Who Wins? A Comparison of Accessibility Simulation Games vs. Classroom Modules

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ABSTRACT

There is a great need to train future software developers in accessibility, and disability simulations can be a powerful way to engage students. In this work, we evaluate the effects of disability simulation games on student empathy and design choices. To do this we recruited 124 students and randomized them into two conditions: students playing simulation games and a control group of students who learned accessibility topics through a video lecture and readings. Although the accessibility lecture and readings were effective at inspiring student empathy towards people with disabilities, the effects were short-lived; in contrast, the simulations inspired greater and longer-lasting empathy and consideration of people with disabilities. However, more work should be done to determine whether these gains influence students' inclusion of people with disabilities in practice.

CCS CONCEPTS

• **Human-centered computing → Accessibility**; **Accessibility**; • **Social and professional topics → Computing education**; **Computing education**; • **Applied computing → Computer games**.

KEYWORDS

accessibility, empathy, computing education, simulations, games

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1 INTRODUCTION

The goal of accessibility is to create applications that do not exclude people with disabilities from using them [20]. With disabilities so prevalent in the US – according to the Institute on Disability [8], "[i]f people with disabilities were a formally recognized minority group, at 19% of the population, they would be the largest minority group in the United States" – it is clear that accessibility is an important goal for software development. In order to both prepare our students for market needs as well as educate them to be socially conscious and responsible programmers, the topic of accessibility is an important one to include in Computer Science (CS) curricula [17]. While many universities have included lectures or modules on this topic, a desire to instill *empathy* for people with disabilities (see [28]) has led others to create their own simulation activities to give students a small taste of the challenges that people with disabilities face [9, 16, 35] as simulations have been effective in STEM learning [6, 7, 43].

Research using the Accessibility Learning Labs (ALL) [9] compared students who used them with a control group, which read content from the Mozilla accessibility page, as well as with students who used the ALL in addition to watching supplementary videos that depicted discussions with people with disabilities. They found that using the simulations or the simulations with videos was more effective at informing students about accessibility principles than the control group; however, while the students who used the labs plus videos had an increase in empathy towards people with disabilities, those who engaged with the simulations alone did not. In contrast, we created simulation games and found statistically significant increases in student empathy due to engaging with their simulation games [16]. However, a limitation of our previous work is that there was no control group comparison, making it unclear whether accessibility simulation games would be more effective at increasing empathy towards people with disabilities than the typical classroom approach.

In this work, we extend our previous work in [16] in three ways by: (1) comparing the games with a control group that included a video recording of an accessibility lecture and content from WebAim.org, (2) examining follow-up results a few weeks later to see if the previous post-survey results continue to hold, and (3) examining classroom assignments to see whether accessibility knowledge was used in practice.

Our research questions are as follows:

R1. Compared to traditional classroom approaches, do disability simulations result in greater increases of student empathy towards people with disabilities and consideration of disabilities when designing software?

R2. Compared to traditional approaches, do disability simulations result in increased duration of accessibility learning gains?

R3. Compared to traditional approaches, do disability simulations result in increased consideration of disabilities in practice?

2 BACKGROUND AND RELATED WORK

There is a driving need to include more accessibility topics in CS courses [38], though many instructors report not teaching accessibility because it is not an integral part of their course [32]. However, preliminary studies suggest that students themselves appreciate the

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import of these topics [18], and research has shown that including accessibility in CS curricula can increase students' understanding of the Americans with Disabilities Act (ADA) and the Web Content Accessibility Guidelines (WCAG) [13]. Still, accessibility can be a difficult topic to teach, especially to those new to the subject, thus creating a need to support instructors by creating accessibility resources and teaching materials [1, 42].

Accessibility topics have been successfully taught using a diverse set of educational experiences, including lectures, assignments and projects [2, 5, 10, 11, 21–23, 26, 27], service learning with people with disabilities [19, 25], videos [29, 30], guest lectures [19, 37], virtual reality [35], and gamification techniques [24, 34].

While inviting and including people with disabilities in this process can be an effective technique in CS classrooms, it is time-consuming and therefore, ideas for teaching accessibility have included simulations and simulation labs [9, 14, 31, 35, 36]. We combined aspects of simulation labs with gamification to create simulation games and found it was effective in increasing empathy – including decreasing negative stereotypes about people with disabilities and increasing awareness of the challenges that they face – and motivating students towards accessible design [16].

To the best of our knowledge, only a few studies have used control groups in order to examine whether the inclusion of accessibility activities was more effective than the control (e.g. [9, 25, 34]); often it may not be possible to have a control group when universities have a fixed curriculum for their courses [27]. In addition to examining the effectiveness of teaching accessibility using a variety of classroom techniques and compared to a control group, one study also examined long-term effects by using the same survey 18-24 months later [44]. They found that while teaching accessibility was effective in the short term, by two years later most of the significant gains were gone.

3 METHODS

3.1 Disability Simulation Games

In our work, we use a series of five accessibility learning games[1] [16] that simulate colorblindness, auditory impairments, physical/motor impairments, blindness and blurred vision.[2]

The games all direct players to pop balls of specific colors as they move about the screen. Play proceeds in four rounds. In the first round, players play in "game mode," with no simulated disability. The second round is "simulation mode," and players experience the play with the simulation of one of the five disabilities. In this round in the colorblindness game, the balls are recolored as they would be experienced by a person with deuteranopia (a common form of red-green colorblindness), making it hard to distinguish the red balls from the green ones. In the auditory impairment game, the sound is disabled, making it impossible to hear the spoken instructions. In the physical/motor impairments game, the mouse action is noisy as though guided by a hand with tremors; the blurred vision game blurs the screen, making it difficult to see the written instructions. Most dramatically, in the blindness game, a black screen is overlaid on top of the moving balls and instructions, making it impossible to see the game action.

In the third round, no disability is simulated and accessibility options are enabled: for example, labels such as 'R,' 'G,' and 'Y' to denote the colors (red, green, yellow) of the balls in the colorblindness game; keyboard support in the physical impairments game; and a combination of audio and keyboard support for the blindness game. Finally, play resumes in the fourth and final round with a return of the simulated disability, this time with the accessibility option to mitigate the challenges posed by the simulation.

After the completion of each game, a page of information is presented about accessibility for that disability, with "how-to" tips about accessibility, relating ideas such as not using color alone for feedback and enabling keyboard support.

3.2 Study Design and Participants

We compare the learning effects of students who play the simulation games with a control group of students who instead watched a video (about ten minutes long) of an instructor's screen-recorded lecture about accessibility and read a series of readings about disabilities, which we adapted from WebAIM articles [39–41]. The idea of this control group was to compare disability simulation games with more traditional (lecture-style) teaching; in fact, the video that we used was previously created by one of the authors for an online course. At the end of each disability segment, the same "how-to" pages were presented to the control group students, to ensure that the technical details were presented equally to both groups.

Students were recruited from two large public universities: from Human-Computer Interaction (HCI), Game Design and Development, and Electronic Commerce courses given at Brooklyn College (BC), and from an HCI course given at Northeastern Illinois University (NEIU). IRB approval was obtained at both universities.

The study was divided into two stages:

Stage 1: Students were given a homework assignment to learn about accessibility via our website. After giving informed consent, students were given a pre-survey (from [16]) that asked for basic demographic information along with questions measuring empathy and accessible design. A copy of the survey questions is given in Figure 1. The first 7 questions are Likert-scale questions, with values ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

Students were then randomly assigned to either the control group or the simulations group; students in the control group were given the lecture video, followed by the WebAIM series of articles, while students in the simulations group were guided through playing all five simulation games. After students completed their educational interventions, they were given a post-survey to complete, containing the same accessibility questions as on the pre-survey.

In total, we had 124 students complete both a pre- and post-survey. They were randomly split into the Control Group (61 students) and Simulations Group (63). Several students completed only the pre-survey but not the post-survey; they are excluded from our analysis. Students who accidentally completed the pre-survey twice generally had only the second entry counted since that ID matched the ID on the post-survey. Demographic and educational background of the 124 students are summarized in Table 1.[3]

[1] https://gooddesignforall.com/

[2] In our original paper, only the first three disabilities had been implemented. We used a later version of the games that includes blindness and blurred vision as well.

[3] Although nine students reported having a disability, none listed a disability severe enough to preclude their participation: for example, mild visual impairments. The

Figure 1: Survey questions (pre-, post-, and final), from Figure 2 in [16]

- **Please rate your level of agreement with the following statements:**
  (1) Most current interfaces are easy for most people to use.
  (2) People with disabilities are not interested in new technology.
  (3) If a person with disabilities has difficulty with technology there will usually be someone around who can help.
  (4) Most developers don't need to worry about providing technology suitable for use by people with disabilities.
  (5) Users with disabilities are likely to face challenges when completing tasks with software.
  (6) Users with disabilities are likely to feel frustrated while using software.
  (7) When I design or develop software, I will try to have in mind users with disabilities.
- Suppose you are creating a computerized race car game in which a user tries to race their on-screen car with other computerized cars. Which potential users should you include when testing your prototype?
- Suppose you were charged by the Board of Elections in your state to create a new voting kiosk for use in the next election. Which potential users should you include when testing your prototype?

Gender	
Male	81
Female	42
Other	0
Prefer not to say	1
Age:	
18 − 25	100
26 − 35	22
36 − 45	1
≥ 46	1
Course	
HCI 1 (BC)	30
HCI 2 (NEIU)	26
Game Design (BC)	34
E-Commerce (NEIU)	34
Major	
CS major	103
Non-CS major	21
Group Assigned	
Control group	61
Simulations group	63

Race	
American Indian or Alaska Native	3
Asian	56
Black or African American	16
Hispanic or Latino	22
White	16
Two or more races	5
Prefer not to say	6
Disability Status (Select all that apply)	
None	101
Visual	2
Colorblindness	2
Auditory	0
Physical	0
Cognitive/neurological	0
Learning disability	3
Other disability	2
Prefer not to disclose	14
Knowledge of Someone with a Disability	
None	79
Acquaintance	11
Friend/family	34

Table 1: Demographic and educational background of participants in Stage 1 ($n = 124$)

After completing Stage 1, we re-assessed students' consideration of accessibility, in two steps:

Stage 2a: About 3-6 weeks after completing Stage 1, students were given a homework assignment that was designed to assess whether students include people with disabilities in their target population. HCI 1, HCI 2 and Game Design students were all given a version of the assignment in Figure 2 while learning how to experimentally evaluate changes to software or game designs. The

Figure 2: Homework assignment (HCI and Game Design)

Suppose you were creating an online math game for middle school students. Outline an experiment you would do to test your new design and know if it helped improve students' math skills. Answer the following:

(1) What will the experiment be?
(2) Will you have a control condition?
(3) Which participants would you use to ensure they represent all target users?
(4) What is the Hypothesis?
(5) Independent Variables?
(6) Dependent Variable(s)?

Electronic Commerce students were given a question in the context of a larger report on an (imaginary) e-commerce business and its design that asked them to: "*Discuss your target audience. Who do you think would want to use your business? Does your business appeal to a diverse set of customers?*" Of the 124 students who originally participated, 113 completed this assignment (56 out of the 61 Control students and 57 out of the 63 Simulation students).

Stage 2b: One to two weeks after completing the assignment in Stage 2a (and with no feedback given about the mention or lack thereof of people with disabilities in their homeworks), students were given a final survey to complete. The questions on this survey were identical to the ones asked on the pre- and post-surveys and were designed to measure duration of educational impact. This survey was given as a brief exercise, during class in two courses (Game Design and HCI at BC) and online in two other courses (E-commerce and HCI at NEIU). In total, 107 students completed the final survey (55 Control and 52 Simulation).

Identifying details (such as names and emails, which were recorded to give students credit for their submissions) were removed from the student data before analysis.

3.3 Measures

To be able to compare our results to our previous ones, we use the same measures for student empathy and accessible design.

Attitude: The first four Likert scale questions (modified in [16] from [3]) measure student attitudes towards people with disabilities. We compute the average responses to these four questions as the Attitudes measure (ranging from 1 to 5, where lower numbers indicate a more empathetic attitude towards people with disabilities).

two colorblind students, who may not have been able to play the games, had been randomly assigned to the control group. We therefore included these students in the analysis.

Challenges: The second three Likert scale questions measure an awareness of challenges faced by people with disabilities. The average response to these three questions is the Challenges measure (ranging from 1 to 5, where higher numbers indicate a greater understanding of the challenges faced by people with disabilities).

Task Domain: Two open-ended questions measured student intent to include people with disabilities across different task domains by asking students which potential users students would use to test prototypes of voting kiosks and racecar games (modified in [16] from work by [25].)

4 RESULTS

4.1 R1: The Impact of Simulated Disabilities on Student Empathy and Design Decisions

In our first research question, we consider whether disability simulations help generate empathy towards people with disabilities and whether it inspires students to design in a more accessible fashion, compared to video lectures and readings.

To answer this question, we compared the pre-survey responses of each group (Control and Simulation) with the post-survey responses, using an analysis similar to [16]. A summary of the responses is shown in Table 2. (Lower numbers indicate disagreement, which is the intended answer for the Attitudes questions; higher numbers indicate agreement, the desired answer for Challenges questions.)

Using a Wilcoxon two-tailed signed-rank test, $\alpha = .05$, we found statistically significant changes for the Control group from the pre- to post-responses for the Attitude questions ($p = 0.007$) with a medium effect size ($r = .34$) but not for the Challenges questions ($p = .2$). For the Simulations group, we found statistically significant changes from the pre- to post-responses for both the Attitude questions ($p < .001$) with a medium effect size ($r = .45$) as well as the Challenges questions ($p < .0001$) with a large effect size ($r = .66$). We therefore note statistically significant changes and a medium effect size for the Attitudes questions for participants in both groups, and statistically significant changes and a large effect size for the Challenges question only for participants in the Simulations group.

We used a Kruskal-Wallis test to directly compare the pre-survey scores for both measures for participants in both groups, because the ordinal data is non-parametric. As would be expected (since participants were randomly assigned to the Control and Simulations groups), there was no statistically significant difference between pre-survey measures for the Attitudes measure ($\chi^2(1, N = 124) = 0.232, p = .63$) or the Challenges measure ($\chi^2(1, N = 124) = 0.268, p = .6$). Although there was likewise no statistically significant difference for the post-Attitudes scores across both groups ($\chi^2(1, N = 124) = 2.424, p = .12$), the Simulations group had significantly better scores in the post-Challenge questions ($\chi^2(1, N = 124) = 16.666, p < .0001$) with a moderate effect size ($\eta^2 = .128$).

We also considered the answers to the Task Domain design questions, in which we asked students which users they would include in testing prototypes of racecar games and voting kiosks. Each answer was coded as a binary value, as mentioning people with disabilities or not.[4]

[4]Coding was conducted independently by two individuals with > 98% agreement.

For each group, we analyzed pre- to post-answers using a McNemar analysis with continuity correction. Statistically significant increases in responses including people with disabilities were present for both questions in both groups: in the Control group, responses including people with disabilities on the racecar question increased from 30% in the pre-survey to 75% in the post-survey ($\chi^2(1, N = 61) = 24.038, p < .0001$, Cohen's $g = .5$) and on the election kiosk question, from 43% to 72% ($\chi^2(1, N = 61) = 12.5, p = .004$, Cohen's $g = .44$). Similar results were shown for the Games group, with responses for the racecar question increasing from 30% to 76% ($\chi^2(1, N = 63) = 25.29, p < .0001$, Cohen's $g = .47$) and for the election kiosk question, from 41% to 75% ($\chi^2(1, N = 63) = 16, p < .0001$, Cohen's $g = .42$). Based on Cohen's definition of a "large" effect size of $g \geq .25$ [4], these findings reflect large effect sizes for both questions in both groups.

Our experiment thus showed that students taught about accessibility – either through lecture and readings or through experiencing simulation games – showed significant increases in their attitudes towards people with disabilities as well as their inclusion of people with disabilities in design scenarios. However, students who experienced the simulation games showed greater increases in empathy: larger effect sizes for the questions about their attitudes towards people with disabilities as well as increases in their understanding of the challenges that people with disabilities face.

This was supported in our open-ended comments in the post-survey asking students to tell us what they thought about the experience. While both groups felt overall that it was educational and helped them learn about accessibility, the simulation games helped students gain a richer understanding of the experiences of people with disabilities, simulating the frustrations they can face even while playing a simple game. The Control group appreciated the new *information* but the Simulation group seemed to articulate a stronger gain in *empathy*.

Some sample Control Group comments include (with minimal modifications to correct typos):

- "I really enjoyed learning about Accessibility needs in software and found the examples very helpful in understanding the translation of Accessibility on the web into real life. This topic brings a different perspective into software engineering and making software inclusive for all!"
- "These modules were very informative and they offered efficient solutions to help developers ensure that they do not inadvertently exclude anyone."
- "This was an interesting exercise which got me to think more about projects I've completed in the past and how I can enhance them to be more accessible to disabled users."

Sample Simulation Group comments, with added emphasis on the "empathy" terms:

- "Very interesting experience in which you could truly *understand what people with disabilities go through in their everyday life*. Truly impressive."
- "It was a great experience! It allowed me to *experience how people with disabilities might feel* when using software that does not have any options in aiding with their disabilities."
- "I enjoyed this exercise and I think it's a great way to get us *thinking more about what it's like to be in the shoes* of

	pre-Attitude		post-Attitude		pre-Challenges		post-Challenges	
	mean	median	mean	median	mean	median	mean	median
Control ($n = 61$)	2.46	2.5	2.3	2.25	3.65	3.67	3.75	4
Simulations ($n = 63$)	2.4	2.5	2.12	2.0	3.6	3.67	4.25	4.33

Table 2: Pre- to post-survey results ($n = 124$)

	pre-Attitude		post-Attitude		final-Attitude		pre-Challenges		post-Challenges		final-Challenges	
	mean	median	mean	median	mean	median	mean	median	mean	median	mean	median
Control ($n = 55$)	2.44	2.5	2.29	2.25	2.5	2.5	3.69	3.67	3.75	4	3.79	4
Simulations ($n = 52$)	2.36	2.5	2	2	2.14	2.25	3.62	3.67	4.34	4.67	4	4

Table 3: Pre-, post- and final-survey results ($n = 107$)

someone who actually has these disabilities. I'll make sure to incorporate these tips into my own programs and games."

- "I really liked this simulation and it really *showed me how difficult* it is to use the internet and games when it is not accessible to individuals with disabilities."

Thus, our answer to R1 is both yes and no: disability simulations do result in a greater increase in student empathy, but they do not seem to result in greater consideration of people with disabilities in design scenarios.

4.2 R2: Duration of Accessibility Learning Gains

Our second question addressed the duration of accessibility learning gains: does learning about accessibility result in longer-term changes in student empathy and awareness than just the immediate post-survey?

To address this question, we consider the results of our final survey (given 4 - 6 weeks after the Stage 1 pre-survey, educational intervention, and post-survey). The survey results are given in Table 3. (Note that the pre- and post-responses do not perfectly align with those in Table 2 because we focus here only on the 107 students who completed all three surveys.) Recall again that the desired responses are lower for Attitudes but higher for Challenges.

For the Control group, we did not find any statistically significant changes from pre- to final-survey for both Attitudes ($p = .47$) and Challenges ($p = .21$). We did, however, find statistically significant changes from pre- to final-survey for the Simulations group, for both the Attitudes ($p = .01$) with a small effect size ($r = .10$) and the Challenges ($p < .01$) with a medium effect size ($r = .43$).

Similar results held for the task domain questions. In the Control group, the rate of inclusion of people with disabilities in the racecar question increased from 30% in the pre-survey to 74% in the post-survey and then dropped to 44% in the final survey, resulting in no statistically significant changes from pre- to final-survey ($\chi^2(1, N = 55) = 2.2273, p = .14$); in the election kiosk, the rates of inclusion of people with disabilities were 44% in the pre-survey, 70% in the post-survey and 59% in the final-survey, with again, no statistically significant increases from pre- to final-survey ($\chi^2(1, N = 55) = 2.7222, p = .1$).

In the Simulations group, however, both questions showed statistically significant increases from pre- to final-survey with large effect sizes. The racecar question had inclusion rates of 29% in the pre-survey, 83% in the post-survey and 63% in the final-survey, showing a statistically significant increase from pre- to final-survey ($\chi^2(1, 52) = 13.14, p =< .001$, Cohen's $g = .41$). The election kiosk's rates were 40% in the pre-survey, 79% in the post-survey and 67% in the final-survey ($\chi^2(1, 52) = 8.45, p = .004$, Cohen's $g = .35$).

The answer to R2, therefore is yes, disability simulations result in longer-term accessibility learning effects compared to lectures and readings. Although the Control group showed short-term improvement in empathy and inclusion of people with disabilities in design scenarios, those effects lasted a scant 4-6 weeks and had virtually disappeared by the time the final survey was administered. In contrast, although the Simulations students' responses were slightly worse in their final-surveys relative to their post-survey responses, there was still a lasting improvement from their pre-survey responses.

4.3 R3: Student Design Decisions In Practice

Rather than rely solely on student self-reported data in the context of surveys about accessibility, we wanted to observe student design decisions in the "real world" (or at least the world of classroom assignments!). A number of logistical complications precluded our using the semester-long group projects that our classes create as the means of observing accessibility inclusion. Instead, we gave all students a homework assignment that included a question designed to ascertain students' inclusion of people with disabilities in a non-survey context (Question #3 in Figure 2).

In addition to being graded on the homework assignment, we took note of student responses for the purpose of this study. Answers to question #3 (and the corresponding question for the E-commerce students) were coded as binary variables reflecting the presence or absence of mention of people with disabilities.

In total, of the 113 students who completed this assignment (57 Simulations, 56 Control), seven students mentioned people with disabilities: two in the Control group (HCI 1 and Game Design) and five in the Simulations group (one HCI 2, two HCI 1, one Game Design, one E-commerce).

We were, understandably, underwhelmed by these responses (which also did not show a statistically significant difference between the Control and Simulations students). It appears that students, distracted by the work of designing and analyzing, largely forget about accessibility and inclusion of people with disabilities.

The answer to R3, therefore, in our experience was no. Disability simulations did not result in evidence of increased consideration of people with disabilities in our assignments when students were not primed to think specifically about accessibility, or when they were distracted by other work.

5 DISCUSSION

In previous work, we created simulation games to teach about accessibility and demonstrated that playing these games resulted in an improvement of student attitudes towards people with disabilities, understanding of the challenges they face, and inclusion of people with disabilities in design scenarios [16]. However, our study did not compare students who played their games with students who were exposed to a more typical form of accessibility education; they also did not include any sort of longer-term study of their games, focusing only on survey results administered immediately after playing the games.

Our work fills in these gaps by comparing the effectiveness of the games to that of another form of accessibility education and by including students' responses on an additional survey given approximately a month later. We demonstrate that although lecture-based accessibility education was successful at decreasing negative stereotypes about people with disabilities and consideration of such users in design scenarios in the short term, this form of education underperformed relative to simulation games even in the short term, since students who played the accessibility games also demonstrated a significantly greater understanding of the challenges that people with disabilities face. Additionally, the learning effects of students in the Control group was short-lived; neither the observed decrease in negative stereotypes nor the inclusion of people with disabilities in design scenarios persisted a month later. In contrast, students who played the accessibility games showed improved outcomes in all three measures assessed (Attitudes, Challenges and Task Domain questions) that lasted through the final survey.

These findings are significant for instructors who teach accessibility (or who are considering teaching accessibility) by helping to ascertain the "optimal" ways to teach about accessibility. Prior work on the subject indicated that experiential learning helps increase student empathy and thus consideration of accessible design (see e.g. [25]); our work suggests that simulation games indeed outperform traditional lectures in teaching about accessibility.

However, our findings also show that "real-world" inclusion of people with disabilities does not necessarily immediately follow from self-reported survey responses. In this, our findings align with that of Ludi et al. [25], who found that increased accessibility knowledge or inclusion of people with disabilities in hypothetical design scenarios did not always correlate with increased accessible design in practice. Although the homework assignment question was similar to the Task Domain questions on the surveys, the "correct" response rate was dramatically smaller. We do caution, however, that it's possible that students behave differently when answering a theoretical question (as in our work) than in actually designing software, since the process of software development may remind students of the need for accessibility in their products.

We also note that students answered the homework assignment with an impressive display of attention to diversity. Responses included mention of participants of various races and ethnicities, economic backgrounds, academic levels, types of schools attending, and languages spoken. This gives us hope that students are already attuned to the needs of diverse populations, and if sufficiently exposed to the needs of people with disabilities, they are likely to consider them as well.

5.1 Threats to Validity

The most significant limitation of our study is that even the 4-6 week interval between the post- and final-survey is insufficient to observe the longitudinal effects of the accessibility educational initiatives described here. Prior work (e.g. [44]) followed up with students 18-24 months after accessibility educational interventions (and found that the vast majority of the learning and attitude effects had reverted).

A second major threat to validity is our use of student responses on a hypothetical homework assignment to see the extent of student consideration of people with disabilities. The accessibility interventions that students received (in both Control and Simulations groups) were geared towards teaching accessibility in a development context and focused on specific software design principles. The homework assignment given to students, in contrast, was hypothetical and engaged them in thinking about experimental design in a way that may have been distracting from their focus on people with disabilities. This drawback makes it difficult to draw any real conclusions from this stage of our study.

Lastly, although both conditions should have taken an equal amount of time for students to complete (about 20 – 25 minutes), we have no way to ascertain whether students in the Control group actually watched the video or read the readings.

5.2 Future Work

A major area of future work is for us to follow up with students after a longer timeframe (such as 18 – 24 months, as in [44]) in order to be able to determine long-term effects. We would also like to revisit the practical portion of this study by assessing students in a software design framework instead of the hypothetical experimental design question. However, the discouraging results of the homework assignments suggest that student inclusion of accessible design in software design may still leave what to be desired.

In fact, we suggest that although our results are encouraging in terms of the ability of simulation games to affect student attitudes and understanding, it is likely that a single accessibility initiative offered one time in one course is insufficient to effect significant and durable change in students' appreciation of accessibility. Rather, it is likely that the most beneficial approach to teaching accessibility is to make it a priority in CS and related departments and programs [33, 38], include it as early as possible in the curriculum [16], distributed throughout the semester [42], and in as many courses as possible (as in [12]), ideally starting even in the K-12 space [15].

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