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)*

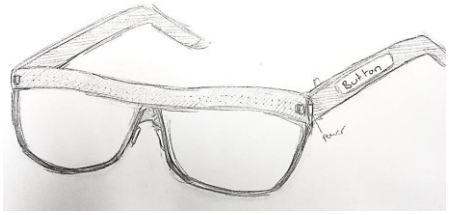

**Figure 3. A sketch of E11's group's glasses design, described as: "designed to have a profile of modern 'hip' glasses."**

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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