)	E11 (M), Deaf

3.1 Participants

Forty-two undergraduate students (12 female) participated in the study. No students had any known disabilities, few students had design experience, and only a handful of students had interacted with people with disabilities prior to the course. Students worked with 11 (seven female) users with disabilities. We referred to users with disabilities as "expert users" to reinforce their expertise as users of accessible technology. Expert users were recruited through local disability groups and assistive technology listservs: Department of Services for the Blind, National Federation of the Blind, Hearing Loss Association, and the university disability club. The study was restricted to people with sensory disabilities.

3.2 Design Projects

Students' groups were randomly assigned design projects: "Project A" groups worked with blind or low vision expert users and were tasked to design an application providing real-time augmented reality (walking) navigation; "Project B" groups worked with deaf or hard of hearing expert users and were tasked to design an application providing real-time captioning of nearby speakers.

Groups met with expert users four times throughout the 10-week term: interviewing, iterating on brainstormed ideas, eliciting feedback on sketches, and then on paper prototypes, and conducting usability tests on interactive high-fidelity prototypes. Each session with expert users lasted approximately one hour, during which time student groups shared design artifacts for feedback. Expert users evaluated the final designs.

At the beginning of the term, a question and answer forum with a blind guest speaker familiarized students with appropriate etiquette for interacting with people with disabilities. The course also included relevant readings and introductory lectures to orient students to existing approaches to design for diverse populations: User-Sensitive Inclusive Design [24], Ability-Based Design [35], Universal Design [21], Participatory Design [28], Design for Social Acceptance [30], and Value Sensitive Design [13]. We consider it compulsory to include design approaches specific to disability and related issues due to course expectations to create accessible designs. Tables 1 and 2 describe groups, expert users, and projects.

3.3 Data and Analysis

Our data comprise student assignments including weekly reflective journals, interview protocols and summaries, observations, brainstorms, sketches, design rationales, user testing results and heuristic evaluations, final design specifications, design process books, and expert user evaluations of student designs. Expert users evaluated student work mid-term and at the end of the course.

Data were analyzed deductively and inductively following systematic qualitative data analysis methods [23,32]. Deductive codes were generated from related work to accentuate known issues about assistive technology use [27,30,31]. Two coders openly and separately coded two groups' data to generate an inductive code list, and discussed and refined code definitions. (See Table 3 for a summary of codes.) Similar concepts that arose were discussed and combined where relevant, and connections were drawn across categories. Then, the two coders independently coded 10% of the student journal entries. A Cohen's Kappa calculated on the coders' results yielded $\kappa = 0.79$, indicating strong agreement between the coders. A single researcher coded the remaining data. All researchers discussed and confirmed the final categories and themes. Analysis focused on how students considered disability as they developed an understanding of design.

4. FINDINGS

All groups successfully created high-fidelity prototypes that they could test with expert users at the end of the 10-week term (Figure 2). Expert users judged that the final designs met their expectations. Thus, our findings confirm that inclusion of diverse users can indeed influence designers toward accessible solutions. We also found new evidence that working with *both* disabled and non-disabled users surfaced different tensions and challenges that encouraged designers to consider accessibility as a key component of all design, not just a specialty, guideline fulfillment, or after-thought. We focus on how tensions across non-functional and functional issues for both groups of users manifested.

4.1 Perceptions of Accessibility

Tensions that emerged from designing for both disabled and non-disabled users were different from challenges typically faced when designing for only one group or the other. These tensions influenced student perceptions of the difficulty or feasibility of accessible design. Learning about expert users' experiences as disabled people encouraged students to re-assess the need for accessible design, while including non-disabled users prioritized non-functional needs. For example, working with expert user E2 emphasized the disparate state of technologies:

We have also paid more attention to refining our choices regarding the placement, sizing, and labeling of inputs and information, all areas in which small changes can modify the effectiveness and physical usability of the application. These changes reflect, for me, a broader change in my understanding of design and accessibility. E2's encouragement to investigate the existing marketplace showed me just how separate the industrial fields of design and design for those with disabilities have become. Seeing him use his devices firsthand has demonstrated why that practice is flawed, ignorant, and impractical. The structure of this course has also been encouraging for me in thinking about the inclusion of users in the design process. (S26, Journal 9)

Table 3. A summary of deductive and inductive codes.

Deductive codes from prior work
Ability and equal access: just like everyone else
Aesthetics and form factor, user appearance
Avoidance
Safety and help
Attitude
Ignorance
Contextual influence
Employment
Technology type: mainstream or proprietary
Breakdowns: functional and social
Social expectations, transitional encounters
User confidence, showing technical savviness, educating/sharing
User self-consciousness
Mis/perceptions: social, technical, contextual, neutral
Inductive codes
Perceptions, expectations: learning and design
Attitude, reflection, learning: disability, accessibility, design thinking
Tensions, challenges: design for disability, cost, complexity
Techniques and tools
Design decisions: accessibility, usability, prioritizing, assumptions
Working with users with disabilities, in groups: prior experiences

Indeed, the challenges we put before students stretched their experience with design and disability; addressing both target user populations was daunting, particularly if student designers had little or no experience with design or disability. As S26 discussed, student perceptions of accessibility changed as they continued to work with expert users. Initially, students had altruistic reactions to the design project. However, despite feel-good attitudes and a desire to "be helpful" to people with disabilities, altruism stemmed from a sympathy toward disability. Sympathetic attitudes are not necessarily a bad thing—sympathy exposes misperceptions and assumptions—but sympathy can manifest as ableist and create barriers to understanding and creating accessible design. Only six students had substantial interactions with people with disabilities before the course, such as having a close friend who is blind. Fifteen students reported limited interactions, from meeting blind massage therapists to grandparents with hearing loss. Of those, four had working interactions, such as briefly tutoring a deaf student. Thus, few of the 42 students interacted with people with disabilities before the course, and almost all students expressed discomfort and self-consciousness prior to meeting expert users, despite the guest lecture about appropriate etiquette. S30 related common concerns:

The nervousness comes from the fact that I'm not quite sure how to act around [disabled people] and I really don't want to say the wrong thing and upset my client. The last thing I want to do is offend them in any way since I have a lot of respect for them. I can't really imagine what it would be like to live without either sight or hearing or even both. I thought about what it would be like before and every time I come to the conclusion that there is no way that I could even come close to imagining it. (S30, Journal 2)

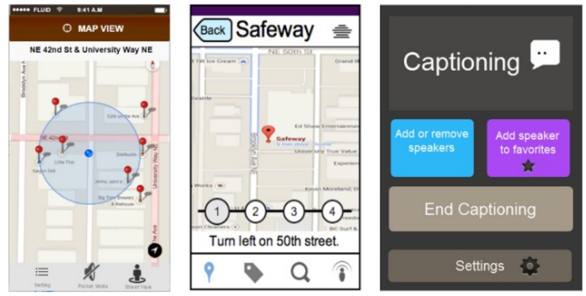

Figure 2. Student designs (from left): G1's and G5's way-finding map interfaces. G11's captioning-in-progress.

Like S30, student designers were self-conscious about their own ignorance of disability. S1 worried she might offend others:

I felt sad and was worried that I could unintentionally hurt [people with disabilities] through my ignorance. The worst fear was sparked by blind people and there were a couple of reasons. First of all, I consider myself a visual thinker, so the loss of vision seems one of the most terrifying complications to me. Therefore, I am worried that I can unintentionally hurt a blind person—I feel so sorry for blind people, but they want to be treated like everyone else. (S1, Journal 2)

Ignorance and discomfort were grounded in inexperience with disability—students were self-conscious about being offensive because they did not know what was acceptable or unacceptable behavior around people with disabilities—the knowledge void was filled by ableist perspectives. The view that, "loss of vision seems one of the most terrifying complications," highlight that students focused on the disability ahead of the person. Understandably, students were unaware of the ableist tendency in this thinking, and they were not expected to know or think otherwise. But what are the implications of such thinking? Do designers with an ableist view create inaccessible technologies? Our findings indicate that students initially assumed it unnecessary to include accessibility:

Working with a person with a disability will affect the considerations I put into the project. If I were making a device for someone without disabilities, I sadly would not have considered factoring in people with disabilities. (S16, Journal 2)

Because he was not disabled, S28 did not think about accessibility:

[E2] had me thinking about things that I don't really pay much attention to, because I have normal vision. (S28, Journal 3)

S28 considered an experience vastly different than his own:

Talking to our expert user made me think about things that I don't really usually think about. That is why our expert user's input is valuable. I could see that being even more evident once we get feedback after presenting our ideas to him. (S28, Journal 4)

Working with expert users, students became aware of the implications of inaccessibility. S36 disregarded what he was taught about accessibility, until he noticed how it affected his expert user:

To be honest, I never find the value of labeling my button when I design a website or other product, because when the professor said we need to focus on the accessibility of our design, I often just let it slip away. However, I realized the importance of labeling when I heard my interviewee saying unlabeled buttons are the most frustrating factor when using applications. (S36, Journal 3)

Because we cannot know exactly what students thought, it would be hard to say whether working with disabled users eliminated ableist tendencies in students or not. But S28 and S36's comments were representative of what students reported as the weeks went on, and here the data confirms findings in prior work [20,33]: Interacting with expert users opened students' minds to a diverse view on accessibility. More time with expert users was beneficial—misconceptions faded as students and expert users developed friendly working relationships. As students adjusted to using appropriate disability etiquette (i.e., asking if a person needs help instead of assuming their impairment means they need help) and overcame communication barriers, the unknowns that made design for disability seem impossible became more passé. As S17 noted:

I have also found more confidence working with deaf people through our interactions with E11. Trying to tiptoe around the fact that he is deaf wastes valuable time we could use discussing button layout and font sizes. (S17, Journal 8)

Multiple sessions helped students learn about their expert user as a person, not a disability, and helped students to learn from their mistakes; one awkward meeting would make the next more productive as students learned better ways to ask questions. Students found that incorporating accessibility did not detrimentally affect the rest of their design; instead it could help the design become more usable overall:

Working with accessibility as one of your central focuses when designing a product does seem to improve the quality and usability of the final design overall. What I was surprised about is that I don't feel this is just because an accessibility focus forces the design to be "easier to use," but because the focus of people with accessibility issues is to be able to behave just like everyone else. Thus, working with people with hearing loss, sight loss, movement problems, etc., helps you focus with laser-precision on the most important and basic human needs. (S40, Journal 8)

As S40 mentioned, students learned that accessibility did not have to be an excessive burden on design, but could be another way to improve design overall. Key to this understanding was for students to be able to see: (1) the multiple issues at play for the various users, and (2) that the students, as designers themselves, could meet the challenges emerging from the tensions between the different issues. We next discuss how a focus on disabled and non-disabled users gave rise to both functional and non-functional issues.

4.2 Functional and Non-Functional Factors

Students struggled to bridge functional and non-functional needs of users with and without disabilities. Students were overwhelmed by what they needed to learn about how disabled people used technologies. Ableist attitudes at first narrowed their perspective: students considered the disability before the person, sometimes myopically focused on functional issues, despite the emphasis in UCD on holistic user *experience*. To address disabled user needs, students began by asking, "what functionality will address impairments?" rather than other concerns, like what a user might find socially acceptable or aesthetically pleasing. Indeed, S2 considered "intuitive aesthetics" unnecessary for blind users:

Though our product will still have to be usable for able-bodied people, it will be interesting to design something that has to have a very intuitive layout rather than intuitive aesthetics. For a blind person, it doesn't necessarily have to look pretty, but the way things are laid out has to provide smooth navigation. I think that might be one of the biggest challenges we'll face; how to organize the features we want to include. (S2, Journal 2)

There exist functional differences between disabled and non-disabled users, but the language S2 used reflected an assumption that disabled users may not care about "aesthetics" as much as non-disabled users. The benefit of working directly with expert users was that students learned about the non-functional needs they otherwise might have overlooked. Expert user E7 emphasized that accessibility was more than just about functionality, it included her busy schedule, safety, and financial security:

Learning about how E7's iPhone was her go-to device was really valuable, because we were then able to identify that we should be designing for an iPhone. We knew it needed to be cheap and simple, because E7's a busy woman, and she's a college student with a light budget. These kinds of facts about our expert user that we learned through the interview helped create more physical and practical constraints on our design. (S14, Journal 8)

S14 highlighted real experiences he was privy to and could draw on as he worked with E7. S21's expert user also prioritized non-functional issues, like safety and customizability:

Our client emphasized that her priorities are customizable fonts, portability, and the fact that she is a single woman with a vision impairment. What she meant with that last bit is that she tries hard not to look lost and vulnerable when she's alone and using her mobile devices. (S21, Journal 4)

The non-functional needs enumerated by expert users contrasted with the function-only view that students initially held. Students benefited from working with expert users who gave feedback highlighting non-functional needs. Students benefited from also designing for non-disabled users because it challenged students to strategize ways to address tensions exposed by non-functional needs. Specifically, students did not try to "imagine what it would be like" to be a user with a disability as a strategy (which tends to be an ableist exercise); they learned that expert users prioritized non-functional characteristics important to any user. Understanding that characteristics like safety and social appeal were important to expert users and non-disabled users alike made students aware of what they had (or did not have) in common with expert users. S16's group referenced its understanding of social decorum and cell phone use supported by feedback from E9:

…we examined the social implications of always having a phone out and reading off a phone while talking with someone. Since so many people find that to be rude, we began to explore ways of allowing our users to read the text while staying engaged in the conversation. E9 was a great help with this by pointing out how important eye contact and facial expressions are to him. (S16, Journal 4)

Another non-functional concern unique to expert users was the aspect of disability itself. Managing an image-as-disabled was an experience of disability that students may not have anticipated.

One of her biggest concerns was the aesthetic of the device and how it should be discreet enough so as to not give away her disabilities. This point has had a conscious impact on my mentality when going about doing the sketches. (S3, Journal 4)

Specifically, some non-functional issues were unique to the experience of disability, and it made sense that as time went on, these issues organically arose:

Perhaps the most important discovery was that two particular factors were most important to our target user: accuracy and unobtrusiveness… She also said that she wanted the application not to call unnecessary attention to her hearing loss; she did not want it [to] be stigmatizing. (S7, Journal 3)

S7's expert user prioritized accurate functional accuracy and unobtrusiveness. Although these two issues are not always opposing, for a person with a disability, they could be. We discuss how students addressed some of these tensions in the next section.

4.3 Tensions and Opportunities

Students applied different strategies to challenges highlighted by tensions between functional and non-functional issues. Our findings indicate that having a requirement to also design for non-disabled users gave students another tool with which to strategize. Like S7's group above, S24's group learned the severity of the non-functional issue of drawing "unnecessary attention" because E11 was less likely to use technology that was not discreet.

We were also able to learn what is important to them when it comes to assistive hearing technology; for example, E11 made it very clear that inconspicuousness is important to them in a product–if something isn't discreet or just about invisible, they are much less likely to use it. (S24, Journal 3)

For E11, functional success alone did not necessarily translate into access. Students took this feedback to heart. E11's group reflected:

Glasses were chosen because, as a group, we figured that holding a device up while talking, or listening to someone would be distracting for all parties involved. We wanted to reduce this social awkwardness as much as possible. (E11's group design rationale, see Figure 3)

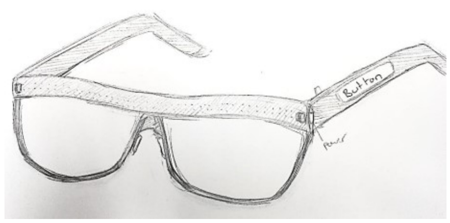

Figure 3. A sketch of E11's group's glasses design, described as: "designed to have a profile of modern 'hip' glasses."

With a clearer awareness of what they, as non-disabled users, had in common with expert users, students sometimes referred to a non-disabled understanding of non-functional issues to find solutions. S10's group referenced its understanding of social cues when deciding on form factor:

In my experience, most people find it rude when people look down at their phone while in a conversation and avoid eye contact. This is why our group decided to avoid a mobile device or other device where a user would have to look away from the person they are speaking with to comprehend the conversation. (S10, Journal 5)

Indeed, students focused on what users have in common:

When looking to create a product for those with and without a visual impairment, it is a great start to focus on what they can do in common… (S23, Journal 3)

Another strategy was to start from expert user's requirements and find ways it might also appeal to non-disabled users:

He constantly suggests things that would make using applications easier for him, and we've figured out ways to turn the interactions that facilitate his accessibility into cool design features that people without disabilities will find useful and interesting. (S31, Journal 6)

S23's group circled between the requirements of both user groups:

We need to constantly be looking back at the problems that we set out to solve with our design. Is this helping people navigate even with visual impairment? Will this let people explore what is around them? By continually referring to these questions and considering if we are still answering a definitive yes then I have confidence our design will stay on track. (S23, Journal 4)

Finally, some challenges that students encountered were due to inaccessible aspects of tools and techniques used and these challenges highlighted the shortcomings of UCD for accessible design. For example, most prototyping techniques assumed that users can see representations, and students found it difficult to work around the inaccessibility of paper prototyping for visually impaired users. The interchangeable parts on S6's perceived flexible prototype fell apart during testing:

For paper prototyping, we tried just having buttons placed on top of the paper. When we did that, it would be lifted and the pieces would fall off. Eventually we got tape to help stick the pieces on, which did help, but the delay made it not as helpful as it could have been. (S6, Journal 8)

In the event that a technique was inaccessible, we encouraged students to seek creative solutions on their own and they were mildly successful at devising accessible workarounds. In one example, S13's team worked around paper prototyping by "having [E6] test the application on her own phone… and a team member voiced the computer and spoke appropriate feedback." Although interacting with the sleek, glass touch screen of a smartphone might feel like a high-fidelity experience, the fidelity of the interaction was considerably lower due to the draft script.

Not all groups were successful at workarounds. E9's group tried to facilitate a realistic user experience by creating a high-fidelity prototype with glasses that captioned in real-time. The group tried to Wizard-of-Oz the interaction with a "captioner" who live-typed conversations that appeared on a tablet in front of the user (Figure 4). The transition from typist to screen was slower than speech-to-text engines and did not create the desired experience. E9 inadvertently relied on lip-reading and an ASL interpreter rather than the prototype, missing much of what appeared on the screen:

Although the captions weren't showing, we felt like we were very close because there were times during the testing where the captioning was on time and E9 used our prototype. We also knew we were close to captioning fast enough because we noticed that the second after E9 would look up to read lips, the captions would almost always appear at the same time. As far as improvements go, we feel the only improvement we can make would be to type faster or to find a way to have speech to text technology be implemented, but the latter would be going towards the actual product rather than a prototype and we don't have the resources for that technology. (S29, Journal 9)

Figure 4. E9 tests a high-fidelity prototype, simulating glasses (he is wearing) displaying captions in real time (on the tablet).

Many user-centered techniques and tools make assumptions about ability. Paper prototyping assumes vision, few prototyping tools support speech-to-text functionality, and students struggled at times to work around these issues. Students persevered with few resources, but it is unclear how much more successful they could have been if tools supported their accessibility needs.

Ideally non-functional issues were brainstormed and prototyped with regard to user-experience, but unique disability-related issues distracted students from these considerations. The design prompt for disabled and non-disabled users challenged students not to disregard one for the other.

4.4 Changing Attitudes Toward Design

Weekly journals served the purpose of tracking issues, difficulties with subject matter, or problems within groups. Journals provided rich data on student effort throughout the term, including how accessibility requirements challenged and changed student perspectives on design for disability. S36 expressed a common concern students had early on about their ability to create a design that would adequately address tradeoffs for both user groups.

I think one aspect that might detract me from my design is the over emphasis on accessibility and make [sic] the product significantly more difficult to use by people without disabilities, and often impossible to use by people with a different type of disability. One thing that I've [sic] keep reminding myself in the process of design is how to balance my design between normal people and people with disability. (S36, Journal 3)

Fortunately, attitudes about possible negative impacts of accessible design and the needs of "normal people" gave way, in the end, to a more enlightened understanding. The impact of expert users was evident, as S37 wrote:

I think I've learned a lot about disabilities by working with E9. Lip reading, accessibility devices, and the challenges of being deaf have all been illuminated to me. A lot of my preconceived notions about people with disabilities have proven to be false, and I feel much more comfortable interacting with someone who may have a disability. I have learned that design can be made universal for people, regardless of the level of their abilities. (S37, Journal 8)

The reflective journals provided a way to track student perceptions and ideas. S25 reflected on how she felt she had changed:

Personally, I believe my perspective on designing for accessibility has done a complete '180', so to speak. Towards the beginning of the class, I was afraid I would have limited knowledge to contribute to my team, because it was a realm I knew very little about. Truthfully, when I had wireframed or designed web pages in the past, it never occurred to me that it is so crucial to design for accessibility. I had always thought, "what is some cool iconography I could use to make this look modern and minimalistic?" Now I just kind of think back on that, and laugh at myself. Design is much more multidimensional, and I not only feel like I've grown with my team, but also as an individual designer with more empathy for all users. (S25, Journal 9)

Similarly, S28 shared how her expert user had influenced her:

I think that having these meetings with our expert user has made me think more actively about accessibility for all. I honestly now find myself always thinking about how disabled people might use an object or interact with a system. I have also experienced having to weigh decisions regarding aesthetics and "innovation" based on their usability. Although I can't say I know for sure what I would do whenever decisions regarding these things are to be made, I now give it a little more thought. (S28, Journal 8)

Toward the end of the course, S13 wrote:

I also used to think that accessibility design is a separate branch of design, but that is not at all design. We can design for accessibility by considering the same parameters you would consider for a regular design and just thinking of different use cases. (S13, Journal 9)

Corroborating S25's, S28's, and S13's sentiment, most students confessed they expected design for users with disabilities to be more difficult than for non-disabled users. But, at the course conclusion, 21 out of 36 students admitted that designing for disability was not as hard as they thought it would be. Ten reported no change, and only 2 felt it was harder. Interactions with expert users helped students gain an appreciation for accessibility.

5. DISCUSSION

Despite emphasis on the user in UCD, current mainstream personal technology design is predominately inaccessible, disregarding disabled users as part of that user-base. To understand how design thinking changed when disability was emphasized, we investigated how designing for disabled and non-disabled users in the UCD process influenced student perspectives. Our findings about student attitudes and perspectives on accessibility corroborated related work indicating that separating disability and mainstream design approaches reinforces the notion that accessibility is someone else's job [2,20,33]. We add to the existing body of research in UD in education [2] an empirical study of students tasked with inclusively designing for people with disabilities in a classroom setting. Our findings expand on strategies bolstering awareness of the importance of accessibility. We found evidence of ableist attitudes implicit in students' initial approaches to accessibility, confirming and extending work by Ludi [20] and Waller [33], that interacting with people with disabilities can help students develop a better understanding of disability and design. In distilling implications for accessible design, we identify key characteristics that facilitated awareness of the disabled experience as it might contribute to a designer's conception of design overall.

5.1 Agency in Accessible Design

The assumptions about design and disability that student designers initially had led us to understand that most first-time designers do not typically come to technology design with an appreciation of the needs of disabled users. Social psychology literature informs us that student designers' expectations around disability are almost certainly shaped by previous experience [5,22]. Students' prior experiences led them to feel uncomfortable with the idea of working with people with disabilities, and some students exhibited ableist views. If students did not regularly engage with disabled people before the course (and most did not), they were unfamiliar with how to approach and interact with people with disabilities.

Students situated their perceptions toward disabled users as a stigmatized "other" [11,12,14]. S1's confession that, "I… was worried I could unintentionally hurt them through my ignorance… I feel so sorry for blind people," revealed bias: as a sighted person, she could not imagine the loss of vision and concluded blind people have it impossibly harder, in a way she could only pity. Sidelining the disabled experience, or like S1, pitying disability, led students to feel self-conscious about offending expert users. Indeed, present-day society socializes disability-sympathetic, if not patronizing and ableist, behaviors [4,10]. Students came to the course influenced by social and cultural stereotypes, and their reactions to disability were likely biased by assumptions of ability. It was not that students felt they should not design for disabled users, but they believed non-disabled users were the presumptive *de facto* target audience.

Simply put, in their role as designers, students did not think it was their job to design for disability.

One way ableism manifested as a barrier to accessible design was that students considered themselves “normal” and addressed accessible needs as separate from needs of non-disabled users. Disability-specific approaches can feed ableist attitudes perpetuating a divide between users with and without disabilities. A divide does not mean one user group is superior to another, but there was evidence that students already had these tendencies likely indicating ableist attitudes toward design for disability. Opening up the concept of the “user” to include disabled and non-disabled people gives more stakeholders an equal chance to influence design. With this requirement, students were prevented from separating “normal” from accessible.

The guest speaker was helpful in setting expectations and clarifying etiquette, the single question and answer forum did not sufficiently provide the perspectives needed to persuade students to weigh accessibility seriously. Instead, perceptions about accessibility and disability changed with increased time spent working with expert users. Addressing challenges in design for disabled and non-disabled users helped students cultivate open-minded views of accessibility, bolstered by their growing ability and confidence as designers to make design accessible. What does this mean for the broader view of design overall? Including people with disabilities involves more than just face time [20,33], it involves enmeshing disabled *and* non-disabled viewpoints throughout the design process. Our findings translate into a need for designers to consider disabled users as part of the whole user base, not as a separate group or set of requirements. When student designers regarded accessibility as part of their larger aims they: (1) gave agency to the disabled user as a *person* (not a disability) with an equal stake in design outcomes like any non-disabled user, and (2) they saw *themselves* as having agency and skill as designers to create technology that fulfilled needs for both groups.

5.2 Implications for Accessible Design

We compile our findings into implications for incorporating accessibility in design. Designers should include disabled and non-disabled users because challenges arise that are unique to the intersection of both groups. Our study suggests extended exposure to expert users helped students understand how the disabled experience amounts to more than functional limitations. Students learned about non-functional issues expert users experienced, such as social use, safety, and discretion, and saw how important such issues were. Although these issues are important for non-disabled users, too often functional needs in disability-centric design overshadow or complicate non-functional issues for disabled users. For example, text-to-speech was a popular design component in projects for blind and low-vision users, but some expert users were sensitive to talking devices attracting attention, for social or safety reasons. Finally, requiring two user groups was one way to challenge ableism by creating a socio-technical space where disabled and non-disabled users were equal contributors.

Tensions between functional and non-functional issues led to the second implication: designers should consider functional *and* non-functional features in their design. In finding ways to bridge different requirements for the two user groups, student designers needed to find solutions that would work across the tensions that emerged. In addition, it was through the process of addressing these tensions between seemingly disparate groups (users with and without disabilities) that students could see that they were capable of creating *accessible*, rather than just *assistive*, technologies.

Our data suggest that the tensions students faced while designing for disabled and non-disabled users and the ways they addressed those challenges allowed students to see the power of their own agency. We recall this sentiment by S25: “Design is much more multidimensional, and I not only feel like I’ve grown with my team, but also as an individual designer with more empathy for all users.”

6. LIMITATIONS AND FUTURE WORK

Our study is limited by students’ novice design experience. We captured students’ perspectives, but we do not know how professional designers would handle similar challenges, and we cannot be sure how *learning* design may impact perspectives. We did not evaluate how specific tools and techniques contributed to design thinking, despite some of the accessibility challenges uncovered in UCD methods. Although we recruited disabled expert users, we did not recruit non-disabled users, and students’ success reaching non-disabled users on their own was varied. Future work will involve explicit recruitment from both populations. In addition, teaching multiple design approaches facilitated an opportunity to compare across them, but our study was not designed to facilitate controlled comparisons. Including approaches in a curriculum that otherwise does not train students to design for disability strongly restricts any pedagogical conclusions and we refrain from making any. Despite this, student experiences and design artifacts speak to the veracity of our findings. Future work will focus on nuanced differences and involve professional designers.

7. CONCLUSION

We studied how student designers cultivate their design thinking when tasked with designing for users with and without disabilities. Addressing tensions between functional and non-functional factors revealed challenges at the intersection of designing for both user groups simultaneously. When students engaged requirements to design for users with and without disabilities, they broadened their conception of accessible design. We distilled our findings into implications for accessible design: (1) target users should include those with and without disabilities (not just one or the other); and (2) designers should consider functional and non-functional elements across both user groups. In tackling these issues, students not only changed their perception that accessible design is possible and feasible, but also that they had the ability and responsibility to achieve accessible design.

Working with users in the design process leads to useful designs [16], and working with disabled users is likely to produce more accessible designs [1,18,20,24,33]. Yet, the dearth of accessible mainstream technologies reveals an opportunity to understand how designers are (or are not) addressing design for disability. Although inclusion of disabled users is effective, more needs to be done to effect change in the way designers approach their own practice of design. Increasing the number of technologies usable by people with disabilities, whether assistive or mainstream, is a positive shift because it improves the ability for a diverse population of users to participate in society. But having similar functionality in different devices is not the same as making all technologies accessible. Thus, we see an opportunity to change how designers engage disability and incorporate accessibility in their overall understanding of technology design.

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9. REFERENCES

[1] Bigelow, K.E. 2012. Designing for Success: Developing Engineers Who Consider Universal Design Principles. 25, 3 (2012), 211–225.

[2] Burgstahler, S. 2015. *Universal design in higher education : from principles to practice*. Cambridge, Massachusetts : Harvard Education Press.

[3] Buxton, W. 2007. *Sketching user experiences : getting the design right and the right design*. Elsevier/Morgan Kaufmann.

[4] Charlton, J.I. 1998. *Nothing about us without us: disability oppression and empowerment*. Univ. of California Press.

[5] Christiansen, C.H. 1999. Defining Lives: Occupation as Identity: An Essay on Competence, Coherence, and the Creation of Meaning. *The American Journal of Occupational Therapy*. 53, 6 (Nov. 1999), 547–558.

[6] Cook, A.M. and Hussey, S.M. 2002. *Assistive technologies : principles and practice*. St. Louis : Mosby.

[7] Cook, A.M., Polgar, J.M. and Livingston, N.J. 2010. Need- and Task-Based Design and Evaluation. *Design and Use of Assistive Technology: Social, Technical, Ethical, and Economic Challenges*. M.M.K. Oishi, I.M. Mitchell, and H. f. M.V. der Loos, eds. Springer. 41–48.

[8] Crutchfield, B. 2016. ADA and the Internet: ADA Settlements-Fitting Accessibility Compliance into Your Product Lifecycle. *SSB Bart Group*.

[9] Davis, F.D. 1989. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*. 13, 3 (1989), 319–340.

[10] DePoy, E. and Gilson, S. 2014. *Branding and designing disability : reconceptualising disability studies*. Abingdon, Oxon : Routledge.

[11] Elliott, G.C., Ziegler, H.L., Altman, B.M. and Scott, D.R. 1982. Understanding stigma. *Deviant Behavior*. 3, 3 (1982), 275–300.

[12] Fine, M. and Asch, A. 1988. Disability Beyond Stigma: Social Interaction, Discrimination, and Activism. *Journal of Social Issues*. 44, 1 (1988), 3–21.

[13] Friedman, B., Kahn, P. and Borning, A. 2006. *Value Sensitive Design and Information Systems*. M.E. Sharpe.

[14] Goffman, E. 1963. *Stigma; notes on the management of spoiled identity*. Prentice-Hall.

[15] Goodman, E., Stolterman, E. and Wakkary, R. 2011. Understanding interaction design practices. *Proc CHI '11* (Vancouver, BC, Canada, 2011), 1061–1070.

[16] Gould, J.D. and Lewis, C. 1985. Designing for usability: Key principles and what designers think. *CACM*. 28, 3 (1985), 300–311.

[17] Kondraske, G.V. 1988. Rehabilitation engineering: Towards a systematic process. *IEEE Engineering in Medicine and Biology Magazine*. 7, 3 (1988), 11–15.

[18] Ladner, R.E. 2015. Design for user empowerment. *interactions*. 22, 2 (2015), 24–29.

[19] Linton, S. 1998. *Claiming Disability: Knowledge and Identity*. New York University Press.

[20] Ludi, S. 2007. Introducing Accessibility Requirements through External Stakeholder Utilization in an Undergraduate Requirements Engineering Course. *Proc. Soft. Eng. '07* (2007), 736–743.

[21] Mace, R.L., Hardie, G.J. and Plaice, J.P. 1991. Accessible environments: Toward universal design. *Design Intervention: Toward a More Human Architecture*. W. Preiser, J. Vischer, and E. White, eds. Reinhold. 155–176.

[22] Mead, G.H. 1962. *Mind, self, and society from the standpoint of a social behaviorist*. Univ. of Chicago Press.

[23] Miles, M.B. and Huberman, A.M. 1994. *Qualitative data analysis: an expanded sourcebook*. Sage Publications.

[24] Newell, A., Gregor, P., Morgan, M., Pullin, G. and Macaulay, C. 2011. User-Sensitive Inclusive Design. *Universal Access in the Information Society*. 10, 3 (Aug. 2011), 235–243.

[25] Norman, D. 1988. *The Design of Everyday Things*. Basic Book.

[26] Roedl, D.J. and Stolterman, E. 2013. Design research at CHI and its applicability to design practice. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Paris, France, 2013), 1951–1954.

[27] Scherer, M.J. 1993. *Living in the state of stuck: how technologies affect the lives of people with disabilities*. Brookline Books.

[28] Schuler, D. and Namioka, A. 1993. *Participatory Design: Principles and Practice*. Erlbaum Assoc.

[29] Sharp, H., Rogers, Y. and Preece, J. 2007. *Interaction design: beyond human-computer interaction*. Wiley.

[30] Shinohara, K. and Wobbrock, J.O. 2011. In the shadow of misperception: Assistive technology use and social interactions. *Proc. CHI '11* (Vancouver, BC, 2011), 705–714.

[31] Shinohara, K. and Wobbrock, J.O. 2016. Self-Conscious or Self-Confident? A Diary Study Conceptualizing the Social Accessibility of Assistive Technology. *ACM Transactions on Accessible Computing (TACCESS)*. 8, 2 (2016), 1–31.

[32] Strauss, A.L. and Corbin, J.M. 1998. *Basics of qualitative research.* Sage Publications.

[33] Waller, A., Hanson, V.L. and Sloan, D. 2009. Including accessibility within and beyond undergraduate computing courses. *Proc. ASSETS '09* (Pittsburgh, PA, USA, 2009), 155–162.

[34] Winner, L. 1980. Do Artifacts Have Politics? *Daedalus*. 109, 1 (1980), 121–136.

[35] Wobbrock, J.O., Kane, S.K., Gajos, K.Z., Harada, S. and Froehlich, J. 2011. Ability-based design: Concept, principles, and examples. *ACM TACCESS*. 3, 3 (2011), 1–27.

[36] Zhang, X. and Wakkary, R. 2014. Understanding the role of designers' personal experiences in interaction design practice. *Proceedings of the 2014 conference on Designing interactive systems* (Vancouver, BC, Canada, 2014), 895–904.