Accessibility for All: Introducing IT Accessibility in Postsecondary Computer Science Programs for K-12 Teachers

Rachel F. Adler[1]
Devorah Kletenik[2]

Abstract

While more universities are including IT accessibility in their computer science programs for undergraduate and graduate students, there is little accessibility training available for K-12 teachers. We created an intervention through which postsecondary students had opportunities to experience five computer games with a simulated impairment (color-blindness, auditory impairments, physical disabilities, blindness, or low-vision); first they played the game that was inaccessibly designed and then they played a version that was accessibly designed. The activity ended with a discussion of accessible design techniques. We tested the intervention with 18 teachers who were students in a university web development course that was part of their computer science training. Results show that teachers were very receptive to including accessibility topics in their future classrooms and thought the intervention was an effective method for teaching high school, middle school, and elementary school students about accessible design.

Keywords: accessibility, empathy, computing education, K-12 teacher training, computer games

Introduction

There are over 1 billion people living with disabilities in the world (World Health Organization, 2011), yet many computer interfaces are inaccessible (WebAIM, n.d.). Applying web accessibility guidelines ensures that "websites, tools, and technologies are designed and developed so that people with disabilities can use them" (W3C, n.d.). Web accessibility not only helps those with disabilities but can lead to better experiences for anyone (Schmutz et al., 2016).

To address inaccessible design issues, accessibility topics have been integrated into some university-level computer science (CS) and engineering programs (Carter & Fourney, 2007; Keates, 2015; Kurniawan et al., 2010; Martin-Escalona et al., 2013; Wald, 2008), and in particular some are seamlessly integrated in web design courses (Harrison, 2005; Rosmaita, 2006; Wang, 2012) in which students are already learning about design. However, to the best of our knowledge there is a lack of accessibility modules implemented at the university level for pre-service or in-service teachers.

In the United States, in 2016, President Obama created the CS for All initiative with a goal that all K-12 students will learn CS (Smith, 2016). Therefore, more opportunities to learn CS topics were offered to K-12 students (Chen et al., 2017), and some teachers were trained through professional development workshops (Pollock et al., 2017). In addition, university-level CS courses were developed for future teachers (Adler & Beck, 2020) and current teachers (Joshi et al., 2019). We argue that in addition to coding and computational thinking, the CS for All movement should promote the inclusion of accessibility topics in the CS curriculum offered to K-12 teachers as well. Such efforts have the potential to foster a better understanding of accessibility barriers and solutions for students in K-12 education.

Including accessibility topics in courses often includes activities which raise awareness of accessibility challenges and promote empathy for people with disabilities (Putnam et al., 2015). One method for inspiring empathy while teaching about accessibility is

[1] *Northeastern Illinois University;* [2] *Brooklyn College, CUNY*

through simulations (El-Glaly et al., 2020; Keates & Looms, 2014) through which students interact with software simulating a disability.

However, disability simulations must be carefully formulated. Some uses of simulations have been criticized because they do not improve attitudes towards people with disabilities (Nario-Redmond et al., 2017) and fail to address coping strategies that people with disabilities have developed and the long-term effects of facing social and physical barriers (French, 1992). In addition, while simulations may promote sensitivity to the limitations people with disabilities face, they often do not share accessible design practices and how to apply universal design (UD) principles (Burgstahler & Doe, 2004).

We introduce disability simulation games at the university level for K-12 CS teacher training that not only simulate inaccessible design for people with disabilities, but also provides tips and suggestions for good designs for all. In particular, they are geared toward motivating the application of the basic principles of universal design for designing for all regardless of a person's ability or other factors (Connell et al., 1997). They also highlight the specific Universal Design for Learning (UDL) principles for presenting content in different ways so it is usable by more people (CAST, n.d.). Our simulations, which are presented as engaging and competitive games, demand no prior CS or HTML knowledge and can therefore be used to train K-12 teachers and students.

Depiction of the Problem

A lack of inclusion of accessibility training in K-12 education leads to students learning to program without thinking about the needs of their target users, furthering the development of software that is inaccessible for people with disabilities that excludes them from its use. To remedy the lack of accessibility in K-12 classrooms, we begin with inclusion of accessibility in CS teacher training in postsecondary education. We tested disability simulation games, which were effective in motivating students towards accessibility in CS undergraduate courses (Kletenik and Adler, 2022), in a university web development course taken by K-12 teachers who teach or plan to teach CS.

This work is novel with respect to introducing accessibility topics and training into teacher education. Through the inclusion of accessibility topics in teacher training, teachers will be able to integrate some of these concepts in their own K-12 classrooms through age-appropriate activities, such as computer games and simulations. This advancement will empower students to develop empathy for people with disabilities and to begin to take steps towards making software more accessible to everyone.

Our research questions are as follows:

1. Does participation in an intervention that includes disability simulation games increase empathy towards people with disabilities and knowledge of accessible design with respect to IT?
2. Will K-12 teachers consider including interventions that use simulation games in their future CS classrooms?
3. What changes would need to be made to these college-level activities to make them fitting for K-12 classrooms?
4. Is the inclusion of IT accessibility topics appropriate for elementary, middle, and/or high school students?
5. How do participants feel and perform when simulating disabilities both with and without accessibility options?

Setting and Participants Demographics

Eighteen teachers (14 female and 4 male) were enrolled in a web development course at Northeastern Illinois University that was offered remotely over Zoom. These teachers (eight elementary, eight middle school, and two high school) were a cohort taking 18 credit hours of study in CS, which count toward the state endorsement to teach CS. Ten (55%) were White, four were Black/African American, three were Hispanic/Latino, and one was Asian. Fifteen of the teachers taught various STEM (science, technology, engineering and mathematics) related courses, one was in special education, one taught English Language Arts (ELA), and one was a Diverse Learner Teacher. Twelve of the teachers (67%) currently included CS topics in their classrooms. Sixteen (89%) reported knowing someone with a disability. All participants completed each activity on their own computers within a 1 hour and 15-minute class session.

Description of Practice

We created five accessibility games simulating the following disabilities: color blindness, auditory impairments, physical/motor impairments, blindness, and low/blurred vision. Each game has 4 rounds: (1) Game mode with no simulated disability, (2) Simulation mode, in which the player plays with a simulated disability, (3) Game+accessibility mode, with no simulated disability and the game is accessible, and (4) Simulation+accessibility mode, where the player plays with a simulated disability and the game is accessible. Our games are free to the public and can be accessed at gooddesignforall.com.

The games feature balls of red, green, and yellow that move across the screen. Players are told to "pop" a red or green ball. If they succeed, they get a point; if not, the computer gets the point and the player loses a point. After a ball is clicked, another color is chosen and gameplay continues until the time limit of 30 seconds per round is reached.

Table 1 shows what happens in simulation mode (Rounds 2 and 4) and with the addition of accessibility features (Rounds 3 and 4). The purpose of Round 1 is to allow the user to try out the game before entering simulation mode. Round 3 was included to show participants how designs would look with accessibility features for someone without that disability, and to counter the misconception that accessibility features reduce usability for people without disabilities, since players can observe that the game was just as fun to play when it is accessible.

Evaluation Measures and Outcomes

We created pre- and post-surveys asking questions relating to participants' attitudes about stereotypes towards people with disabilities, whether the teachers felt the intervention would be helpful for teaching IT accessibility in K-12, whether they would use the games in their courses, and any modifications they deemed necessary to make it appropriate for the K-12 level. We also collected in-game metrics denoting performance and sentiment to measure the impact of disability simulations on the players. Performance was measured as a binary value where 1 indicates that they won the round. After each round, participants were prompted to select one predefined sentiment that reflected their feelings about that round. We measured this too as a binary value of positive vs. negative (e.g., "fun" is positive while "frustrating" is negative).

After the participants gave informed consent, the pre-game survey was loaded, followed by the five games, and lastly, a post-game survey. At the end of each of the five games, participants were brought to a tips page which displayed information on creating accessible content for people with that disability, thus enabling reflection on the experience and teaching about designing for people with that disability. Further, after completing the activity and post-survey, we followed up the activity with a short lecture and discussion on Web accessibility to reinforce the concept to the teachers, which we encouraged they impart to their students, on how to create websites that are usable for people with disabilities.

To address our first research question and examine whether disability simulation games increase empathy towards people with disabilities and knowledge of accessible design with respect to IT, we considered the responses to the pre- and post-survey questions regarding stereotypical attitudes towards people with disabilities. The questions, depicted in Table 2, were asked on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). These questions were adapted from a survey about stereotypes of elderly people and technology (Carmichael et al., 2007) and used previously in evaluating our simulation games on college

Table 1

Games and Rounds

	Game Mode	Simulation Mode	Game + Accessibility Mode	Simulation + Accessibility Mode
Colorblind	Play the ball popping game	Cannot distinguish colors of balls	Letter written in each ball (e.g., R for Red)	Simulates colorblindness. Letter in each ball too
Auditory	Color to pop is *heard* instead of on screen.	Cannot hear the color to pop	Words (e.g., Pop Red) are written on the screen	Simulates deafness. Words (e.g., Pop Red) are written on the screen
Physical	Play the game	Mouse becomes shaky	Keyboard navigation included	Mouse is shaking. Kerybooard navigation is available
Visual	Play the game	Cannot see the game. Black screen	Keyboard navigation with audio announcing the color of the selected ball	Simulates blindness. Keyboard navigation with audio is available
Low Vision	Play the game	Blurred vision	Can magnify the screen to remove bluriness	Blurry screen. Can magnify

Table 2

Pre- and Post-Attitude Questions

Attitude Towards People with Disabilities
Most current interfaces are easy for most people to use.
People with disabilities are not interested in new technology.
If a person with disabilities has difficulty with technology, there will usually be someone around who can help.
Most developers don't need to worry about providing technology suitable for use by people with disabilities.

students (Kletenik and Adler, 2022). We compared pre- to post-survey results using a two-tailed Wilcoxon signed-rank test and found statistically significant changes in the pre- to post-responses for the attitude questions. The pre-median of the average attitude response decreased (indicating greater disagreement with negative attitudes) from 2 to 1.75, $p = 0.005$, with a large effect size ($r = .66$); therefore, we note statistically significant changes with a large effect size in improving the attitude of participants towards people with disabilities.

Student comments that support this increased awareness of accessibility issues and knowledge of how IT can be made more accessible to people with disabilities include the following:

- "I think this game gives insight into situations that many know about. This allows others to know and empathize about their concerns and need to be heard."
- "This does a great job of putting you in the shoes of someone with a disability. Once that happens it give[s] some ideas for solutions but also opens the door for new and more innovative solutions from our students."

To address our second research question, and examine whether K-12 teachers will consider using activities that include these types of games in their future CS classrooms, we examined survey responses that showed that 16 participants (89%) agreed or strongly agreed that if they were to teach CS topics they would likely use a game as part of their curriculum for teaching about accessibility.

In terms of these games, 16 participants (89%) agreed or strongly agreed that they would use them in their classroom. In addition, a high percentage of teachers agreed or strongly agreed that these games would be useful for teaching accessibility in high school (n = 17, 94%), middle school (n = 17, 94%), and elementary school (n = 15, 83%). Supporting comments included the following:

- "Students as young as K can understand that students with certain impairments may need additional resources and accommodations for successful computer learning."

We also asked participants what changes we would need to make to these college-level accessibility games to make it fitting for K-12 classrooms (see our third research question). While participants seemed to find the games suitable for K-12, their concerns were primarily in terms of our instructions before each round. Participants suggested that we make it easier for children to absorb the instructions, since they may gloss over the reading. Some responses included the following:

- "There are a lot of instructions and [they] are very wordy. [L]ittle children may skip the reading and not get all the instructions."
- "Everything was pretty clear except students will need to have the ability for directions to be read to them…"
- "YES. I realized that the instructions come in bulletin form. Nevertheless, I missed the instruction about what color needed to be popped under the timer."

To address our fourth research question, and examine whether the inclusion of accessibility topics was appropriate for K-12 students, we looked at answers to survey questions and found that a high percentage of teachers agreed or strongly agreed that teachers who teach CS should include accessibility topics in high school (n = 17, 94%), middle school (n = 16, 89%), and even elementary school (n = 16, 89%). Teachers were overwhelmingly positive about including accessibility topics at all levels.

In order to examine our fifth and final research question, how performance and sentiment were impacted when simulating disabilities both with and without accessibility options, we looked at the number of wins and positive emotions from Rounds 2, 3, and 4. Round 1 was removed from analysis since it was used primarily as a practice round and was allowed to be skipped in later games. Two participants were removed from the auditory game analysis due to technical difficulties with audio.

We used the sentiment chosen by the user in each round to ascertain whether participants had more negative emotions in Round 2 (simulation mode) than Rounds 3 and 4. A Cochran's Q test showed there were significant differences for emotions for all the games ($p < .0001$); follow-up pairwise McNemar tests showed that this difference was because emotions reported on second rounds were significantly more negative than in Rounds 3 and 4 ($p < .05$).

In terms of performance, we similarly compared participants' scores in Rounds 2-4 and found significant differences in performance for all but the physical game ($p < .0001$), with Round 2 having significantly lower scores than Rounds 3 and 4 ($p < .05$). Note that similar to Kletenik and Adler (2022), participants were still able to win Round 2 of the physical game (with the shaky mouse), and therefore there were no significant differences in percentage of wins, though reported sentiment was lower for that round. In the case of Visual, performance in Round 4 (where the game was still hidden by a black screen) was also significantly lower than Round 3. Despite accessibility options, participants struggled with not being able to see at all.

Implications and Transferability

The goal of our IT accessibility exercise is for K-12 teachers who teach (or will teach) CS classes to learn the importance of incorporating accessibility content in their own classrooms and give ideas for accessible design for students even as early as K-12. We found that participants were overwhelmingly positive in their support of including accessibility, and of using games, and particularly these games, when teaching K-12 about accessibility. A limitation of the evaluation is our small sample size. Future work is needed to test this intervention with more K-12 teachers and directly with students in K-12 classrooms to examine whether accessibility simulation games can be effective with students as early as elementary school. Our results suggest that while the games may be suitable for K-12, the directions should be modified to make them more age appropriate, perhaps by re-wording them and offering a read-aloud option.

While our results show promise for including accessibility in CS teacher training, activities that include accessibility simulations can also be considered in other education programs. For example, one teacher wrote: "It would ALSO be a great game to teach disability in courses training special education teachers." We envision expanding this work into other departments, thereby increasing accessibility awareness at all levels.

References

Adler, Rachel F., & Beck, K. (2020). Developing an introductory computer science course for pre-service teachers. *Journal of Technology and Teacher Education, 28*(3), 519-541. https://www.learntechlib.org/primary/p/214351/

Burgstahler, S., & Doe, T. (2004). Disability-related simulations: If, when, and how to use them in professional development. *Review of Disability Studies: An International Journal, 1*(2), 4-17.

Carmichael, A., Newell, A. F., & Morgan, M. (2007). The efficacy of narrative video for raising awareness in ICT designers about older users' requirements. *Interacting with Computers, 19*(5-6), 587-596.

Carter, J. A., & Fourney, D. W. (2007). *Techniques to assist in developing accessibility engineers.* Proceedings of the 9th International ACM SIGACCESS Conference on Computers and Accessibility, 123-130.

CAST. (n.d.). *About Universal Design for Learning.* Retrieved from www.cast.org/impact/universal-design-for-learning-udl

Chen, G., Shen, J., Barth-Cohen, L., Jiang, S., Huang, X., & Eltoukhy, M. (2017). Assessing elementary students' computational thinking in everyday reasoning and robotics programming. *Computers & Education, 109*, 162-175. https://doi.org/10.1016/j.compedu.2017.03.001

Connell, B. R., Jones, M., Mace, R., Mueller, J., Mullick, A., Ostroff, E., Sanford, J., Steinfeld, E., Story, M., & Vanderheiden, G. (1997). *The principles of universal design*. https://design.ncsu.edu/research/center-for-universal-design

El-Glaly, Y., Shi, W., Malachowsky, S., Yu, Q., & Krutz, D. E. (2020). *Presenting and evaluating the impact of experiential learning in computing accessibility education.* 2020 IEEE/ACM 42nd International Conference on Software Engineering: Software Engineering Education and Training (ICSE-SEET), 49-60.

French, S. (1992). Simulation exercises in disability awareness training: A critique. *Disability, Handicap & Society, 7*(3), 257-266. https://doi.org/10.1080/02674649266780261

Harrison, S. M. (2005). *Opening the eyes of those who can see to the world of those who can't: A case study*. Proceedings of the 36th SIGCSE Technical Symposium on Computer Science Education, 22–26. https://doi.org/10.1145/1047344.1047368

Joshi, A., Jain, A., Covelli, E., Yeh, J., & Andersen, T. (2019). *A sustainable model for high-school teacher preparation in computer science*. 2019 IEEE Frontiers in Education Conference (FIE), 1-9.

Keates, S. (2015). A pedagogical example of teaching universal access. *Universal Access in the Information Society, 14*(1), 97-110.

Keates, S., & Looms, P. O. (2014). The role of simulation in designing for universal access. In C. Stephanidis & M. Antona (Eds.), *Universal access in human-computer interaction. Design and development methods for universal access* (pp. 54-63). Springer International Publishing.

Kletenik, D., & Adler, R. F. (2022, February). Let's Play: Increasing Accessibility Awareness and Empathy Through Games. In *Proceedings of the 53rd ACM technical symposium on computer science education v. 1* (pp. 182-188).

Kurniawan, S. H., Arteaga, S., & Manduchi, R. (2010). *A general education course on universal access, disability, technology and society.* Proceedings of the 12th International ACM SIGACCESS Conference on Computers and Accessibility, 11-18.

Martin-Escalona, I., Barcelo-Arroyo, F., & Zola, E. (2013). *The introduction of a topic on accessibility in several engineering degrees. 2013* {IEEE} Global Engineering Education Conference ({EDUCON}), 656-663.

Nario-Redmond, M. R., Gospodinov, D., & Cobb, A. (2017). Crip for a day: The unintended negative consequences of disability simulations. *Rehabilitation Psychology, 62*(3), 324.

Pollock, L., Mouza, C., Czik, A., Little, A., Coffey, D., & Buttram, J. (2017). *From professional development to the classroom: Findings from CS K-12 teachers*. Proceedings of the 2017 Acm Sigcse Technical Symposium on Computer Science Education, 477-482.

Putnam, C., Dahman, M., Rose, E., Cheng, J., & Bradford, G. (2015). *Teaching accessibility, learning empathy*. Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility, 333-334.

Rosmaita, B. J. (2006). Accessibility first! A new approach to web design. *ACM SIGCSE Bulletin, 38*(1), 270-274.

Schmutz, S., Sonderegger, A., & Sauer, J. (2016). Implementing recommendations from Web Accessibility Guidelines: Would they also provide benefits to nondisabled users. *Human Factors, 58*(4), 611-629.

Smith, M. (2016). *Computer Science For All*. https://obamawhitehouse.archives.gov/blog/2016/01/30/computer-science-all

W3C. (n.d.). *Introduction to Web Accessibility*. Retrieved from w3.org/WAI/fundamentals/accessibility-intro/

Wald, M. (2008). *Design of a 10 credit Masters level assistive technologies and universal design module*. International Conference on Computers for Handicapped Persons, 190-193.

Wang, Y. D. (2012). *A holistic and pragmatic approach to teaching web accessibility in an undergraduate web design course*. Proceedings of the 13th Annual Conference on Information Technology Education, 55-60.

WebAIM. (n.d.). *The WebAIM Million: The 2022 report on the accessibility of the top 1,000,000 home pages*. Retrieved from https://webaim.org/projects/million/

World Health Organization. (2011). *World report on disability*. World Health Organization.

About the Authors

Rachel F. Adler received her B.S. degree in computer and information science from Brooklyn College, CUNY and Ph.D. from the Graduate Center, CUNY. She is currently an Associate Professor in the Department of Computer Science at Northeastern Illinois University. Her research interests include human-computer interaction, accessibility, and computer science education. She can be reached by email at: r-adler@neiu.edu.

Devorah Kletenik received her B.S. degree in computer science from Touro College and Ph.D. from NYU School of Engineering. She is currently an Associate Professor in the Department of Computer and Information Science at Brooklyn College and the Graduate Center of CUNY. Her research interests include theoretical computer science, computer science education, accessibility and serious games. She can be reached by email at: kletenik@sci.brooklyn.cuny.edu.

Acknowledgement

We thank Nour Sleiman for her help developing the games and implementing the experimental setup.