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Beyond Swipe and Tap: Cultivating Mobile Accessibility Awareness and Knowledge in Computing Disciplines

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Abstract

People with disabilities face challenges when interacting with inaccessible mobile devices and applications. Educating next-generation software designers about mobile accessibility is important to ensure software accessibility. In this paper, we designed games to teach mobile accessibility, particularly concerning blindness, low vision, and physical impairment, based on formative interviews with blind people and people with dexterity impairments. We then tested the games with 45 undergraduate students in two US institutions to explore possible approaches to teaching mobile accessibility. Our results confirmed the lack of mobile accessibility education in the current computing curriculum, leading to students' limited awareness regarding mobile accessibility. Positive changes in the students in terms of accessibility awareness, attitudes, and knowledge were observed after playing the games. The students appraised our game-based approach as insightful, experiential, and engaging, potentially bridging the gap in teaching mobile accessibility. Our research sheds light on extending accessibility education in computing disciplines to mobile contexts.

1 Introduction

Teaching university students about accessibility is important to raise their awareness and knowledge regarding the accessible design of software. Prior literature emphasizes learning objectives [1], learning outcomes [2], teaching methods [3], and other aspects of accessibility education.

Empathy towards the technology barriers experienced by people with disabilities has been identified as a leading goal of accessibility education [4], [5], and experiential learning has been effective in inspiring this outlook while conveying accessibility concepts [6], [7]. One notable gap is that much of previous accessibility education, including many experiential approaches, has primarily focused on computers [6], [7]. We used Kletenik and Adler's games [7]–[9] to teach web accessibility to university students on laptops/computers, and some students expressed that these games should also be taught in mobile scenarios, given the wide use of mobile devices. For example, one student said, *"I think this education should be available on mobile devices because most people use mobile devices for everything, including people with disabilities. So I think only being able to use a laptop or desktop is not entirely accurate."*

As of 2024, mobile phones generated over 60% of website traffic [10]. The mobile environment presents unique accessibility challenges due to small screens and other factors. Researchers consistently report mobile accessibility issues [11]–[14] in fundamental aspects of human life, such as government service websites and higher education. The prevalence of mobile device usage and accessibility issues stresses the importance of teaching mobile accessibility to equip next-generation software designers with the necessary awareness and knowledge of mobile-accessible design.

To our knowledge, only a few studies have reported mobile accessibility education in computing education (e.g., [15], [16]), and no one has evaluated the use of games to provide an engaging mobile accessibility education. To narrow the research gap, we expanded upon Kletenik and Adler's games [7]–[9] to make their modality more flexible. These games were chosen as they are geared toward novice computing students and can be used on any mobile device without installation. We conducted formative interviews with people with disabilities and designed mobile-compatible games simulating blindness, low vision, and physical impairments. We then taught mobile accessibility with these games to 45 undergraduate students in two US-based institutions. We aimed to answer the following research question: **Can mobile-compatible education games affect college students' awareness, knowledge, and empathy regarding mobile accessibility?**

2 Related Work

2.1 Mobile Accessibility Challenges

Mobile applications are often found inaccessible, with unique accessibility challenges for people with disabilities [17] and older adults [18], [19]. Researchers have evaluated the accessibility of mobile apps in different domains and developed automated accessibility inspection tools [20]. Su revealed accessibility issues of mobile apps in the higher education sector in Portugal, particularly challenges for people with visual impairments regarding text/image contrast, resize text, touch target, and accessibility label [11]. Using a WCAG checker and a mobile readiness checker, Agrawal et al. found government service websites in India were of low usability, incompliant with WCAG 2.0, and not accessible on mobile devices [12]. An examination of 479 Android apps with IBM Mobile Accessibility Checker uncovered an astonishingly high rate of 94.8% in terms of accessibility violations [14]; most outstanding accessibility issues included "lack of element focus, missing element description, low text color contrast, lack of sufficient spacing between elements, and less than minimum sizes of text fonts and elements." Ballantyne et al. identified more violations of accessibility guidelines at the design and content levels than at the system level [21].

The inaccessible mobile app infrastructure rose from many factors. Developers tended to ignore accessibility when developing mobile apps due to "the lack of developers' awareness of accessibility concerns and the lack of tools to support them during the development" [22]. An analysis of StackOverflow revealed that developers seldom used accessibility APIs in practice [23]. Developers' enthusiasm for accessible development was further hindered by the low priority of accessibility in organizations that employed them [17]. Even if accessibility features were implemented, users were found unaware of the features, necessitating explicit feature recommendations on mobile devices [24].

Given the prevalence of accessibility issues in mobile apps [14] and developers' lack of knowledge and awareness of accessibility, educating next-generation software designers and developers about mobile accessibility is important.

2.2 Accessibility Education in Higher Education

Accessibility education is an integral part of both Computer Science (CS) and non-CS education in higher education. According to Kang et al., the following learning objectives were important for accessibility education [25]: (1) understanding fundamental principles of inclusive design, (2) interacting with diverse people, (3) showing increased empathy towards people with disabilities, (4) viewing accessibility from cultural, social, and legislative perspectives, and (5) showing motivation to continuously learning about accessibility.

Accessibility has been taught in various college contexts, such as human-computer interaction (HCI) [26]–[30], software engineering [31], [32], web design [33], and non-CS [34] courses. Both traditional pedagogical methods, such as lectures [3] and projects [35], and novel ones, such as experiential labs [6] and games [7] have been utilized to teach accessibility.

Despite the wide implementation of accessibility education in higher education, limited efforts emphasized mobile accessibility. To our knowledge, Bhatia et al.'s mobile app development course was among the few reported efforts to teach mobile accessibility awareness, technical knowledge, and empathy [15]. They used a combination of guest lectures, lectures, programming assignments, and experiential activities to achieve these learning goals. El-Glaly et al. developed mobile apps for accessibility education [16]. However, they can be used only for experienced CS students and developers since they rely on technical knowledge of mobile app programming and particularly as they require the installation of Android Studio. The researchers also did not evaluate the use of their games on students. We have not yet seen an analysis of the use of accessibility games tailored for the mobile context and for beginner CS students. We bridge this research gap by developing mobile accessibility education games, based on [7], which have proven an engaging means to teach novice computing college students about accessibility on computers and testing them with college students in two US universities.

3 Designing Education Games on Mobile Accessibility

We designed education games on mobile accessibility based on Kletenik and Adler's games which are designed to be used on computers/laptops [7]–[9], which have four rounds. In the first round, people are asked to pop as many red, green, or yellow balls as possible within 30 seconds, with instructions on which color to pop each time; in the second round, people have to pop balls under disability conditions (e.g., the mouse is shaking in the Physical Impairment Game, players cannot see the balls because of the black screen overlaid on top of the moving balls and instructions in the Blindness Game, and balls are blurry in the Low Vision Game); in the third round, accessibility accommodations are provided in the regular game-playing mode; in the fourth/final round, accessibility options are provided in the disability mode. A dedicated page listing accessibility guidelines for each disability is provided at the end.

The accessibility accommodations in the Blindness and Physical Impairment games fail to work in mobile settings. In the browser version, the accessibility feature for the Blindness Game provides blind users with the option to use keyboards to select (Right Arrow Key) and pop (Enter Key) balls with auditory feedback simulating a screen reader, in addition to the use of a mouse to click on balls. The accessibility feature for the Physical Impairment game similarly provides the option to use keyboards since users with a shaking hand may have difficulty selecting balls with a mouse. However, there is no physical keyboard when using mobile devices such as smartphones. Therefore, people who are blind and people with physical impairment, in particular, motor/manual dexterity impairments, will need alternative interaction methods to select and pop balls. In addition, the Low Vision Game was not responsive on mobile devices, which required technical fixes.

To inform our design of mobile accessibility education games pertaining to physical impairments, blindness, and low vision, we conducted formative interviews with people with physical impairments and blind people.

3.1 Formative Interviews

We conducted formative interviews with four blind people and two people with motor/manual dexterity impairments to gauge their experiences of and solutions to mobile accessibility challenges and inform the design of alternative interaction methods. This ensured our education games accurately depicted the software experiences of people with disabilities. Each interview lasted roughly 45 minutes, for which the participants, recruited from Twitter and personal contacts, received $10 as compensation. Following consent, the first set of interview questions concerned accessibility in general, such as their disability status and challenges with technology use. Then, we asked questions about accessibility for mobile devices, such as challenges with mobile devices, challenges with specific apps, assistive technology used, and seeking help from others. The interviews were recorded and later transcribed for analysis. The interview study was IRB-approved. The lead author took a thematic analysis [36] approach to analyze the interview transcripts and notes taken during the interviews.

Through the formative interviews, we elicited several design insights. For blind people, precise interactions such as typing through an on-screen keyboard are challenging, leading to typos and frustration. Gesture-based interactions, i.e., using fingers to select and navigate through a touch screen, were perceived as more convenient and less error-prone. People with physical (dexterity) impairments found larger fonts and elements helpful, which made it easier for them to *"toggle between things, select a button, and avoid miss-clicking."*

3.2 Our Designs

Based on the insights from the formative interviews and discussions within the research team, our mobile-compatible accessibility accommodations were as follows. For the Physical Impairment Game, balls were made larger to make the clicking easier. Further, to simulate a dexterity impairment in rounds 2 and 4, rather than using a shaking mouse, which is not used on a mobile device, we implemented shaking balls to simulate the difficulty that someone with a physical impairment may have when trying to click in the area. For the Blindness Game, in addition to verbally announcing color instructions, people had the option to swipe and tap on the screen: they

(a) Round 1. (b) Round 2.

Figure 1: Round 1 and round 2 of the Blindness Game.

could swipe up or down to select a ball and use a two-finger tap to pop the ball. In addition, the Blindness Game had a different look, with a vertical instead of a random layout for the balls. This represented how a screen reader would "linearly" work, navigating tabs and other web elements in a specified order instead of randomly exploring a web page. Note that as this was implemented as a responsive web application, users on computers still have the keyboard option, but those on mobile devices have swipe/two-finger tap options instead. For the Low Vision Game, we made the zooming bar mobile-responsive, which is particularly helpful in round 4 as it makes the blurred balls and text clearer. See rounds 1 and 2 in the Blindness Game in Figure 1.

4 Education Activities

4.1 Procedure

The IRB-approved education activities were conducted fully online via Zoom at two US institutions. In June 2024, we used an 80-minute session of an undergraduate-level HCI course at a Midwestern university with six synchronous students and five asynchronous students who were in different time zones or absent. An additional student from the university who was not a member of the course, but was interested in accessibility research, was invited to join the synchronous session, for a total of 12 participants. For the synchronous activities, one researcher led the activities, and three other researchers took notes of students' reactions and responses and monitored Zoom chat. Accommodations were made for each study component for asynchronous students, collecting survey responses into a Google Sheet and eliciting open responses through email.

In December 2024, we used a 75-minute session of an undergraduate-level game design and development course at another US university with 33 synchronous students.

Below, we elaborate on the three study components: (1) game playing, (2) pre-game and post-game surveys, and (3) post-game discussions.

4.1.1 Game Playing

The students were asked to use their mobile devices to access the three games: Blindness Game, Physical Impairment Game, and Low Vision Game. We provided the link and the QR code to the games.

4.1.2 Surveys

Following a consent process, the pre-game survey asked for demographic information, including the year in college, major, gender, race, disability status, and whether the students know anyone personally who has a disability. Then we asked two sets of open-ended questions: (1) challenges people with disabilities had when using applications on computers and mobile applications, respectively; (2) whether the students previously learned about software accessibility issues in general and accessibility issues in mobile applications, respectively. In the end, we used an existing instrument in the computer accessibility domain, i.e., a set of 6 Likert-scale awareness questions (a-f) adapted from [7], [9], with answers that ranged from Strongly Disagree (1) to Strongly Agree (5), and with an additional open-ended question (g):

a. Many current mobile applications are difficult for people with disabilities to use.

b. People with disabilities are interested in new technology.

c. A person with disabilities should not have to rely on someone around who can help.

d. Software developers should provide technology suitable for use by people with disabilities.

e. People with disabilities are likely to face challenges when interacting with many mobile applications.

f. If I design mobile applications, I will try to keep in mind people with disabilities.

g. For example: If I design mobile applications, I will try ...

The post-game survey administered immediately after game playing asked for students' comments on each of the three games separately. Then, students were given the Likert-scale questions again. Finally, we asked for additional comments on the games and our teaching activities.

4.1.3 Post-game Discussions

After the students played the three games and finished both surveys, we initiated a discussion on mobile accessibility and the games. The discussion questions focused on prior accessibility education, perceived accessibility challenges on mobile devices, accessible design solutions and challenges, comments on the games, and how accessibility education can be best implemented. Students who participated asynchronously were asked the questions through email. Due to time constraints, we did not get to some of the questions in the second class, which were later distributed to the students in a written format.

4.2 Student Participants

The first session was a human-computer interaction course for Information Science students and the second session was in a game design and development course in a Computer Science department. A total of 45 undergraduate students completed the activities, including 5 sophomores, 5 juniors, and 35 seniors; 7 Information Science majors, 3 Information Science + Data Science majors, 32 Computer Science majors, 2 Multimedia majors, and 1 undecided major; 37 male students, 7 female students, and 1 indicating "prefer not to say"; 26 Asian students, 4 Hispanic or Latino students, and 7 White students. In terms of lived experience with disabilities, three students self-reported being neurodivergent, and other students did not have a disability. 25 students personally knew close friends, family members, acquaintances, or classmates who had a disability.

4.3 Data Analysis

4.3.1 Qualitative Analysis

Our analysis is predominantly qualitative, given the relatively small sample size and the exploratory nature of our study. We qualitatively analyzed responses to discussion questions, either verbal (documented by Zoom's live captioning function) or written (through Zoom chat for synchronous students, offline emailing for asynchronous students, and written answers for two offline questions in the second class), and open-ended survey responses, through a thematic analysis approach [36]. The first author organized emerging themes, subthemes, and quotes into a hierarchical structure and shared them with the research team to reach a consensus. "Accessibility awareness" and "feedback on education" emerged as major themes in both survey responses and discussion question responses. Additional themes that occurred in discussion question responses included "envisioned accessible designs and practices" and "envisioned accessible design challenges." In this paper, we use anonymized quotes from the students to illustrate our findings.

4.3.2 Quantitative Analysis

There has been no universal definition of empathy in the HCI/CSCW literature [37]. Some example definitions include "an ability to understand and interpret experiences of others," "putting oneself in the other's perspective," and "an affective response to another's situation." The questions we adapted in the survey captured these facets of the definition of empathy, inquiring about students' understanding of the software experiences of people with disabilities when software is inaccessible. To evaluate student empathy and their intention to design accessibly, we employed a two-tailed Wilcoxon signed-rank test with continuity correction to compare responses to Likert-scale questions from the pre- and post-surveys.

5 Results

5.1 Survey Responses

Through the survey responses, we noticed positive changes in terms of students' awareness and knowledge regarding accessibility. We also elicited rich feedback on the games. We elaborate on these aspects below.

5.1.1 Awareness Change Regarding Accessibility

The Likert-scale survey responses revealed a trend in terms of positive awareness change regarding accessibility. Before playing the games, the students' mean and median scores for the awareness questions (a-f) were 3.926 and 3.833, respectively; after playing the games, the mean and median scores increased to 4.248 and 4.333, respectively ($p < 0.01$, effect size = 0.43). According to Cohen's classification of effect size [38], we observed statistically significant changes with a medium effect size in the averaged test of the six Likert-scale awareness questions. This reflected students' increased awareness of mobile accessibility challenges faced by people with disabilities and increased intention to consider them when designing mobile applications.

5.1.2 Knowledge Gain in Accessible Design

Before game-playing, students exhibited some willingness to design accessibly in their responses to the open-ended question following the Likert-scale questions, but their responses were general, e.g., *"To keep in mind people with disabilities," "To create accessibility options for those with certain disabilities," "If I design mobile applications, I will try to include accessibility feature for people with disability as well," "Thinking from a consumer's mind," "Make it inclusive and accessible for all users, ensuring it meets diverse needs through thoughtful design and testing."* This suggests the students' lack of knowledge of accessible design before playing the games.

After game-playing, students expressed more concrete strategies to design accessibly, e.g., *"include a variety of tools like zooming, reading instructions out loud, clear tasks in place, use larger and consistent text, be knowledgable of the overall audience of the app beforehand so I can better cater to all individuals"*, *"If I design mobile applications, I think I would still be open to the ideas of adding text-to-speech and larger visual implementations, but I have also really like the idea of fixing the zoom-in feature of an application page so visually impaired individuals can comfortably look at a U.I. that they have set themselves."* These comments suggest the perceived effectiveness of our accessibility accommodations.

5.1.3 Student Feedback on Games and Learning Activities

According to some of the students, the Blindness Game was the most challenging and frustrating one, *"It was impossible to play when everything was all black, and the audio does not help since you can't see anyways."* However, others felt it was a representation of how blind people experienced mobile applications in round 2, *"I thought the Blindness Game was definitely a very accurate representation as I could not see anything, and this allowed for the computer to win."* One student recognized that the fully black screen was not an ideal way to simulate blindness, yet was a way to teach people about accessibility, *"I thought it was very 'unrealistic' in the sense that blindness isn't just a black screen over someone's eyes 24/7, but I saw the reasoning behind it as a way to teach the player the TTS (text-to-speech) system."* Another student suggested including the simulation of partial blindness to make the blindness game more effective.

In the Low Vision Game, students felt that the ball-popping task was harder to complete in round 2, but it was not impossible, *"The Low Vision Game was a mix of difficulty. It was hard in the second round to read which color I was supposed to be popping. I could make out the colors of the circles, but I couldn't read which color was correct. In this case, it was easier than the blindness, but still didn't allow me to be successful."* This student also noted that the zooming feature allowed her to do much better in the final round. Another student who wore glasses acknowledged that the Low Vision Game was the most relatable one and that the zooming feature was a good accessibility accommodation.

The physical impairment simulation mode was deemed less frustrating than the other two disability modes, only causing a delay in completing the task, e.g., *"I thought this was the easiest one to do, even with the disability lens."* Nevertheless, it helped students understand how people with physical impairments had difficulty clicking buttons, *"I think the shaking balls are a very clever way to simulate physical impairment! It really does put into perspective how annoying small buttons are for people with physical impairment."*

Overall, the students praised the games and our teaching activities as insightful: *"This was very fun. I also thought it was very insightful and really gave me a first hand experince of the challenges people with disabilties might have when using a mobile device"*; experiential: *"It was a great game so that people without disability can experience how people with disability might feel and experience how mobile application would actually showing to them"*; and engaging: *"I think this was a great way to have a hands-on, engaging experience, to learn how to better assist those with disabilities and to have more understanding for their struggles."*

5.2 Post-Game Discussion

Students' post-game discussion revealed a lack of mobile accessibility awareness due to limited education, increased empathy and understanding for people with disabilities after playing the games, envisioned accessible design practices and challenges, and insightful feedback on the games and mobile accessibility education.

5.2.1 A Lack of Mobile Accessibility Awareness due to Limited Education

Students' awareness regarding mobile accessibility was scarce before playing the games, as expressed by this student, *"Honestly, I have not thought much about it [mobile accessibility]. When hearing 'disabilities,' I tend to think about more physical obstructions, such as stairs being a hassle for disabled people. I also think about vision issues from elderly people regarding mobile applications, but not sure if that counts as a disability."*

A lack of mobile accessibility knowledge may be attributed to minimal relevant accessibility education in computing curricula. One student mentioned that software accessibility was taught briefly in some courses but was not specifically about mobile accessibility. Another student echoed this view, *"I've learned about accessibility issues in terms of computers via a Human Computer Interactions course but I'm not familiar with it on the mobile end."*

Although none of the students mentioned substantial instruction of mobile accessibility in their courses, they noted that learning about accessibility could happen through daily life. For example, one student encountered accessibility settings when using mobile applications, *"I have previously learned about this [mobile accessibility] as well because in the past, I have configured my settings for certain applications and videogames, and I scroll past accessibility settings that cater to color-blind disabilities and others... I guess I have not really taken a course on this, but I have encountered these types of tools on my own."*

5.2.2 Empathy and Understanding for People with Disabilities

The process of playing the education games cultivated a sense of empathy in the students. For example, one student realized how challenging it was for people with disabilities to interact with mobile applications if they were not designed accessibly; the frustrating interaction would, in turn, demotivate them from using mobile applications. She said, *"I think it could just really stump their motivation and desire to learn any new mobile applications or to explore what's out there. I feel like even in the games that I was doing, especially the blindness one, whenever I couldn't see anything and it was just a black screen, I was like, well, I can't even play. It kind of stumped me."*

Students' sense of empathy was related to the knowledge they acquired from the games, particularly the accessibility guidelines outlined at the end of each game. This student was a typical example, *"It is a fact that people with disability have some trouble while using mobile applications which do not possess accessibility features. For instance, those who cannot see will be unable to navigate and use apps that are not compatible with screen readers. Furthermore, poor color contrast between the text and background makes it difficult for visually impaired users to read content, while unadjustable fixed text sizes add up to these problems."*

One student expressed that people with disabilities should not be deprived of equal rights to use mobile applications and that accessibility considerations should be mandated in the development process, *"People with disabilities should have equal privileges to use an application like everyone else. To do better, we need to incorporate them in our plans during development. This inclusion ensures that their specific needs and challenges are addressed, leading to a more inclusive and user-friendly experience for all."*

5.2.3 Envisioned Accessible Designs and Practices

Students uttered accessibility features they would consider when designing mobile apps, such as voice commands for people with physical impairments and blind people, built-in screen readers for blind people, and customizable versions for different disabilities. One student talked about how customizing text size could enhance older adults' digital experience, applying knowledge learned to a new accessibility setting and population. Simplistic designs were regarded as key to reducing information and cognitive loads for people with disabilities, whereas an on-demand help guide could supplement streamlined onboarding information.

Learning about disabilities and keeping people with disabilities in the design loop were deemed important for designing accessible mobile applications, *"It is important to get educated on different disabilities and also do research or listen when a customer does bring up any new concerns."* According to one student, software designers should conduct formative research with people with disabilities to identify accessibility barriers and potential solutions. Another student suggested extending this participatory design process to the user testing phase to identify and solve inaccessible designs.

5.2.4 Envisioned Accessible Design Challenges

The students expressed many potential challenges in accessible design practices, such as balancing accessibility with aesthetics and functionality, keeping up-to-date with the latest accessibility guidelines, ensuring compliance with standards like WCAG, conducting thorough testing with a diverse group of users, and allocating sufficient resources and time in the development process to focus on accessibility, which *"can sometimes be overlooked in favor of other priorities."*

Tradeoffs existed between accessibility and usability. One student described how larger elements may change the function layout in an unusable direction, *"Larger buttons and texts may require a further simplified interface. This means certain functions might need to be removed or moved to another place, which can make it potentially more complex or difficult to use."* Another student similarly brought up the challenge of *"balancing the needs of diverse disability groups while maintaining a streamlined and functional user interface."*

Tradeoffs also existed between accessibility and privacy. For example, reading sensitive information out loud for blind people could lead to accidental privacy leakage, *"I think the games, especially the blindness one, really got me thinking about how we can make items more accessible for those who are blind. You could always implement text readers and text-to-speech. I really think hard on, like, maybe there was a privacy concern. Maybe it's a financial app that they wanna use, and they don't want certain information on their screen to be read aloud somewhere."*

5.2.5 Feedback on Accessibility Education

The students commonly praised the education games as a good demonstration of the challenges of inaccessible software with clear instructions. Experiencing disabilities in a hands-on manner was helpful for gaining awareness of accessibility, according to one student, *"I feel like any type of hands-on method is definitely, at least in my opinion, the most beneficial and what I get the most* *out of because I feel like it really opened my eyes. It's kind of seeing a little version of the perspective of someone with a disability. I think that would be the most beneficial and have the most effect on college-age students."* One student noted that the games nudged people to consider simple accessibility design solutions that were often overlooked yet helped improve the experience for people with disabilities.

In terms of making accessibility education more effective, one student suggested using themes that align better with daily life rather than games, such as financial or transportation apps. Hearing from people with disabilities in the form of guest talks/lectures was seen as a helpful complement to experiential learning in education.

6 Discussion

Our design of easy-to-use mobile accessibility education games and experience of teaching mobile accessibility to undergraduate students shed light on extending accessibility education in higher education, from emphasizing web accessibility, as in [7], [32], to mobile contexts. Our game-based approach adds to the existing literature on traditional methods [15] and experiential learning [16].

The games were praised for being insightful, experiential, and engaging. The students particularly appreciated the hands-on education, which they thought was suitable for college-age students and provided an immersive and intuitive learning experience. This echoes prior studies of experiential learning of accessibility in university [6] and K-12 [39] settings, where a simulation-based communication of accessibility concepts led to an enjoyable and effective learning experience.

We observed evidence of students' increased awareness regarding accessibility after playing the games. The students indicated insufficient coverage of mobile accessibility concepts in computing disciplines, which has led to their lack of awareness of accessibility, as expressed by some students in the class discussion. Such limited accessibility awareness is likely to persist in professional settings [40]. After playing the games, the students were able to understand the challenges arising from inaccessible designs and were more motivated to design for people with disabilities. Students' scores in the Likert-scale awareness questions increased significantly after playing the games. The learning outcome was similar to that of the education of web accessibility for college students [7].

Knowledge-wise, the students were not aware of concrete design interventions before playing the games, but they learned accessibility features such as larger visual elements and audio announcements through our education. The knowledge gained was related to the accessibility features we implemented in the games and the accessibility guidelines provided after each game.

The students further exhibited an understanding of abstract design principles, such as keeping people with disabilities in the design loop, and reflected on potential challenges in their future accessible design efforts, such as tradeoffs between accessibility and usability, and tradeoffs between accessibility and privacy. Such insights reflect a relatively in-depth discussion in undergraduate-level courses on mobile accessibility, fulfilling the learning goal of "understanding fundamental principles of inclusive design" [25], which is likely to be replicated in other computing-related courses.

6.1 Limitations and Future Work

Our study has several limitations. First, our sample size is relatively small, with the games tested with 45 students in two classes. Nevertheless, we managed to collect rich data [41] from the small sample on students' awareness and knowledge regarding mobile accessibility. Future research could consider teaching the games in a wider range of classes to validate our exploratory results – mobile accessibility is an important consideration in courses such as software engineering, mobile healthcare, and Android development. Second, our study is limited to US universities. More education efforts in accessibility are encouraged in global south contexts, where more stigma around disabilities and insufficient accessibility infrastructure create even more barriers for people with disabilities.

7 Conclusion

To promote mobile accessibility education in computing disciplines, we designed mobile-compatible accessibility education games and used them in two undergraduate-level courses. Students' awareness, knowledge, and empathy regarding accessibility increased after playing the games, indicating the potential of the games to deliver mobile accessibility concepts. The students particularly favored the hands-on and experiential nature of the games, providing implications for future education efforts.

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