Tenets for Social Accessibility: Towards Humanizing Disabled People in Design

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Despite years of addressing disability in technology design and advocating user-centered design practices, 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 multiple disabled and nondisabled users encouraged students to think about accessibility in the design process. Across two university course offerings one year apart, we examined how students focused on a design project while learning user-centered design concepts and techniques, working with people with and without disabilities throughout the project. In addition, we compared how students incorporated disability-focused design approaches within a classroom setting. We found that designing for multiple stakeholders with and without disabilities expanded student understanding of accessible design by demonstrating that people with the same disability could have diverse needs and by aligning such needs with those of nondisabled users. We also found that using approaches targeted toward designing for people with disabilities complemented interactions with users, particularly with regard to managing varying abilities across users, or incorporating social aspects. Our findings contribute to an understanding about how we might incur change in design practice by working with multiple stakeholders with and without disabilities whenever possible. We refined *Design for Social Accessibility* by incorporating these findings into three tenets emphasizing: (1) design for disability ought to incorporate users with and without disabilities, (2) design should address functional and social factors simultaneously, and (3) design should include tools to spur consideration of social factors in accessible design.

CCS Concepts: • **Human-centered computing → Accessibility design and evaluation methods**;

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1 INTRODUCTION

Despite the emphasis on understanding users in design thinking and User Centered Design (UCD) [3, 16, 36], current mainstream personal technologies are often inaccessible; people who create mainstream technologies do not regularly incorporate accessible design except, perhaps, to satisfy legal requirements [10]. When limiting accessible design to either technologies for people with disabilities only or to meet minimal legal requirements, fewer mainstream technologies are usable by people with disabilities, even though they could be. For example, today's smartphone technologies have technical sophistication that, when harnessed appropriately, are usable by people with vision or hearing impairments. Yet, despite opportunities to harness technical capabilities so that people with disabilities can use today's mobile devices, blog and social media posts throughout communities of disabled people warn of product-updates that cause accessibility regression [26].

Although accessibility research espouses the benefits of designing with people with disabilities [19, 28, 36, 42], 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 [7, 8]. Although prior work has demonstrated that designing directly with people with disabilities can improve accessible technology outcomes [1, 23, 40], it remains unclear how to encourage designers to adopt accessibility as a core goal of the technology design process, what we refer to as accessible design.

We conducted a study through two offerings of a university undergraduate design thinking course to investigate how student designers shaped their perspectives on accessible design. Specifically, we explored how different elements of the design thinking process—such as working with both disabled and nondisabled stakeholders—influenced student designers' perspectives on accessibility and design (Figure 1). Although it is well known and accepted that people gain awareness and empathy from exposure to people *not* like themselves [23, 40], our account expands this work by showing processual change during engagements with each of the formative stages of students' design thinking. We demonstrate how expanding accessible design to include a broader, diverse view of users can positively influence the design process. We further show how strategies that students applied can be useful for shifting perspectives in accessible design. Finally, we consolidate our findings into a framework and method cards, what we hope are the beginnings of an orientation and practice that guides designers toward accessible design.

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 an inclusive approach to design overall [37]. For example, we found that designing for both disabled and nondisabled users surfaced specific tensions between social and functional needs across both user groups [37]. Social needs included non-functional design aspects, such as factors influencing use and perception of the technology, like social appropriateness, professional presentation, adherence to decorum (e.g., is it loud during a work meeting when people should be quiet?), and so on. Addressing functional/social tensions challenged students to re-assess their view of disability and accessibility, stretching their capacity as designers of accessible solutions.

This article is an expanded version of an article presented at the 2016 ACM SIGACCESS Conference on Computers and Accessibility (ASSETS 2016) [37]. In this expanded account, we present new material that represents findings across both university course offerings, including: how students addressed challenges designing for multiple disabled stakeholders, and the role of different design approaches meant to foster accessible design in shaping student design thinking. We offer suggestions to improve inclusive design practice: (1) work with multiple stakeholders with and

Fig. 1. A blind user tests a high-fidelity prototype designed by design thinking students.

without disabilities whenever possible, (2) simultaneously approach design decisions with a balance of social and functional accessibility considerations, and (3) prompt designers with diverse perspectives and multiple viewpoints. To the last point, we developed a framework and set of design method cards, informed by our findings, to actively prompt consideration of diverse perspectives and encourage awareness of various social contexts. The goal is for these findings to inform an improved *Design for Social Accessibility* promoting accessibility in design thinking in general [39].

2 BACKGROUND AND RELATED WORK

People choose from a variety of technologies to help them do more. Yet, most mainstream technologies are not accessible, and people with disabilities instead use assistive technologies to bridge the gap between themselves and their technologies. Inaccessible technologies are indicative of a shortcoming in current approaches to technology design. We therefore see an opportunity to encourage technology designers to incorporate accessibility in their design thinking [12].

2.1 Accessible Technology Design

Technologies accessible to people with disabilities tend to fall into one of two categories: *assistive technologies* typically are proprietary devices, created only for people with disabilities to use; *accessible technologies*, on the other hand, are devices that are usable by people without disabilities (and most likely created for "mainstream" use), which incorporate some degree of accessibility such that people with disabilities can also use them. While there are a plethora of devices that are proprietary, made specifically for people with disabilities, few mainstream technologies are created to be accessible to users with disabilities out-of-the-box. To address inaccessible mainstream technologies, traditionally proprietary technologies, add-ons or software applications have been added. In addition, although assistive technologies serve a great purpose in providing access for people with disabilities, proprietary devices tend to be expensive, sometimes only affordable through health insurance, and hard to obtain and maintain.

It is important to note that mainstream technologies can often be used by people with disabilities *if* they are made accessible. Unfortunately, because most mainstream technologies are not made accessible, people with disabilities do not often use them, thus perpetuating the myth that they do not use mainstream technologies because they cannot do so. The "blame" often falls on users and their lack of abilities rather than on inaccessible systems.

As technologists, we have an opportunity to pivot the way that we perceive technology access in the first place, to change the ways that technologies are designed. Indeed, technology students and designers alike may not identify their work as an opportunity to incorporate accessibility in the early stages of design. Prior work showed the benefits of incorporating accessibility in engineering [1, 25] and computer science [23, 32, 40] by encouraging students to create accessible solutions. Bigelow [1] incorporated Universal Design in her introductory engineering courses and found that, when exposed to Universal Design principles, students were more likely to think broadly about diverse users in their engineering projects. Likewise, Martin-Escalona et al. [25] integrated accessibility modules within an introductory course for each of five different engineering disciplines, finding that students of the different engineering domains achieved different levels of success.

In examining curricula across institutions, Bohman [2] conducted a thematic case study of how three different universities incorporated accessibility in their information technology programs, and Whitney and Keith [17] proposed guidelines for curriculum that connects young engineers and designers with older users as a strategy for encouraging "Design for All in ICT." At the instructor level, Putnam et al. [30] investigated how individual faculty taught courses that focused on accessibility. In Bohman's, Whitney and Keith's, and Putnam et al.'s studies, it was determined that necessary resources, such as having access to people with disabilities, coupled with awareness about the importance of accessibility, could enhance student learning about the role of technology in access. In these studies, however, those who taught accessibility were characterized as having a personal motivation to do so, whether they felt it was important, or had experience with or knew someone with a disability. From these studies, it is clear that when advocating for accessibility in information technology education, the pervasive theme is that accessibility is important, but that it is difficult to support necessary resources in existing curricula.

Increasingly, research has focused on how to incorporate accessibility into computing and information technology curriculum [2, 17, 20, 30], elevating the argument that including accessibility as part of technology education is important and can be done [20]. In addition to the notion that accessibility benefits technology-in-general, the challenge that resources are often not available for dedicated accessibility-focused curriculum emphasizes the benefits of incorporating accessibility into existing courses. Therefore, the focus of our current study is to demonstrate (1) one way to incorporate such thinking into the very early stages of design work in a holistic and focused way, (2) and how doing so can shift perspectives among student designers, giving them skills and experiences that enable them to create accessible technology designs, while shaping their approach to design overall.

2.2 Design Thinking Practices

The Design Thinking paradigm, made popular through IDEO[1] and Stanford University's d.school,[2] emphasizes five stages in an intentional design practice of reflection and iteration. The five stages are: (1) empathize with users, (2) define the problem, (3) ideate and brainstorm possible solutions, (4) prototype, and (5) test. These five stages intentionally ground technology solutions in user needs, place focus on problem spaces and constraints, and encourage iteration and reflection on both successes and failures to find solutions. Within these practices, designers arm themselves with experience and a "designerly way of knowing" as they engage design practice [9, 27]. A unique skillset comprising reflexivity, creativity and discipline within constraints, design practice champions the making of new things, but also reflects on made things and on whether or not they

[1] https://www.ideo.com/.
[2] https://dschool.stanford.edu/.

worked. Thus, we acknowledge, a great deal of skill is involved in the *practice* of design, not just in producing a final product [27].

Key characteristics of design practice, then, are reflection-in-action, and reflection-on-action, as explored by Schön's "Educating the Reflective Practitioner" [34]. Building on design's iterative process, Schön observed that architecture students were encouraged to externalize, understand, reflect and then repeat the exercise in an effort to cycle through thought processes until they reached a satisfying solution. Furthermore, Schön recognized that this practice manifests in two ways: first, in real-time, a designer thinks and adjusts while working; second, in a *post hoc* sense, taking a step back, a designer might extoll the virtues or flaws of a whole system by examining how it manifests within the larger framework.

In understanding how we might approach technology design, we recognize the values of Schön's practice of reflection. Specifically, in personal technology design, the solution does not merely exist as an entity unto itself. Personal technologies exist within users' larger personal, social, and functional ecosystems. That is, a smart watch does not merely tell time and post email notifications. It also lives on a person's wrist throughout the day, an ever-present accessory seen by others with a notification system that impacts daily activities, including social ones.

This notion of design thinking, particularly how it influences UCD strategies, informs our understanding of how student designers begin to shape their ideas of design, i.e., technology users, whether disabled or not, do not just rely on *functional* aspects of technology, but a whole host of other artifact characteristics, including many that affect *social* situations. Where Schön identified the reflective work that emerged from students' interactions with ideas and designs, we examine further the implications of a variety of stakeholders throughout the design process, and how this might affect the ways that students construct their own "designerly ways of knowing."

2.3 Disability-Specific Design

User-Centered Design (UCD) emphasizes inclusion by focusing on users and the user experience in the design process [36]. 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 [36]. But in practice, the dearth of mainstream technologies that are accessible out-of-the-box 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, 23, 28, 40]. In contrast with design approaches like UCD, where designers tend to assume a nondisabled target user population, disability-specific approaches explicitly emphasize that to make technologies accessible, designers should include people with disabilities in the design process itself. Popular approaches include: Universal Design [1, 24], which focuses on principles like equitable use, flexibility in use, and simple and intuitive use; User-Sensitive Inclusive Design [28], which emphasizes getting to know disabled users and focusing on specific needs; Design for User Empowerment [19], which includes people with disabilities as the designers and engineers creating accessible technologies; and Ability-Based Design [42], which emphasizes ability over disability, and advocates systems aware of and responsive to users' abilities. In many of these approaches, a disability-centric focus is a lingering aspect of assistive technology's relationship with rehabilitation engineering [7, 18], the result of which is a "special" category of technologies specific to people with disabilities [6, 21, 33].

Assistive technologies may meet the need that people with disabilities have for accessing technology or their environment. 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 that *only* disabled people can use. Unfortunately, disability-only devices perpetuate an ableist view; mainstream devices remain inaccessible, because "special" accommodations are available for those who cannot use them [21]. Ableism is a tendency to consider nondisabled people as superior to disabled people; the consequences of ableism have far-reaching historical and socially detrimental effects [6, 11, 21]. These topics are outside the scope of this study, but we highlight ableism to raise awareness of the implications of design practices that assume nondisabled users [41].

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, 31, 43], and how to effect change. We studied novice designers to understand specific characteristics of inclusion that shaped their newly developing design thinking.

2.4 Teaching Technology Students Design and Accessibility

Previous research in college technology design courses examined how students address disability in requirements gathering, brainstorming, and prototyping solutions [1, 23, 40]. These courses introduced engineering and computer science students to accessibility, highlighting the benefits of working with users with disabilities. Ludi [23] and Waller et al. [39] focused primarily on requirements gathering and the engineering process. Bigelow [1] incorporated Universal Design principles in engineering courses to get students into a more human-centered mindset in engineering design practice. 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 Universal Design in education promotes increasing awareness of accessibility in teaching and learning, confirming that prioritizing accessibility and including people with disabilities improves understanding about disabled technology-users' needs [4]. Yet, while Universal Design in education promises to increase student exposure to disabilities, strategies for inclusive design tend to remain disability-specific. Finally, more recent research examining the prevalence and practices of computer science instructors in higher education found that a lack of awareness, resources, and institutional support result in few people teaching accessibility [30]. Thus, more must be done to broaden awareness and inclusion of accessibility into computing curricula. Training engineering and computer science students to consider disability in design may result only in functional disability-specific solutions; it may not translate into accessible mainstream technologies. To avoid exacerbating this problem, we expanded our university course project to challenge students to design for multiple users with and without disabilities 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 diverse users.

3 METHOD

We conducted our study through two university course offerings of design thinking, taught one year apart. Our goals were to investigate how student designers shape their perspectives on design,

Fig. 2. A student from Course B observes as an expert user tests a paper prototype.

and to determine how elements of the design process compel students to incorporate accessibility in their thinking and design practice.

The introductory design thinking course we studied is a requirement for the major. Although the curricular goals of the two offerings of the course were the same, we made subtle changes to the second course offering after reflecting on the successes and challenges of the first course. In this section, we first describe the course overall, its curriculum goals and the general structure that we used. Then, we describe distinguishing details of the individual course offerings.

3.1 Design Thinking Course Overview

In this section, we describe the curricular outline common between the two course offerings. We conducted our design thinking course study with student designers as they learned UCD, focusing our investigation on how students engaged users with disabilities, and on student reactions and thoughts throughout the design process. We prioritized inclusive design by having student designers work with both disabled and nondisabled users to facilitate awareness of different perspectives. Via weekly journals, we prompted students to reflect on their experiences, specifically on how they viewed and interacted with disability and design.

The curriculum of design thinking—a university course utilizing Norman's and Buxton's popular texts [5, 29]—focused on core elements of the user-centered design process: needs assessment, ideation, low- and high-fidelity prototyping (see Figure 2), 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 for both 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 for the entire term. We referred to the participants with disabilities as "expert users" to emphasize their expertise in the use of accessible technologies. Working with expert users helped students to become aware of and address accessibility issues in their designs. To aid students in addressing nondisabled user requirements, we facilitated in-class paired feedback sessions, heuristic evaluations, and usability testing to assess nondisabled user interactions. Each week, students were introduced to a new concept and participated in activities to gain experience working with different techniques

Table 1. Project Teams in Course A focused on Real-Time Augmented Reality Navigation

Grp.	Student Designers	Design Approach	Expert User
AG1	A12 (M), A22 (M), A41 (M), A31 (F)	Design for Social Accessibility	AE1 (M), Blind
AG2	A1 (F), A26 (M), A28 (F), A36 (M)	User-Sensitive Inclusive Design	AE2 (M), Blind
AG3	A19 (M), A21 (M), A33 (M), A35 (F)	Universal Design	AE3 (F), Low-vision
AG4	A6 (F), A8 (M), A23 (M), A34 (M)	Ability-Based Design	AE4 (F), Low-vision
AG5	A2 (F), A9 (M), A15 (F)	Participatory Design	AE5 (F), Blind
AG6	A11 (M), A13 (M), A25 (F), A42 (M)	Value-Sensitive Design	AE6 (F), Blind

Table 2. Project Teams in Course A focused on Real-Time Live Captioning

Grp.	Student Designers	Design Approach	Expert User
AG7	A14 (M), A30 (M), A38 (M), A39 (M)	Participatory Design	AE7 (F), Deaf
AG8	A3 (M), A5 (F), A20 (M), A32 (M)	User-Sensitive Inclusive Design	AE8 (F), Hard of Hearing
AG9	A10 (F), A16 (F), A29 (M), A37 (M)	Design for Social Accessibility	AE9 (M), Deaf
AG10	A4 (M), A7 (M), A27 (M)	Ability-Based Design	AE10 (F), Hard of Hearing
AG11	A17 (M), A18 (M), A24 (F), A40 (M)	Universal Design	AE11 (M), Deaf

around that concept. Students were assigned a term project to engage with all phases of the design process.

To aid students in the task of designing for users with disabilities, we included readings from various existing approaches to design for diverse populations: User-Sensitive Inclusive Design [28], Ability-Based Design [42], Universal Design [24], Participatory Design [35], Design for Social Accessibility [38, 39], and Value Sensitive Design [13]. The exact approaches and level of detail of instruction on the different approaches differed by course offering. In addition, student groups in both courses were assigned a dedicated design approach to work with. However, building on lessons learned in the first course, in the second course, we adjusted which approaches were assigned and how. We discuss the details below.

At the beginning of each course offering, a blind guest speaker familiarized students with appropriate etiquette for interacting with people with disabilities through a question and answer forum. Students met with their groups' main expert users roughly every other week (a total of four times). 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 during a fifth session. Next, we discuss detailed differences of the individual course offerings, and we characterize students and participants with disabilities.

3.2 Unique Components of Course Offering A

In Course offering A (referred to hereafter as "Course A" and denoted by "A" in student, group, and expert user identifiers), we examined how students' design thinking was shaped when incorporating accessibility throughout the course. Course A students learned about the following design approaches for diverse user groups: Ability-Based Design [42], User-Sensitive Inclusive Design [28], Universal Design [24], Participatory Design [35], Value Sensitive Design [13], and Design for Social Accessibility [38, 39]. Each student group was randomly assigned a dedicated design approach to draw on for their design work during the course (see Tables 1 and 2 for groups and design approaches). In-class lectures to the entire class briefly covered each design approach, while individual student groups were assigned specific readings to become more familiar with each approach. For example, while the entire class received a lecture about the basic principles for

Ability-Based Design, only students in groups 3 and 10 were assigned in-depth research articles about the origin and use of the approach. Students in Course A were not given other instruction on design approaches and were encouraged to incorporate what they could from each design approach. We considered it compulsory to introduce students to disability-aware design approaches due to course expectations to create accessible designs; we recognize the lack of in-depth instruction on each approach precluded students' ability to gain expertise.

Student project groups were divided between two randomly assigned design prompts. Project groups in Table 1 worked with blind or low-vision expert users and were tasked to design a real-time augmented reality (walking) navigation application; project groups in Table 2 worked with deaf or hard of hearing expert users, and were tasked to design an application providing real-time captioning of nearby speakers.

Participants. Forty-two undergraduate students (12 female) participated in the study. No students had any known disabilities, few students had formal design experience, and only a handful of students had interacted with people with disabilities prior to the course. Specifically, only six of the 42 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 with people with disabilities, from meeting blind massage therapists to grandparents with hearing loss. Of those, four had working interactions, such as briefly tutoring a deaf student.

Students worked with 11 (seven female) expert users who were either blind or low-vision or deaf or hard of hearing. Expert users were recruited through local disability groups and assistive technology listservs, such as the Department of Services for the Blind, National Federation of the Blind, Hearing Loss Association, and the university disability club.

3.3 Unique Components of Course Offering B

Course offering B (referred to hereafter as "Course B" and denoted by "B" in student, group, and expert user identifiers) built on findings from Course A—how students' design thinking was shaped when working with people with disabilities—and focused investigations on specific elements of students' design experiences that may have influenced their thinking. Upon our own reflection on Course A, we chose to further investigate the influence of working with people with disabilities. For example, Course A feedback revealed students might benefit from working with more than one disabled user. Thus, in Course B, we explored how students worked with multiple stakeholders; groups worked with a main expert user but conducted additional feedback sessions with other expert users. In addition, in contrast to Course A, to facilitate expert user rotation, and to allow for refined analysis around a particular design experience, all student groups were tasked with the same design prompt: indoor wayfinding for blind or low-vision users. A bulleted list of the main differences between courses A and B follow after project and demographic information about course B.

Building on lessons learned in Course A, we assigned fewer design approaches to more groups, giving us a richer data set and a better sense of how approaches influenced student thinking. Thus, we narrowed down design approaches in Course B to: Ability-Based Design [42], Universal Design [24], User-Sensitive Inclusive Design [28], and Design for Social Accessibility [38, 39]. We conducted two in-class workshops to facilitate in-depth engagement with students about their design approaches. Workshops were grouped by design approach and the first author facilitated discussion among students to situate their design approach in the context of their project. For example, students in groups 1, 5, and 9 met together in a single workshop to discuss Design for Social Accessibility and how it might apply to their design work.

All student groups in Course B were given the same prompt: to design an indoor wayfinding application. Students were told to presume indoor building information would be crowd-sourced

Fig. 3. An expert user tests the high-fidelity prototype's navigation in the hallway.

with appropriate data points to help navigate inside buildings. The rationale for this design prompt was to create a solution that new visitors as well as blind users to a public building could use to help navigate their way around. For example, a solution might be a tool that prospective students new to campus could use to navigate a building dedicated to undergraduate programs, something that might function similarly to a map or building legend. Although the tool could be helpful for new visitors to campus, it was also required to be accessible to blind users. Thus, students were tasked with designing an appropriate interface and interactions to assist blind, low-vision, and sighted users with finding their way around inside university campus buildings (see Figure 3).

Participants. Thirty-six students worked in 10 arbitrarily assigned groups of three or four. Sixteen students reported some limited experiences with people with disabilities, such as distant relatives or high school classmates. Of those 16, eight students had substantial interactions with people with disabilities before the course, such as leading youth camps, or volunteering with an organization. Twenty students reported little or no past experiences. A greater percentage of students in Course B reported some level of prior experience with people with disabilities compared to Course A. Although the increase in student experience with disability in the second year could be due to chance, we acknowledge a possibility that students communicated between years and the course reputation for accessibility might have attracted students who self-selected into enrolling in the second offering. However, a majority of the students across both courses had little or no prior experience with people with disabilities. Students met with their main expert user four times throughout the term. In the second and third meetings, students spent 15min with a new expert user and 30min with their main expert user. These "round-robin" sessions allowed students to receive feedback from multiple stakeholders with a range of visual impairments. Student groups and their assigned expert users are shown in Table 3.

Although the learning goals for both course offerings were the same—to learn design thinking—we applied lessons learned from Course A both from a pedagogical perspective and a study design perspective to adjust portions of the course. These differences included:

- Student groups in Course A were assigned a single expert user with whom they met regularly throughout the course, but that approach provided students with only one disabled user's perspective. Student groups in Course B were also assigned an expert user with whom they met regularly throughout the course, but they worked with additional expert users at two separate points during the course as well, in a round-robin fashion.
- Although students in both courses were assigned design approaches to use, student groups in Course A were given little guidance above and beyond dedicated readings and course

Table 3. Student Groups in the Second Course

Grp.	Student Designers	Design Approach	Main Expert User	Round Robin 1	Round Robin 2
BG1	B1 (F), B11 (M), B21 (M), BS31 (F)	Design for Social Accessibility	BE6 (F), Low-Vision	BE4	BE9
BG2	B2 (F), B12 (M), B22 (F), B32 (M)	Ability-Based Design	BE4 (M), Blind	BE6	BE3
BG3	B3 (M), B13 (F), B23 (F), B33 (M)	User-Sensitive Inclusive Design	BE10 (M), Blind	BE9	—
BG4	B4 (F), B14 (M), B24 (M), B34 (M)	Universal Design	BE9 (F), Low-Vision	BE10	BE4
BG5	B5 (M), B15 (F), B25 (M), B35 (F)	Design for Social Accessibility	BE2 (F), Blind	BE8	BE1
BG6	B6 (M), B13 (M), B26 (M), B36 (M)	Ability-Based Design	BE1 (M), Blind	BE7	BE2
BG7	B7 (M), B17 (M), B27 (M)	User-Sensitive Inclusive Design	BE5 (M), Blind	BE3	—
BG8	B8 (M), B18 (F), B28 (M)	Universal Design	BE3 (F), Blind	BE5	BE6
BG9	B9 (M), B19 (M), B29 (F)	Design for Social Accessibility	BE8 (F), Low-Vision	BE2	BE7
BG10	B10 (F), B20 (M), B30 (F)	Ability-Based Design	BE7 (F), Low-Vision	BE1	BE8

lectures on specific approaches. Feedback indicated that students desired more information and experience using their design approach. To accommodate that desire, we reduced the number of design approaches taught in Course B to: Ability-Based Design [41], Universal Design [24], User-Sensitive Inclusive Design [27], and Design for Social Accessibility [38, 39], and facilitated in-class workshops to engage students in in-depth learning about specific approaches. In these workshops, students focused on how their assigned design approach could be used in their design work.

- Finally, Course A student groups were split between working with blind/low-vision expert users and deaf/hard of hearing expert users, but that limited our ability to analyze across student groups and to provide multiple expert user perspectives. In contrast, all student groups in Course B worked with blind/low-vision expert users. Limiting target audiences allowed us to facilitate round-robin expert user sessions, and to analyze student projects across all groups.

Overall, making changes to Course B allowed us to learn more about the impact of multiple stakeholders and design approaches on student design thinking, and to attempt a better learning experience for the students.

3.4 Data and Analysis

Data sets from both courses comprised 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

Table 4. A Summary of Deductive and Inductive Codes from the First Course Analysis

Deductive codes from prior work [38, 39]
Ability and equal access: just like everyone else
Aesthetics and form factor (technology use and appearance)
Avoidance (choosing not to use technology)
Safety and help (concerns for safety, when help is needed or not, asking for help)
Attitude of the user when using technologies
Ignorance of bystanders
Contextual influence (factors of the environment)
Employment (work and job opportunities affected by technology use)
Technology type: mainstream or proprietary
Breakdowns: functional and social aspects of technology use negatively affect access
Social expectations, transitional encounters (drawing attention)
User confidence, showing technical savviness, educating/sharing
User self-consciousness when using technologies (unwanted attention)
Mis/perceptions: social, technical, contextual, neutral perceptions others have of technologies and users
Inductive codes from Course A [37]
Perceptions, expectations: learning and design
Attitude, reflection, learning: disability, accessibility, design thinking
Tensions, challenges: design for disability, cost, complexity
Techniques and tools students used to address challenges
Design decisions: accessibility, usability, prioritizing, assumptions
Working with users with disabilities, in groups: prior experiences
Codes from Course B analysis
Multiple Stakeholders: helping with strategies and design decisions, giving perspective, understanding diversity in disability, using design approach; also, challenging and complicated to address multiple perspectives
Design Approaches: complements perspectives from multiple stakeholders
- Ability-Based Design: intersecting abilities, adaptation
- Universal Design: for multiple stakeholders, focusing on tasks and situations
- User-Sensitive Inclusive Design: for multiple stakeholders, mainstream appeal
- Design for Social Accessibility: mainstream perspectives, aesthetic, social use

expert user evaluations of student designs. Expert users evaluated student work mid-term and at the end of the course.

We analyzed data from Course A both deductively and inductively following systematic qualitative data analysis methods [23, 32]. Table 4 summarizes our codes. We selected 14 deductive codes based on related work to accentuate known issues about assistive technology use [27, 30, 31]; for example, findings from prior work highlighted social perception, and user confidence and self-consciousness as emergent qualities of user interactions with accessible technologies. Each successive code book incorporates codes from the items listed above it in the table. For example, inductive codes from Course A were applied alongside deductive codes from prior work. Codes for Course B were applied alongside codes for Course A and deductive codes from prior work. Building on these known themes allowed us to connect student designer experiences with user perspectives on technologies for people with disabilities. In this way, applying established deductive codes connected user and designer perspectives to design outcomes thematically.

We identified an additional six inductive codes based on our data. Two coders openly and separately coded two groups' data to generate an inductive code list. We discussed and refined code definitions: 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. To test validity of the codes, a Cohen's Kappa was calculated on the coders' results, and yielded $\kappa = 0.79$, indicating strong agreement between the coders. With two researchers coding the data, the Cohen's Kappa tests the inter-rater agreement, to determine the possibility of agreement occurring by chance (and thereby negating meaning for a single code). Since the calculated value showed strong inter-rater agreement, we are more certain the two coders independently agreed on the meaning for individual codes than that agreement happened by chance. With the Kappa validation confirmed, 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.

Data from Course B were analyzed deductively based on findings from Course A, following the 20 high-level codes derived from the initial course (Table 4). Additionally, analysis also focused on how students incorporated design approaches and on what strategies they utilized to address multiple stakeholders with and without disabilities. The first author conducted the initial analysis pass on data from Course B based on the coding manual from Course A, and to identify codes and themes that emerged from differences in Course B around design approaches and multiple stakeholders. The initial pass was followed by additional discussion and analysis with co-authors.

In conducting our analysis, we referenced codes from prior work [38], analyzing how major themes emerged across the different projects. The list of codes in Table 4 illustrates: (1) how users with disabilities feel about using their technologies in social and public spaces (from prior work [38, 39]), (2) how bystanders without disabilities perceive assistive technology use and how technology, context, and the user inform perceptions (also from prior work [39]), and (3) how novice designers engage accessibility, user preferences and needs, particularly concerns raised in (1) and (2). Common threads stretching across these projects evolved around the influence of presentation and perception on use of accessible technologies in social spaces. In our analysis for this article, we continue the thread by asking how designing for people with disabilities and addressing social uses manifested in the student designer experience. Thus, the codes presented here represent a progression of analysis and understanding about technology design and user experience that eventually led to the themes presented in this article.

4 FINDINGS

All groups from both A and B course offerings successfully created high-fidelity prototypes that they could test with expert users at the end of the 10-week term. Expert users judged whether or not the final designs met their expectations. Experiences and reflections reported by students from both course offerings confirmed that inclusion of users with disabilities influences designers towards accessible solutions. Findings from Course A indicated that challenges and tensions surfaced when students designed solutions to satisfy both disabled and nondisabled users, and that the experience of working with expert users influenced students' attitudes positively about accessibility overall. Students from Course A reported their changing perspectives about: (1) designing for disability, particularly that it was not as hard as they initially thought; and (2) that they had a role and responsibility in their work to create accessible designs.

Findings from Course B corroborated those from Course A. In addition, building on Course A provided detailed insights about specific strategies inherent in the various design approaches (i.e., bringing diversity in ability or disability to the forefront of a design process as a matter of core steps to the process). Working with multiple expert users strongly guided student design thinking, such that students in Course B recognized that individual differences and preferences—even within similar disabilities—influence and are influenced by design decisions, a realization that broadened student awareness of disabled experiences.

We discuss in-depth findings for Course A in our ASSETS 2016 article [37], including how student perceptions of accessibility changed, how students addressed tensions and opportunities, and in what ways student attitudes shifted over the course. In the following section, we add to those themes the findings from Course B, specifically the influence of working with multiple stakeholders with and without disabilities, and of the different design approaches.

4.1 Multiple Stakeholders With and Without Disabilities

In Course A, we found that working with both disabled and nondisabled users was helpful for students in addressing functional and non-functional factors in design [37]. In this section, we expand on non-functional factors as social considerations in design, and we show how, in Course B, working with multiple stakeholders helped students address such factors.

4.1.1 Functional and Social Factors. Balancing different user requirements for users with and without disabilities was nontrivial for students as they had to manage differences across user needs. Students did so by reframing challenges as constraints and creating opportunities for design ideas. Specifically, the challenge of designing for both disabled and nondisabled users was different from designing for only one group or the other [37].

One challenge students faced was to bridge the functional and non-functional needs of disabled and nondisabled users. **Functional needs** detail what fundamental technical implementation is necessary for expert and nondisabled users to be able to operate the design. **Non-functional needs** are those needs that are not required for operating the components of the design, but that impact how a design is perceived or used in specific contexts. Because of the social nature of perception and the role of context in influencing non-functional factors, we hereafter refer to non-functional factors as **social factors**, drawing on similar concepts explored in Shinohara and Wobbrock [38, 39].

We saw the challenge of functional and social factors manifest in the initial strategies and attitudes students employed in the beginning of the course: 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 focusing on functional issues. To address disabled user needs, students began by asking, "what functionality will address impairments?" rather than other concerns, such as how might a design operate in the social ecosystem of technology use. A2 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. (A2, Journal 2)

The function-centric and disability-focused approaches espoused by A2 runs counter to the emphasis in UCD on holistic user *experiences*. It also ignores the importance of *others'* perceptions of the technology, beyond the blind user. Functional differences do exist between how disabled and nondisabled users use technology, but the language A2 used reflected an intentional view that blind users may not care about "aesthetics" as much as nondisabled users. The benefit of working directly with expert users was that students learned about the non-functional needs they otherwise might have overlooked [37]:

> Learning about how AE7'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 AE7'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. (A14, Journal 8)

The social needs enumerated by expert users contrasted with the function-only view students initially held. Furthermore, because of regular feedback from expert users, students did not try to "imagine what it would be like" to have a disability as a strategy, which tends to be an ableist exercise; rather, they learned directly from expert users when social issues were a priority [37]. Social factors also characterized other aspects of technology use, such as safety and social appeal. For example, a social concern unique to expert users was the aspect of disability itself. Managing an image-as-disabled was a disabled experience that students did not anticipate:

> 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. (A7, Journal 3)

A7's expert user prioritized functional capability ("accuracy") and unobtrusiveness. Although these two issues are not always opposing, for a person with a disability, they can be.

In summary, students uncovered functional and social needs as key user requirements in accessible design. In the next section, we show how students leveraged both disabled and nondisabled user experiences to address both social and functional factors.

4.1.2 Disabled and Nondisabled Perspectives Help Address Social Factors. Our findings indicate that requiring students to also design for nondisabled users provided students another tool with which to address social needs in accessible design. The following example demonstrates how students learned of social needs, and leveraged common social decorum to address the design problem. A24's group learned the severity of the social issue of drawing "unnecessary attention," because AE11, a deaf expert user who used hearing aids, 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, AE11 made it very clear that inconspicuousness is important to them in a product—if something isn't discreet or just about invisible, then they are much less likely to use it. (A24, Journal 3)

For AE11, functional success alone did not necessarily translate into access. Students took this feedback to heart when designing the real-time captioning solution. AE11's group reflected [37]:

> 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. (AE11's group design rationale, see Figure 4)

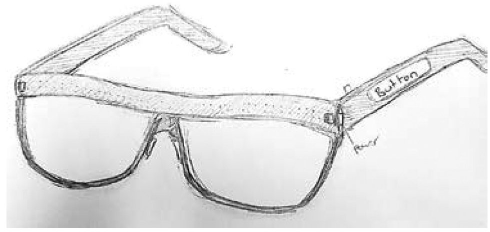

Fig. 4. A sketch of AE11's group's glasses design for a real-time captioning solution would allow a user with hearing impairments to read captions on the lens as the user looked at the person who is speaking. AE11's group described its solution as "designed to have a profile of modern 'hip' glasses."

With a clearer awareness of what they, as nondisabled users, had in common with expert users, students sometimes referred to a nondisabled understanding of social issues to find solutions. B25 indicated how his group balanced challenges:

> When designing for people without disabilities, I felt like I was designing something for myself or for a friend. I had more of an immediate idea of what direction to take. When designing for the blind, I felt like I needed direction from our expert user, who would come up with very good ideas that I most likely would have never thought of. (B25, Journal 10)

Indeed, students focused on what users have in common or started from their expert user's requirements and found ways it might also appeal to nondisabled users. A23's group circled around 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. (A23, Journal 4)

Students benefited from working with expert users who gave feedback highlighting social needs, and from designing for nondisabled users, because it challenged students to strategize ways to address tensions exposed by non-functional needs. Relating, as designers often do, to their own experiences as nondisabled technology users, addressing social factors made students aware of what they had (or did not have) in common with expert users:

> . . . 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. AE9 was a great help with this by pointing out how important eye contact and facial expressions are to him. (A16, Journal 4)

In A16's comment, the assessment that "so many people find that to be rude," is an example of how student designers draw on their own knowledge as a technology user and designer to weigh non-functional concerns of technology design from expert users. Thus, students leveraged both disabled and nondisabled perspectives to address social factors.

4.1.3 Multiple Stakeholders: Prompting Awareness across Diverse Issues. Recall that Course A groups were divided into working with two types of expert users: (1) blind and visually impaired, and (2) deaf and hard of hearing, whereas all groups in Course B worked with multiple blind and visually impaired expert users. Although we know that people with the same or similar disability have very different experiences of disability, Course B students did not make the distinction as it related to their design work until they switched expert users and were faced with different requirements.

Our observations of Course B students working with multiple stakeholders corroborated and built on findings from Course A. Students gained awareness of accessibility issues by interacting with expert users. Students also learned how to discern accessible design requirements from personal preference:

> It has been interesting to work with different expert users. I think that the more that we work with, the more obvious it is becoming which aspects of the app our user has liked boil down to personal preference rather than actual functionality or usability of the application. (B31, Journal 6)

Working with multiple expert users required students to address diverse perspectives within even a "single" disability, like low-vision. At the outset, these complex factors could be considered difficult, a complicated task for novice student designers. However, we found that students, often guided by their design approaches, were able to find ways to incorporate multiple points of view.

> We found out that one expert user found something completely not helpful to the indoor navigation process, but found out another expert user would find it extremely helpful. This helps us realize that some of our ideas may not actually be worthless and may only appeal to a portion of our users. But having each idea critiqued and evaluated really helped us identify if they were viable for actual usage. (B5, Journal 5)

Students recognized the challenges and benefits of incorporating several viewpoints:

> Having as many potential users as possible critiquing the experience definitely adds to our overall design, and lets us learn about the different types of accessibility needs we need to address. (B25, Journal 5)

Yet, students were open to new perspectives on design presented by multiple expert users:

> It has been both easy and difficult to incorporate the different perspectives of users who have varying levels of ability. I had not realized how much I depend on my own perspective when designing. (B27, Journal 10)

As B27 admitted, addressing multiple views put the designers' role into perspective as one of several possible ways to design a solution to the given prompt.

4.2 Perspectives in Design Thinking

Students reported changing the way they thought about accessibility, and most confessed they expected design for users with disabilities to be more difficult than for nondisabled users. But at the conclusion of Course A, 21 of 36 students admitted that designing for disability was not as hard as they thought it would be. Ten reported no change, and only two felt it was harder. In Course B, 18 of 36 students indicated they felt designing for disability was not as difficult as they thought it would be, 14 reported no change, and four indicated they thought it was more difficult.

In this section, we show some ways that student design thinking was shaped: (1) by a shift in attitudes generated while thinking through accessible design, and (2) by prompting the right questions from expert user feedback and design approach principles and techniques.

4.2.1 Attitudes about Disability and Accessibility: Awareness through Accessible Design. Learning about disabled experiences compelled students to reassess their understanding of accessible design [37]. For example, working with expert user AE2 emphasized the disparate state of mainstream and assistive 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. AE2'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. (A26, Journal 9)

Addressing both target user populations was daunting, particularly if student designers had little or no experience with design or disability. But these perceptions of accessibility changed as they continued to work with expert users. Initially, many students expressed discomfort and self-consciousness prior to meeting expert users, despite the guest lecture about appropriate etiquette. Some students found the guest speaker helpful, but for others it did not allay fears of being offensive, because students lacked experience of one-on-one interactions.

> I am very nervous… I don't know what to say, or how to act around a disabled person. Even though guidelines were handed out in class, I am worried I will forget the polite behavior I studied, and simply make a fool out of myself. (B21, Journal 0)

Students were self-conscious about their ignorance of disability:

> 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, 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. (A1, Journal 2)

B34 had a similar reaction, guided by social stigma and perceptions about disability.

> Another aspect that leads to my fear is the concept of not being able to behave normally. I am scared that I will be both awkward and uncomfortable. I, myself, have fears of being inflicted with disabilities and as a result the sight of seeing those with the disabilities may lead me to not act or speak normally. (B34, Journal 0)

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 only by their unconscious ableist perspectives [37]. The view that B34 had about disabilities, of "fears of being inflicted with disabilities" that made him feel "awkward and uncomfortable" emphasized how students focused on the disability instead of the person, unaware of the ableist tendency in this thinking, though students were not expected to know or think otherwise at this early point in the course. Such sentiments were common among students as the weeks went on, and here the data from both course offerings confirms findings from prior work [23, 40]: Interacting with expert users opened students' minds to accessibility in design thinking, despite their initial concerns. More time with expert users was beneficial. Students overcame communication barriers [37], and working with multiple expert users broadened conceptions about variations even within a "single" disability.

> It was also interesting to discuss our ideas with a new expert user, because it allowed us to gain another perspective. With User-Sensitive Inclusive Design, it is important to be inclusive of our entire audience. BE10 and BE9 have different backgrounds and have different needs. It is important to remember that their lifestyles will differ, even though they are both visually impaired. (B13, Journal 5)

As they continued to work with expert users, students became more informed about the disabled experience and could make educated design decisions to address issues described by expert users. Rather than trying to imagine not having sight, students learned from someone who had skill and experience navigating the world without sight. We contrast the sentiment in the following statement that defers to the expert user's navigation skill with comments from A1 and B34, above, which implied that being blind rendered one helpless.

> Our expert user is, though blind, perfectly capable of navigating himself if he is aware of what is around him. To that end we focused a lot of brainstorming time on building an app that doesn't tell him where to go, but instead tells him where he is and what is around him, then lets him do the navigating himself, because he can do that just fine and sometimes he really prefers to do that rather than take step by step directions. (B12, Journal 4)

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:

> 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, and so on, helps you focus with laser-precision on the most important and basic human needs. (A40, Journal 8)

As A40 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 acknowledge [37]: (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.

4.2.2 Design Approaches and Complex User Requirements. In this section, we discuss how Course B students leveraged their assigned design approaches to address conflicting issues among multiple stakeholders. Students were assigned to work with either Ability-Based Design [42], Universal Design [24], User-Sensitive Inclusive Design [28], or Design for Social Accessibility [39]. Our findings show that students exhibited a pattern of referring to design approaches to solve problems that arose from expert user needs, especially to address conflicts between multiple stakeholders. Design approaches launched students in distinct directions, and design approaches also had a hand in directing how students approached complex problems.

Each design approach provided a different perspective that students benefited from in their design processes. Student reflections about design approaches highlighted how student thinking emerged around nuanced concepts. For example, student groups working with Ability-Based Design notably had positive experiences with the approach and were likely to point to the intersection of abilities as their main strategies for addressing complex user scenarios. We discuss the different perspectives that emerged through each design approach in detail below.

Ability-Based Design. Students who worked with Ability-Based Design [42] intentionally focused on abilities rather than disabilities. As we noted, without knowing what it is like to be disabled, students were at a loss as to how to design for people with disabilities. The guidance by Ability-Based Design to focus on users' abilities was a defining strategy for students using this design approach.

In the beginning, students embraced the core principles of Ability-Based Design to focus first on what users *can* do, and not users' limitations or impairments. For example, B32 reflected on how his group intended to proceed with their project based on his group's understanding of Ability-Based Design, with attention to how people with disabilities currently use smartphones, not comparing that to how nondisabled users might complete smartphone tasks.

> Our interview questions will be based more about the current things they are doing with applications on their phones, and by closely examining these actions we will be able to build a stronger conceptual model of our final application, in the hopes of not even having to mention that [they] are hearing or vision impaired. (B32, Journal 2)

B22 reflected on how focusing on ability guided specific design decisions along the way.

> The design approach my group has taken is Ability-Based Design, and this approach has greatly helped us in our design process. We have been perceiving problem-solving differently, by thinking about what our users can do, and how this application can be the most efficient for them. (B22, Journal 6)

As projects continued, students' ability to follow through with their design approaches was tested. Tasked with designing for users with and without disabilities, and grappling with feedback from multiple expert users, students using Ability-Based Design relied on useful principles in their design approach to help them through challenges. As B10 explained:

> Taking perspectives from both nondisabled expert users and disabled expert users into consideration definitely increases the difficulties of the design. The requirements of these stakeholders might even conflict. We discussed this situation… and finalized the design based on the guidelines of the Ability-Based Design approach. (B10, Journal 10)

B20 articulated how his group referred to adaptation when they could no longer find solutions to meet intersecting expert user requirements:

> I was unclear on how to apply our approach, because not all users have the same abilities. So I did not know what abilities we should focus our design on. However, after working with the expert users I realized that they have similar abilities with one another. So we just focused on those similar abilities and based our design off

> of those abilities. We made sure that when we created our design that the user would not have to adapt to the system. We designed our project so that the system has to adapt to the user. (B20, Journal 6)

B20 continued on to elaborate how Ability-Based Design helped his group:

> The idea of focusing on an ability instead of disability makes it so that no person is discriminated against. I think the seven principles of Ability-Based Design are solid and are good guidelines for designers to follow. Also having the system adapt to the user takes a lot of the burden away from the user and makes the application a lot easier to use if implemented correctly. (B20, Journal 10)

The guiding principle of Ability-Based Design to focus on what users can do shaped how B20 thought about design in a fundamental way: by creating a system that adapted to user needs, rather than placing the onus on the user to find the right accommodation. The assumption of the burden of access is shouldered by the student designer, and Ability-Based Design's principles were flexible enough to accommodate divergent requirements.

Ability-Based Design encouraged students to take an honest view of how they wanted users to interact with their designs. Rather than glossing over disabilities or attempting catch-all solutions, students had to dive deep into understanding how to leverage specific abilities.

Universal Design. Students who worked with Universal Design [24] had the benefit of a design approach that necessitated thinking about broader user groups from the beginning. While students using Ability-Based Design attempted to create designs that could be customized for different abilities, students working with Universal Design interpreted their requirement as creating a comprehensive design to address individual issues.

> Getting conflicting feedback has been very beneficial, because it has reminded us to keep universal design in mind as we are talking to the expert users. We can ask them questions about what they think will be most beneficial for all users and then give ideas about changing settings so that the application will work for each individual's needs.... we are able to meet the needs of a broader audience, which is the main goal of universal design. The process is undoubtedly allowing us to improve our design. (B4, Journal 6)

We note that view expressed by B4 is in contrast to typical design attitudes, which, by the nature of defaulting to target users without disabilities, assumes that users with disabilities are themselves responsible to gain access or find accommodation. Students working with Universal Design addressed conflicting feedback in different ways from students working with Ability-Based Design. Using Universal Design, students sought a single unmodified design that would be useful to a wide audience. Students strove to find, within a single solution, the set of features that would be usable to the widest possible user group.

> One facet of Universal Design is an attempt to not have to design extra features for any specific group. This leads our group to a problem. Any program that relies solely on sound would be difficult to use by a person with sight. It also would be unusable by a deaf person. This means that our product must have multiple avenues of use, which is a bit contradictory to Universal Design. (B14, Journal 2)

Whereas Ability-Based Design, through its seven principles, could give students structured guidance about how to address specific nuances, such as what to do when conflicts arose between users, Universal Design was, in practice, much less clear, leading students like B14 to sometimes misinterpret its principles. B14 was confused as to how contradictory feedback from expert users could be consolidated into one design, not understanding customization to be within the auspices of universal design.

> The main focus of the design approach is to design something that may be used by the widest possible audience, without adding alternate implementations or features except when absolutely necessary. (B4, Journal 6)

Thus, while at the outset, Universal Design's appeal to a wide audience was welcoming for students, in practice it was difficult to implement. The principles of Universal Design set about a framework, but did not provide bootstraps to help students if they discovered no plausible set of features was possible for non-intersecting use cases.

User-Sensitive Inclusive Design. User-Sensitive Inclusive Design [28] led students to begin their design thinking through a social perspective. User-Sensitive Inclusive Design advocates developing rapport with users toward a working relationship grounded in mutual respect; designers interact with users both as traditional experts in functional needs, but also as people in a social sense.

> To take this population into account, the User-Sensitive Inclusive Design approach's main goal is to foster a relationship between the designer and the user with disability. (B33, Journal 2)

Embracing empathy is a core value emphasized in User-Sensitive Inclusive Design: the more designers can understand the user's experience, the more likely they are to refer to such a perspective throughout the design process and beyond.

For students who were unaccustomed to working in design, much less with people with disabilities, the guidance from User-Sensitive Inclusive Design to approach users in "everyday" ways reflected strongly in how they pursued their design work. Specifically, while students working with Ability-Based Design closely examined expert users' abilities to inform features useful across different users, students working with User-Sensitive Inclusive Design consciously focused on users as social actors who use technologies. Students interpreted this perspective as fostering relationships before individual technical and functional needs:

> I feel we are able to apply our design approach during these feedback sessions by talking with BE10 like we would with any other user about how our design should be changed. We don't view him as a "special" type of user that we need added features for. Rather, we include him as a user who is just as important as any sighted user and are fully able to use our design approach of User-Sensitive Inclusive Design by taking his perspectives as valuable opinions that are completely considered in our design moving forward. (B23, Journal 6)

Although it may seem that treating expert users as "just as important as any sighted user" should go without saying, recall that students were nervous about interacting with people with disabilities. The separation between students and disability in students' daily lives was a barrier to interacting with people with disabilities; students, like most nondisabled people, were socialized to see the disability, not the person. B23 outlined how her group specifically asked questions about their expert user's experience, while not asking about accessibility from the start. The fundamental view of users as social actors clearly influenced student attitudes toward their expert users, shifting initial focus from "what are your dis/abilities?" to "who are you as a person and what is your user experience?" B23's groups thus chose to allow their user to dictate the course of the conversation about his accessible technology use:

> We also demonstrated concepts of User-Sensitive Inclusive Design by not asking BE10 any specific questions about his blindness. Although being visually impaired clearly affected his answers to almost all of our questions, we could have had the same interview questions for someone fully sighted. This demonstrates ideas in User-Sensitive Inclusive Design by choosing to include users with disabilities rather than treat them as a special case with questions that clearly set them apart as a different type of user rather than keeping in mind the idea that BE10 is just another potential user that we should cater our design to. (B23, Journal 3)

Design for Social Accessibility. Like User-Sensitive Inclusive Design, Design for Social Accessibility [39] emphasizes a social perspective on design, rather than based on any specific orientation to ability or disability. And like Universal Design, Design for Social Accessibility offers few specific strategies to help students incorporate social consideration in their design practice. Instead, Design for Social Accessibility provides a high level view on accessible design featuring social consideration as its core principle, while leaving students to work out details using traditional UCD techniques. Students initially emphasized superficial aspects of social appeal before uncovering how functionality and social behavior influenced design and use.

> Our design approach might detract the functionality aspect from our design, because we might focus too much on the aesthetics of it, trying to make it suitable for the non-visually impaired as much as the visually impaired that we might not make it as useful and functional for the visually impaired. We might be inclined to choose a design that looks more visually appealing rather than one that is more functional for a visually impaired user. (B1, Journal 2)

A corollary to the focus on aesthetic appeal was that accessible design does not have to be proprietary. Students aligned social consideration and appeal by unifying preferences across disabled and nondisabled target users: the best way to ensure a design does not inappropriately call attention to a user is to create a design that is suitable for use by mainstream standards.

> This design approach... will offer many implications of what my design has to be. Personally, I don't think creating proprietary hardware is feasible for this kind of design approach. Having a gadget that is only for way-finding, separate from every other device people use would almost certainly stand out in public. (B21, Journal 2)

In turn, students relied on their own understanding of mainstream design.

> We decided that [using Design for Social Accessibility] would mean that we ought to limit the way in which our device looks and the way in which it communicates with the user to things that are already common in mainstream technology. This would ensure that the user would not be sticking out for using some foreign, alien-like device. (B31, Journal 10)

Although the strategy of aligning accessible design with mainstream design led students to construct a more egalitarian view of design in general, students encountered challenges when users prioritized function over aesthetics. B25 was caught off guard when his expert user had no problem with how a particular technology might look:

> BE2 was actually very indifferent to the subject. When asked if she would sacrifice some functionality for gains in terms of how beautiful the device looked. She said she would much rather it function well and consistently well, and she expressed

> that she cares little how she looks to others. She stated she enjoyed talking to people, and even if her technology was viewed as odd, then it would serve as a conversation starter in any case. (B25, Journal 3)

In B25's quote above, when asked about the "beauty" of her device versus its functionality, BE2 unequivocally prioritized the latter. Students misinterpreted "social" in Design for Social Accessibility to only mean aesthetic dimensions, not social implications of use. Yet, we note BE2's response gets to the social life of assistive technology use when she refers to her devices as a "conversation starter."

Although groups using Design for Social Accessibility initially assumed social issues of use were mainly cosmetic, the role of functional implications in social contexts became evident. As the course continued and students worked on specific design decisions, they began to realize implications of use in social situations. Students reflected on instances of technology use that aligned with expectations for social behavior and interactions, not just aesthetic appeal.

> We realized that one of the main functionalities that really made [BE6] feel uncomfortable in public was that her phone made too many loud sounds at once and that seemed to catch the attention of people around her. Our understanding of our design approach evolved from just focusing on the aesthetics of our app or the common functionality of it, to also focusing on expectations in a given social interaction. (B1, Journal 6)

Students' awareness of social implications of technology use heightened their critiques of designs more focused on function.

> Having overheard a bit from other groups testing their projects during the last lab, our solution, which includes a mute mode, silent option and the ability to customize sounds to make the application seem more normal, drastically contrasts with the solutions that are constantly spewing directions and navigational information. (B31, Journal 6)

In the end, student groups reconciled social situations of use as not just aesthetically relevant, but also connected to functional expectations of use and interactions in social contexts.

> We focused on developing self-efficacy and confidence through our minimalist, easy-to-navigate layout as well as through our tutorial/help and tips feature that takes a user step by step through using our application with an option to opt out at any time. (B29, Journal 10)

Aspects of design approaches that had an impact on how students perceived design, along with working with multiple expert users, guided student impressions about disability and accessibility.

Cumulatively, our findings from both course offerings inform our understanding about how we might improve design practice by working with multiple stakeholders with and without disabilities whenever possible and contextualizes what it means to implement existing strategies for designing with people with disabilities. First, we observed that student attitudes and perspectives changed as they worked with their expert users, learning how to address functional and social factors impacted by disability in design, and learning how to interact appropriately with people with disabilities. The initial attitudes that students had—that viewed users with disabilities as so different they felt nervous and afraid to work with them—characterized people with disabilities as "other" for the student designers [14, 22]. Such attitudes reinforce the notion that design for disability must be a "special" case, handled by someone else. Despite these initial perspectives, we observed several factors that positively influenced students' attitudes toward accessible design. Second, we have nuanced how different design approaches meant to foster accessible design with people with disabilities played out in practice in learning about design. Whereas Universal Design and Design for Social Accessibility provided frameworks that guided students' interactions with expert users, User-Sensitive Inclusive Design and Ability-Based Design provided more concrete strategies for user interactions and for transferring user feedback into designs, respectively. And finally, expert user knowledge contributed to gaps that occurred across the different approaches: groups using User-Sensitive Inclusive Design and Design for Social Accessibility learned about functional accessibility needs even as they prioritized building social rapport, meanwhile groups using Universal Design and Ability-Based Design learned about social factors from expert users.

5 DISCUSSION

We investigated how designing for disabled and nondisabled users in the UCD process influenced student design thinking. We found evidence that working with people with disabilities helped students develop a better understanding of accessible design and shifted their (sometimes ableist) attitudes toward accessibility, corroborating work by Ludi [23] and Waller et al. [40]. In addition, our findings do not just confirm *that* perspectives changed, but extend our understanding of *how* perspectives changed: by addressing social issues through creating designs for multiple disabled and nondisabled stakeholders, and through an increased awareness of the impact of accessibility—and the feasibility of accessible design—and through gaining skill by working with specific design approaches.

Our findings revealed that novice designers may initially approach accessible design with preconceptions about including people with disabilities, but that these perspectives can change with the right prompting. Building on these findings, we developed techniques and tools to foster inclusive design thinking. We constructed a framework to promote thinking along both social and functional dimensions. Also, to facilitate prompts grounded in multiple user perspectives (e.g., the many perspectives student designers got from multiple stakeholders) and approaches to design (e.g., the framing from design approaches that benefited students), we created a set of method cards to prompt awareness of different social contexts of use.

5.1 Confluence of Constraints: Multiple Expert Users and Design Approaches

Whereas prior work has shown that working with people with disabilities compels designers and engineers to pursue accessible solutions [1, 23, 25, 40], our study sheds light on techniques that helped students create accessible designs *and* influenced their design thinking to incorporate accessibility.

5.1.1 Social Factors in Accessible Design. A key aspect of accessible design revealed by working with disabled users was that social issues as well as functional factors were important for users. This aspect of the students' design experience was notable, because students initially dismissed social factors as not important in lieu of perceived difficult functional design challenges. Students made assumptions that expert users might only be concerned with functional success of the design, and disregarded non-functional dimensions of design by prioritizing an "intuitive layout rather than intuitive aesthetics." Instead, students found that there were social factors associated with technology use that were just as important to expert users as functional factors. In addition, social factors were not limited to only "aesthetics" but the non-functional ways the design operated in various contexts within a user's purview.

These observations about students' consideration for functional and social factors corroborate and build on prior work [38, 39] foregrounding social issues in technology design for people with disabilities. Where prior work showed user's perspectives on social issues in technology design, however, this study highlights social factors from the designer's perspective: how students first dismissed social factors as important to users, and how they came to realize the role of social issues in nondisabled and disabled user needs, highlighting similarities in preferences among the seemingly different user groups. We discuss these below.

5.1.2 The Nondisabled Perspective Is Key to Holistic Accessible Design. Students leveraged viewpoints from nondisabled and disabled users to address the social factors that arose in their design process. Specifically, students adopted strategies to work through complex requirements involving social issues for expert users, because—and this is particularly true as they learned how to work with expert users—students did not want to make assumptions about users' needs. Where students initially felt self-conscious about working with people with disabilities, over time, this nervousness dissipated as students learned how to ask questions and interact appropriately with expert users. Students applied this new knowledge to tackling the challenges of addressing both functional and social factors in their design: while students drew on nondisabled user experiences to address some social needs, they checked these design decisions with their expert users. Students took advantage of having to design for disabled and nondisabled users by leveraging both viewpoints to address social factors in their designs.

Indeed, initial student perspectives on designing for disability indicated that without the nondisabled requirement, students may have tried to design for expert users as disabled "others," focusing exclusively on creating design that would be useful for a person with a disability, but not necessarily for themselves [22]. There is nothing inherently improper about designing for disabled users (and not nondisabled users), in fact, some design projects may require it. However, we recognize that incorporating the two viewpoints helped students root the problem space within a mainstream design construct—where constraints come from several factors, social factors being the focus in this project—and not a disability-only construct, where attending to disability-related constraints can supersede other factors. In addition, doing so helped students to address some of the social factors that arose (with guidance from their expert users).

5.1.3 Multiple Stakeholders and Design Approaches Increase Awareness. As mentioned in Section 5.1.2 above, students harnessed nondisabled viewpoints, particularly to help them address social factors (for both disabled and nondisabled users) that arose in their projects. We emphasize that students' strategy in doing so was not to replace disabled perspectives, rather expert users' feedback and insight prompted students to consider complex scenarios—some of which students realized also related to nondisabled perspectives. In Course B, expert users differed slightly on specific user requirements, further prompting students to work out intersections of unique user scenarios. When presented with multiple viewpoints, students then drew from a host of experiences—from both expert users and nondisabled stakeholders—in considering possible solutions.

Similarly, in Course B, we observed that key principles in design approaches prompted students to become aware of different dimensions of design. For example, Ability-Based Design transformed framing for students toward abilities, not disabilities, bringing a different perspective than they originally considered to their projects. Likewise, User-Sensitive Inclusive Design and Design for Social Accessibility guided students to consider approaching the design problem from a social stance initially, rather than a purely functional one. In any case, we observed the value of design approaches to compel students to consider complex scenarios and diverse use cases.

5.2 Strategies to Incorporate Accessibility: Tenets for Design for Social Accessibility

As enumerated in the section above, we observed students incorporating specific strategies that could improve accessible design practice. Addressing requirements for disabled and nondisabled

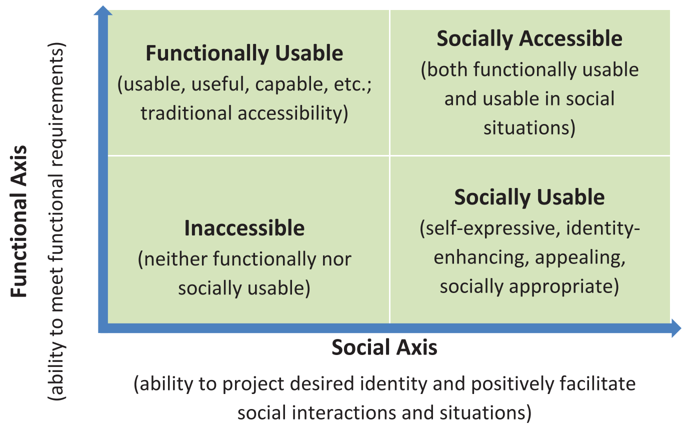

Fig. 5. The Design for Social Accessibility Framework illustrates the relationship between functionally (y-axis) and socially (x-axis) usable aspects in socially accessible design. Designs considered functionally and socially usable are socially accessible (top-right).

users revealed functional and social factors as key in technology design. Likewise, incorporating multiple viewpoints from disabled and nondisabled stakeholders helped students address these factors. We highlight that students appropriately incorporated these views as they overcame self-consciousness and learned how to interact with expert users. Finally, students were able to learn, because they were gently prompted both by multiple expert users and by their assigned design approaches to broaden their awareness about different facets of design and disability (i.e., approaching design from a social perspective and developing rapport as espoused by User-Sensitive Inclusive Design). We harness these findings into guidelines to refine Design for Social Accessibility, and we propose a framework and techniques informed by the results of this study.

Our goal in revisiting and refining Design for Social Accessibility is to motivate accessible design in the larger ecosystem of personal technologies. The emphasis on social situations of use, while a defining characteristic of Design for Social Accessibility, is just one piece of the larger context of the impact of accessible design. Thus, we present a set of grounding tenets for Design for Social Accessibility aimed at changing how we think about design in general, to benefit design for accessibility.

- *First, design ought to fundamentally incorporate users with and without disabilities throughout the design process.* Finding a solution that bridged these two seemingly disparate user groups was a driving force that compelled students to seriously evaluate how their ideas addressed functional and social requirements. Because students also worked with people with disabilities, centering designs within a mainstream context in no way limited the accessibility of the final design. These aims are similar to Design for User Empowerment [19], which emphasizes increasing the number of designers and developers with disabilities; the design purview overall should encompass users with disabilities as part of key target users.
- Second, design ought to address functional and social factors simultaneously because of the power of each dimension to affect accessibility outcomes. Although User-Sensitive Inclusive Design and Design for Social Accessibility helped guide students through high-level concepts pertaining to social situations of use, students assumed that social consideration were limited to aesthetic appeal. Social behavior, or interactions with others, did not initially register as part of social consideration. Thus, we constructed a framework (Figure 5)

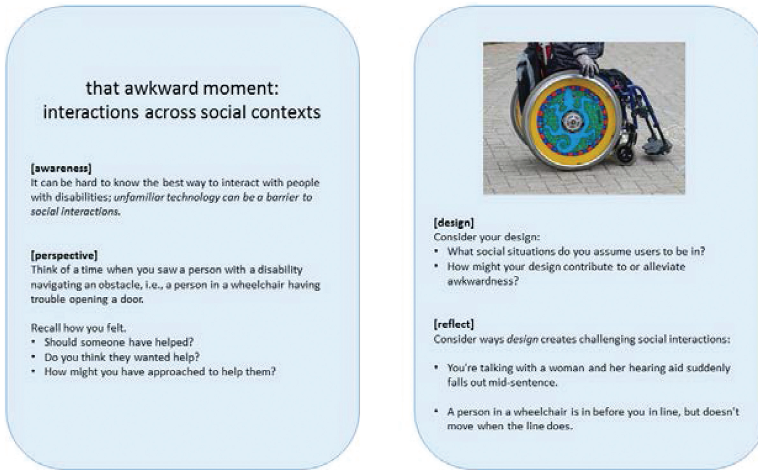

Fig. 6. An example Design for Social Accessibility Method Card: "audience: perceptions of 'special' technologies" aims to broaden awareness for issues in assistive technology use in social situations.

to help direct consideration along social and functional dimensions, emphasizing the roles each plays in accessible design.

- *Third, designers ought to work with tools such as method cards to foreground social factors in accessible design.* In addition to the framework (Figure 5), we created a set of five method cards to prompt designers for contexts of use that may be relevant for disabled users (see Figure 6). The method cards are an amalgamation of themes that emerged from findings and participant feedback from this and prior work. The cards serve several purposes: (1) to raise awareness of social and functional accessibility issues in design, (2) to address specific social and professional uses, i.e., prompting designers to consider how workplace dynamics affect technology use, (3) to elicit reflection on social contexts of use, for example, drawing on social expectations and decorum in professional or social gatherings. The cards touch on topics of technologies in the workplace, addressing socially awkward moments of technology use, issues of non-use or abandonment, scenarios where technologies attract unwanted attention, and design that fits mainstream technology expectations. The goal of the method cards are to aid nondisabled designers in systematically thinking through circumstances they would not be familiar with, to help them ask the right questions of the right people, and to help them make in-depth considerations of more than just functional issues. Thus, we designed the cards to be used throughout the User-Centered Design process (i.e., in ideation, reflection, or evaluation), to prompt designers to consider different social contexts. Future work will iterate on existing cards to expand as needed to help designers and developers, and further investigation will be conducted to examine how professional designers and students incorporate method cards in their design process.

Framing the three tenets for Design for Social Accessibility creates concrete actions a designer can take toward accessible design practice. We envision that these tenets and tools can be used in a practical context: to include people with disabilities, to consider functional and social aspects of technology use, and to employ the tools we created to help facilitate the first two. Although it is well known that working with people with disabilities ought to improve accessible design, encouraging designers to incorporate social factors is meant to combat the "othering" of disabled users in the design process. Our observations showed students incorporating mainstream design aspects when brainstorming ways to address social factors in design. With these tenets and tools, Design for Social Accessibility should direct designers toward more inclusive design in general.

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 for the first time might have impacted student perspectives. Although we recruited disabled expert users, we did not recruit nondisabled users, and students' success reaching nondisabled users on their own was varied. Future work will involve explicit recruitment from both populations. In addition, while we taught and qualitatively assessed student experiences across design approaches, our study was not designed to facilitate controlled comparisons. Despite this, student experiences and design artifacts speak to the veracity of our findings. Future work will focus on examining design approach strategies effective for professional designers.

6 CONCLUSION

Including people with disabilities involves more than just face time [23, 37, 40], it involves enmeshing multiple stakeholders of both disabled *and* nondisabled viewpoints throughout the design process. Student designers regarded accessibility as part of their larger aims when they: (1) gave agency to the disabled user as a *person* (not a disability) with an equal stake in design outcomes like any nondisabled user, and when (2) they saw *themselves* as having agency and skill as designers to create technology that fulfilled needs for both groups [37].

Despite emphasis on "the user" in user-centered design (UCD), current mainstream personal technology design is predominately inaccessible, disregarding disabled users as part of that userbase. To understand how design thinking changed when disability was emphasized, we investigated how designing for multiple disabled and nondisabled users, while guided by specific design approaches in the UCD process, influenced student perspectives. We found that student attitudes and perspectives on accessibility corroborated prior work indicating that separating disability and mainstream design approaches reinforces the notion that accessibility is "someone else's job" [4, 23, 37, 40]. We found that interacting with people with disabilities and incorporating accessibility-focused design approaches prompted students to consider broader issues in technology use. We defined a set of Design for Social Accessibility tenets based on findings that emerged from this study. These tenets emphasize working with multiple users with and without disabilities, framing designs along functional and social dimensions of accessibility to fit accessible design in the mainstream milieu, and using tools specifically tailored to bring awareness to social aspects of accessible technology use.

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