Introducing Accessible Design to Students in Computer Science

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Abstract

People with disabilities rely on a range of accessible technologies to interface with the digital world. However, their needs are often not considered when developing applications in introductory computer sciences courses. These courses traditionally focus on teaching technical skills that do not include those for designing and developing accessible and inclusive applications. Thus, there is a critical need to enhance students' understanding of designing, developing, and building applications with the needs of people with disabilities in mind early in the computer science program. In this work, we introduced students to designing, developing, and evaluating accessible applications over three academic semesters. We then assessed the impact of accessibility-related activities and the course delivery mode on students' knowledge about accessibility in computer science courses. Our study involved students enrolled in undergraduate computer science courses (*N*=76) and analyzed students' feedback to provide insights that can inform the decision of teaching accessible application design in higher education settings. The results indicate that students became more confident, interested, and familiar with accessible technology after attending a workshop that introduced them to accessibility measures and how they can be included in the software development process. Moreover, students reported that they would consider designing and developing accessible and inclusive applications in their future work.

Keywords: accessibility, computer science, undergraduate courses

Section One: Introduction

Traditionally, computer science courses focus on teaching programming, technical, and problem-solving skills. Students enrolled in computer science programs have few opportunities to learn about designing and developing accessible applications that meet the needs of people with disabilities. According to the Teach Access fact sheet (Teach Access, 2020), the percentage of engineering and computing technology course descriptions that reference "accessibility" or "people with disabilities" is less than 3%. Examples of courses that have incorporated accessibility in their curriculum include (Shinohara et al. 2018) software engineering (Martin-Escalona, 2013), web development (Ko & Ladner, 2016), Human Computer Interaction (HCI), and design courses. However, introductory and first-year programming courses in computer science focus mostly on how to learn the basics of programming and not on how to develop accessible and inclusive applications. Although people with disabilities rely on a range of accessible technologies to interface with the digital world, their needs are usually not considered when developing applications in such introductory courses. Therefore, there is a critical need to enhance students' understanding of designing, developing, and building applications with the needs of people with disabilities in mind early in the computer science program.

One way to enhance students' understanding is for instructors to consider new components for teaching how to design and develop accessible applications, evaluate applications in terms of accessibility, and create accessible data visualizations. Data visualization gives us a clear idea of what the information means by giving it visual context through maps or graphs (Ryan et al., 2019). Visual context makes the data more nat-

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ural for the human mind to comprehend and therefore makes it easier to identify trends, patterns, and outliers within large data sets. However, creating accessible data visualization is usually a challenge. A typical practice for creating accessible data visualizations is to provide alternative text or a data table. This practice may be limited to simple charts and not support analytical tasks or more advanced designs (Siu et al., 2021). Also, many visualization tools do not support accessible design or, even when they do, they can be difficult or confusing to learn (Joyner et al., 2022).

In this paper, we surveyed students enrolled in introductory computer science courses before and after being introduced to accessibility-related activities and teaching materials. We conducted this study to assess the impact of accessibility-related activities and the course delivery mode on students' knowledge about accessibility in undergraduate computer science courses. The objective is to understand if students' knowledge about accessible design increased after being introduced to the accessibility-related activities and identify any changes in students' knowledge due to the course delivery mode and the addition of an accessibility workshop. The study also aims to study students' decisions on accessible design by having them evaluate applications that they commonly use. This paper presents the results and student feedback of the study. Although we may not be able to generalize the results due to the scope of the research, the findings can still suggest recommendations and insights to computer science instructors and institutions on how to select and implement accessibility-related activities in their courses.

The paper presents a case study of accessibility-related material and activities adopted in two computer science courses. More specifically, the course instructors of the Computer Science I and the Data Structures course at our university developed accessibility-related material and introduced students to a workshop in the Fall 2020, Spring 2021, and Fall 2021 semesters. Our study is expected to contribute to further exploratory or descriptive research in the area of teaching accessibility in computer science. Even though our research is solely based on student surveys, the authors expect that instructors and academic experts will be able to find the results and student feedback useful and identify any changes in student knowledge due to the course delivery mode and the type of accessibility-related materials. The outcomes identified in this study provide useful insights that can inform faculty decisions when adopting or creating accessibility-related activities in their courses.

The remainder of the paper is organized as follows: Section Two describes related work on teaching accessibility in computer science courses. Section Three provides an overview of the study design and participants along with a description of the courses and the activities related to teaching accessible design. Section Four describes our assessment of the impact of these activities through student surveys administered before and after instruction about accessibility and presents results from Likert-scale and open-ended feedback from students about their experience teaching accessibility course enhancements. Finally, Section Five reflects on lessons learned and recommendations for future efforts to teach accessibility.

Section Two: Background

The demand for accessible software has continuously increased over the past years. For example, in the United States (U.S.), Section 508 of the Rehabilitation Act (https://www.section508.gov/) requires all electronic technology procured, developed, and used by the federal government to be accessible to people with disabilities. However, most software engineers and designers are not taught about accessibility (Velasco et al., 2004) and overlook the accessibility of software products and services. Thus, educational institutions nationwide and, particularly, computer science programs need to educate the general student population to understand the needs of people with disabilities so that they can design accessible applications.

A number of postsecondary instructors have begun teaching accessibility as part of computer science courses. A survey conducted by Shinohara et al. (2018) examined the extent to which computing and information science faculty in the U.S. teach accessibility. The study had a representative sample of at least one response from 318 institutions, for a total of 1,857 responses. The results indicated that half of the institutions (50%) had at least one instructor teaching accessibility and approximately 2.5% of faculty overall teach accessibility.

Other efforts reported by faculty involved the incorporation of assistive technology or teaching accessibility into computer science courses (Cohen et al., 2005; Shinohara et al., 2017; Zhao et al., 2020). Moreover, consortiums such as Teach Access (https://teachaccess.org/) and AccessComputing (https://www.washington.edu/accesscomputing/) develop accessibility learning materials and offer professional development workshops and resources to faculty to help them teach more about accessibility. Work has also been done on documenting accessibility courses to provide insights on how to create a course on accessibility and what is needed to maintain it. For example, El-Glaly (2020) described the development

process for teaching accessibility within a graduate software engineering course. The results from this study revealed that software engineering students became more engaged with accessibility through programming and technical problems rather than through educational activities used in design and HCI courses.

In this paper, we present a case study of adopting accessibility-related material and activities in two computer science courses, aiming to assist computer science faculty in their decisions to adopt or create accessibility-related activities to include in their courses.

Section Three: Study Design

This research involved surveying students from two computer science classes before and after being introduced to accessibility-related material. The pre- and post-accessibility surveys included questions about the students' accessibility knowledge, interest in the field, and exposure to accessibility-related technology. Most of the questions were multiple-choice with a couple of open-ended questions related to the students' overall thoughts about the accessibility-related material used in class. The study was designed to assess the impact of accessibility-related activities and the course delivery mode on the students' knowledge about accessibility in computer science courses. The study can provide insights and further recommendations on the introduction of accessible design in computer science courses during the first years of study.

Procedure

We collected data through online surveys that were distributed to undergraduate students enrolled in the Computer Science I course during the Fall 2020, Spring 2021, and Fall 2021 semesters and to students enrolled in the Data Structures course during the Fall 2021 semester. To achieve higher response rates and reduce bias in sampling, the instructors offered extra credit points to complete the survey. Sixty-one (N=61) students (51%) completed the survey. All students participated voluntarily, with the assurance of anonymity. A list of the courses included in this work is provided in Table 1.

Courses and Accessibility Workshop

Computer Science I is an undergraduate programming course that introduces students to computers and programming, problem solving, and algorithm development. Through course and lab assignments, students deliver functional command-line Python applications and develop two essential skills: problem solving and programming skills. Data Structures is an undergraduate course that aims to extend the concepts of primitive data structures that pervades both the theoretical and practical domains of computer science. The Computer Science I course is the first course in the sequence of programming course while Data Structures course is the third.

During the Fall 2020, Spring 2021 and Fall 2021, students in Computer Science I were introduced to newly developed modules related to accessible design principles using the Python 3 programming language. The class was taught online during the Fall 2020 semester (synchronously), online during the Spring 2021 semester (asynchronously with pre-recorded video lectures), and face-to-face during the Fall 2021 semester. The pre-recorded video lectures were available to students across all delivery modes. The students completed surveys before and after they were introduced to the modules. The lectures for all delivery modes included the same accessibility content: presentations of accessibility-related definitions, tools, and applications; videos of people with disabilities interacting with technology; and hands-on programming activities. For more information about the materials and content taught in the course, readers can refer to the project website (Angelopoulou, 2020a) and/or the related LibGuide (Angelopoulou, 2020b).

During the Fall 2021, students in Computer Science I and Data Structures courses were introduced to accessibility through a workshop conducted by the university's accessibility specialist. During the workshop, students were introduced to the benefits of accessible applications for people with disabilities and accessibility standards with examples of the implementation of accessible design in different phases of the software development cycle. Students were provided with resources including accessible design tutorials.

In order to compare the students' confidence, interest, and familiarity with respect to the use of accessibility in the software development cycle, the students were asked to complete pre- and post-surveys. After attending the accessibility workshop, students in both courses completed a group project that involved looking at an application that they often use and evaluating the aspects of that application with respect to accessibility. Students in the Data Structures course completed an additional assignment that involved the development of accessible data structure visualizations while providing rationale for the accessibility measures/aspects they used.

Section Four: Data Analysis and Results

This section summarizes the results from the pre- and post-accessibility online surveys and the assignments/projects that the students completed per

Table 1

Overview of Courses Included in this Work (OS = Online Synchronous, OA=Online Asynchronous, F2F = Face-to-face)

Course Name	Semester	Students (pre, post)	Delivery Method	Accessibility Lectures
Computer Science 1	Fall 2020	(24,11)	OS	2
Computer Science 1	Spring 2021	(26,24)	OA	2
Computer Science 1	Fall 2021	(17,16)	F2F	3
Data Structures	Fall 2021	(9,8)	F2F	1
Total	**All semesters**	**(76,59)**	**OS, OA, F2F**	**8**

course. The survey items used a Likert-scale of 1 to 5, with 1 being "Strongly Disagree/Not at all confident" and 5 being "Strongly Agree/Highly Confident." The students' responses and feedback were analyzed by course, delivery mode (i.e., face-to-face, online synchronous, online asynchronous), and inclusion of an accessibility workshop as part of the course content to better understand the impact of each factor on the students' knowledge about accessibility in computer science courses and provide further insights to faculty interested in introducing accessibility in computer science courses.

Analysis by Course

Computer Science I. For the pre-survey, there were a total of 24 responses in Fall 2020, 26 in Spring 2021, and 17 in Fall 2021. For the post-survey, there were a total of 11 responses in Fall 2020, 24 in Spring 2021, and 16 in Fall 2021. The results from the student surveys for Fall 2020, Spring 2021, and Fall 2021 are summarized in Tables 2-4, respectively. The results from student surveys indicate that students' knowledge about accessibility design increased across all semesters. Usage of assistive technologies also significantly increased.

In Fall 2020, all students felt more confident after being introduced to accessibility-related lectures, assignments, and materials. More specifically, students felt more confident about giving examples of universal design, accessible technologies, and technological barriers that people with disabilities might face, as well as about defining the Web Content Accessibility Guidelines (WCAG). These differences between the pre- and post- confidence around examples of accessibility and universal design were statistically significant ($p < 0.05$) using two-sample t-tests. Table 2 summarizes the results for Fall 2020.

The results from the Spring 2021 semester surveys indicate that, in some cases, student confidence decreased after being introduced to accessibility-related topics. More specifically, student confidence for giving an example of describing a type of disability decreased. Moreover, students' interest in learning more about designing or developing technologies for and with people with disabilities or in pursuing a job or research in accessible technology and the development of accessible applications decreased. However, these differences in students' confidence and interest in accessibility were not statistically significant.

On the other hand, students felt more confident in giving examples of inclusive or universal design and how accessible technology can be used by people with disabilities. They were also more confident in defining the purpose of the Americans with Disabilities Act and the Web Content Accessibility Guidelines (WCAG). Table 3 summarizes the results for Spring 2021.

The results from the Fall 2021 semester surveys indicate that students' confidence and familiarity with accessibility-related concepts and features was increased. More specifically, students felt more confident about giving examples of inclusive or universal design, defining the purpose of the Americans with Disabilities Act, and explaining the Web Content Accessibility Guidelines (WCAG). These differences between the pre- and post- confidence around examples of accessibility and universal design were statistically significant ($p < 0.05$) using two-sample t tests. However, students' interest in learning more about designing or developing technologies for and

Table 2

Pre- and Post-Survey Results for the Computer Science I Course During Fall 2020

Statement	**Pre (*N*=24)**	**Post (*N*=11)**	**Delta**
Give an example of a type of disability	3.75 (1.29)	4.50 (0.85)	+20%
Define "accessibility" as the term relates to technology and media	3.30 (1.26)	3.90 (0.99)	+18.03%
Give an example of inclusive or universal design	2.54 (1.25)	4.00 (1.25)	+57.38% (*p*-value = 0.00452)
Give an example of how accessible technology is used by people with disabilities	3.39 (1.12)	4.60 (0.70)	+35.64% (*p*-value <0.001)
Give an example of how assistive technology is used by people with disabilities	3.21 (1.21)	4.00 (1.25)	+24.68%
Give an example of a technological barrier somebody with a disability might face	3.42 (1.44)	4.40 (1.07)	+28.78% (*p*-value = 0.0335)
Define the purpose of the Americans with Disabilities Act	2.38 (1.24)	3.30 (1.34)	+38.95%
Explain the Web Content Accessibility Guidelines (WCAG)	1.88 (0.99)	3.00 (1.49)	+60% (*p*-value = 0.039)
Learning more about designing or developing technologies for and with people with disabilities	3.42 (1.17)	3.91 (1.22)	+14.41%
Pursuing a job or career in accessible technology	3.38 (1.31)	3.27 (1.49)	-3.03%
Pursuing research in the development of accessible technologies	2.96 (1.30)	3.18 (1.25)	+7.55%
Have you ever used assistive technology (such as a screen reader for blind or low vision users)?	4.17%	18.18%	+336.36%
How familiar are you with the accessibility features built into devices (such as smartphones, computers or smart TVs)?	3.33 (1.20)	3.18 (1.07)	-4.55%

Table 3

Pre- and Post-Survey Results for the Computer Science I Course During Spring 2021

Statement	**Pre (*N*=26)**	**Post (*N*=24)**	**Delta**
Give an example of a type of disability	4.40 (1.08)	4.08 (1.35)	-7.20%
Define “accessibility” as the term relates to technology and media	3.88 (1.11)	3.83 (1.34)	-1.32%
Give an example of inclusive or universal design	3.08 (1.55)	3.26 (1.51)	+5.98%
Give an example of how accessible technology is used by people with disabilities	3.69 (1.29)	3.83 (1.34)	+3.82%
Give an example of how assistive technology is used by people with disabilities	3.80 (1.32)	3.96 (1.40)	+4.17%
Give an example of a technological barrier somebody with a disability might face	4.08 (1.26)	4.13 (1.23)	+1.10%
Define the purpose of the Americans with Disabilities Act	3.42 (1.52)	3.58 (1.28)	+4.68%
Explain the Web Content Accessibility Guidelines (WCAG)	2.65 (1.41)	3.00 (1.53)	+13.04%
Learning more about designing or developing technologies for and with people with disabilities	3.58 (1.24)	3.29 (1.56)	-7.97%
Pursuing a job or career in accessible technology	3.38 (1.50)	2.96 (1.49)	-12.59%
Pursuing research in the development of accessible technologies	3.42 (1.42)	3.13 (1.45)	-8.71%
Have you ever used assistive technology (such as a screen reader for blind or low vision users)?	19.23%	33.33%	+73.33%
How familiar are you with the accessibility features built into devices (such as smartphones, computers or smart TVs)?	3.46 (1.27)	3.46 (1.61)	0%

with people with disabilities decreased. Table 4 summarizes the results from the pre- and post-surveys during Fall 2021.

Overall, the applications that the students developed during all semesters in the CS1 course became more accessible compared to the previous years' applications. Students' programs had more descriptive prompts that were clear to the user and allowed for input interactivity. Also, when students were asked if there is content relating to disability or accessibility that they wished had been covered in this course that was not, all students answered that they felt well-informed. They also provided examples of how they will apply what they learned about accessible design and development in their future education, career, or personal life, such as being more aware of the needs of people with disabilities and making sure to include more accessible content when designing their software or web applications.

Overall, all students' confidence and interest in accessibility increased in all semesters, except during the Spring 2021 semester, when the confidence was lower. The decrease in students' confidence and interest in accessibility during the Spring 2021 course may be due to the different format of the class and the pandemic. During the Fall 2020 semester, students were introduced to the concepts online via synchronous delivery. During the Spring 2021 semester, the course format was asynchronous online, so students may not have watched the video or completed the relevant activities on their own. Also, two students in the post-survey answered with "1" across the board, which may indicate that they thought 1 was the highest score rather than the lowest or they just completed the survey without reading the questions properly. We further investigate the impact of the course format on the students' confidence and interest in the next subsection.

Impact of course format on student confidence. We performed a one-way analysis of variance (ANOVA) test to determine if differences in the mean scores of the students' confidence and familiarity with accessibility could be attributed to the course delivery (i.e., face-to-face, online synchronous, or online asynchronous). We further explored if there are differences by conducting pairwise comparisons among the three course delivery modes via the Tukey HSD test.

The results from the tests indicate that there are no significant differences in the mean scores of the students' confidence and familiarity with accessibility based on the course delivery mode. However, it was observed that the confidence in giving examples of inclusive or universal design, of how accessible technology is used by people with disabilities, and of a type of disability, as well as the interest in pursuing a job or career in accessible technology was lower during the online asynchronous delivery mode compared to the other two course delivery modes. Moreover, students' confidence in defining accessibility and the purpose of the Americans with Disabilities Act was lower during the face-to-face course compared to other two course delivery modes. Finally, the students' confidence and interest in accessibility were higher when the course was delivered online synchronously.

Data Structures course. The accessibility-related activities were introduced in the Data Structures course in the Fall 2021 semester for the first time. For the pre-survey, there were a total of 9 responses in Fall 2021. For the post-survey, there were a total of 8 responses. The results from the student surveys are summarized in Table 5.

The results from the Fall 2021 semester surveys indicate that the confidence in some cases was lower after the students were introduced to accessibility-related activities. More specifically, student confidence for giving an example of type of disability or a definition for disability decreased. Students' confidence in defining the purpose of the Americans with Disabilities Act or giving an example of how assistive technology is used by people with disabilities was also decreased. Moreover, students' interest in learning more about designing or developing technologies for and with people with disabilities or in pursuing a job or research in accessible technology and the development of accessible applications decreased. However, these differences in students' confidence and interest in accessibility were not statistically significant.

On the other hand, students felt more confident in defining the Web Content Accessibility Guidelines (WCAG) (p = 0.0281), and became more familiar with the accessibility features built into devices (p = 0.047).

Analysis of Results for Both Courses and the Workshop During Fall 2021

In this section, we analyze the results for both courses separated by confidence, interest, and familiarity questions. During the Fall 2021 semester, we received a total of 26 pre-survey student responses and 24 post-survey responses.

The confidence questions asked how confident students felt about various accessibility aspects from a scale of 1 (Not at all confident) to 5 (Extremely confident). The results of the confidence questions are presented in Table 6.

Table 4

Pre- and Post-Survey Results for the Computer Science I Course During Fall 2021

Statement	**Pre (N=17)**	**Post (N=16)**	**Delta**
Give an example of a type of disability	4.29 (0.92)	4.50 (0.73)	+4.79%
Define “accessibility” as the term relates to technology and media	3.24 (0.90)	3.75 (0.93)	+15.91%
Give an example of inclusive or universal design	3.00 (1.00)	3.75 (0.93)	+25% (*p*-value = 0.033)
Give an example of how accessible technology is used by people with disabilities	3.35 (0.93)	3.88 (1.02)	+15.57%
Give an example of how assistive technology is used by people with disabilities	3.47 (1.12)	3.88 (0.89)	+11.65%
Give an example of a technological barrier somebody with a disability might face	3.94 (1.03)	3.94 (1.06)	0%
Define the purpose of the Americans with Disabilities Act	2.29 (1.10)	3.06 (1.00)	+33.49% (*p*-value = 0.0434)
Explain the Web Content Accessibility Guidelines (WCAG)	2.06 (0.90)	3.00 (0.89)	+45.71% (*p*-value = 0.00509)
Learning more about designing or developing technologies for and with people with disabilities	3.35 (1.22)	3.13 (1.02)	-6.80%
Pursuing a job or career in accessible technology	2.65 (1.32)	3.06 (1.29)	+15.69%
Pursuing research in the development of accessible technologies	2.35 (1.22)	2.88 (1.15)	+22.14%
Have you ever used assistive technology (such as a screen reader for blind or low vision users)?	41%	56%	+36.61%
How familiar are you with the accessibility features built into devices (such as smartphones, computers or smart TVs)?	2.65 (0.93)	3.31 (1.01)	+25.14%

Table 5

Pre- and Post-Survey Results for the Data Structures Course During Fall 2021

Statement	**Pre (N=9)**	**Post (N=8)**	**Delta**
Give an example of a type of disability	4.33 (1.12)	4.00 (1.41)	-7.69%
Define "accessibility" as the term relates to technology and media	3.67 (1.00)	3.50 (1.31)	-4.55%
Give an example of inclusive or universal design	2.89 (0.93)	3.25 (1.28)	+12.50%
Give an example of how accessible technology is used by people with disabilities	3.78 (1.30)	4.13 (1.46)	+9.19%
Give an example of how assistive technology is used by people with disabilities	3.78 (1.30)	3.25 (1.28)	-13.97%
Give an example of a technological barrier somebody with a disability might face	4.00 (1.12)	4.25 (1.39)	+6.25%
Define the purpose of the Americans with Disabilities Act	2.33 (1.41)	2.25 (1.04)	-3.57%
Explain the Web Content Accessibility Guidelines (WCAG)	1.89 (0.93)	3.25 (1.28)	+70.06% (*p*-value= 0.0281)
Learning more about designing or developing technologies for and with people with disabilities	3.56 (1.33)	3.13 (1.25)	-12.11%
Pursuing a job or career in accessible technology	2.78 (1.30)	2.63 (1.06)	-5.50%
Pursuing research in the development of accessible technologies	3.22 (0.97)	2.88 (0.99)	-10.78%
Have you ever used assistive technology (such as a screen reader for blind or low vision users)?	25%	25%	0%
How familiar are you with the accessibility features built into devices (such as smartphones, computers or smart TVs)?	2.67 (0.50)	3.50 (0.93)	+31.25% (*p*-value= 0.047)

In general, all students felt more confident after the workshop regarding accessibility issues. This confidence was most pronounced for explaining the Web Content Accessibility Guidelines (WCAG), and the difference was statistically significant ($p < 0.001$) using the Wilcoxon Signed-Rank survey. Students felt moderately more confident about defining accessibility in technology, giving examples of universal design and accessible technologies, and defining the American with Disabilities Act. There was a very little increase in confidence for students to give examples of a disability, an assistive technology, and a technological barrier.

The second part of the pre-survey and post-survey was gauging student interest on further opportunities regarding accessibility, including pursuing a career or doing research involving accessibility technologies. The scale for the interest questions ranges from 1 (Not interested at all) to 5 (Extremely interested). Table 7 shows summary results for the second part of the surveys.

As can be seen from Table 7, students were more interested after the workshop in pursuing a job or career and doing research in accessible technology. However, students were slightly less interested in learning more about designing or developing technologies for people with disabilities after the workshop. Perhaps, this could be explained by the fact that the students did learn more during the workshop, so after the workshop they may be less interested, as they had just learned quite a bit.

The last section of the survey had one last question about student familiarity with accessible technology in devices, such as TVs and phones. The answers ranged from 1 (Not at all familiar) to 5 (Extremely familiar). The results from this question are shown in Table 8. The difference in familiarity from the pre-survey to the post-survey is statistically significant ($p = 0.017$) using the Wilcoxon Signed-Rank survey. This implies that the workshop greatly increased student familiarity with accessibility features built into devices.

In addition, students had a chance to evaluate the workshop by answering three questions. The students were allowed to respond on a scale of 1 (Not at all) and 5 (Extremely) to the following questions. The results are in Table 9.

Overall, students were mostly moderately interested, as the averages were all slightly above 3 (Moderately). A majority of students (54.16%) would recommend the workshop to other computer science students, while a slightly higher percentage (58.33%) would recommend the workshop to all students.

Students also had the chance to write-in answers regarding how they would apply what they learned from the workshop in the future. Approximately 15 students did explain further, and a majority (53.33%) said they would be more aware of people with disabilities and make sure to include more accessible content. A few more mentioned specific strategies, including being aware of color contrasts for colorblind people, making audio available so closed captioning could be provided for hard-of-hearing or deaf people, and making font sizes larger for people that are hard-of-seeing or use glasses. In summary, the students did become more confident, interested, and familiar with accessible technology after the workshop, and the students implied they would be more aware and more inclusive in their future work.

Section Five: Conclusions

In this paper, we summarized our efforts in introducing accessibility in introductory computer science courses and analyzing the results from student surveys before and after being introduced to accessibility-related activities and teaching material. We provided a detailed description of our findings about the impact of accessibility-related activities and the course delivery mode on students' knowledge about accessibility.

In general, students' confidence and knowledge about accessible design increased after being introduced to accessibility-related activities across all semesters during the pandemic. Our key findings are summarized below:

- Students' confidence in giving examples of universal design and accessible technologies, defining the purpose of the Americans with Disabilities Act, and explaining the Web Content Accessibility Guidelines (WCAG) significantly increased after the introduction of accessibility-related activities
- Students' interest in pursuing a job or career in accessible technology decreased in most of the cases. The interest was increased when the Computer Science I course was offered via face-to-face delivery with an accessibility workshop addition during the Fall 2021 semester
- The course delivery mode did not have a statistically significant impact on the students' confidence and interest in accessibility in technology. However, the students' responses indicated higher confidence and interest when the course delivery mode was online synchronous
- The addition of the workshop on accessibility increased students' confidence, interest, and familiarity with accessible technology. In par-

Table 6

Average Pre- and Post-Survey Responses to Confidence Questions for Both Courses in Fall 2021

Statement	Pre (N=26)	Post (N=24)	Difference
Give an example of a type of disability.	4.31 (0.97)	4.33 (1.01)	0.03
Define accessibility as the term that relates technology and media.	3.38 (0.94)	3.67 (1.05)	0.30
Give an example of an inclusive or universal design.	2.96 (0.96)	3.58 (1.06)	0.62
Give an example of how accessible technology is used by people with disabilities.	3.50 (1.07)	3.96 (1.16)	0.46
Give an example of how assistive technology is used by people with disabilities.	3.58 (1.17)	3.67 (1.05)	0.09
Give an example of a technological barrier somebody with a disability might face.	3.96 (1.04)	4.04 (1.16)	0.08
Define the purpose of the Americans with Disabilities Act.	2.31 (1.19)	2.79 (1.06)	0.48
Explain the Web Content Accessibility Guidelines (WCAG) (or other guidelines for accessible design and development).	2.00 (0.89)	3.08 (1.02)	1.08 (*p*-value <0.001)

Table 7

Average Pre- and Post-Survey Responses to Interest Questions for Both Courses in Fall 2021

Statement	Pre (N=26)	Post (N=24)	Difference
Learning more about designing or developing technologies for and with people with disabilities.	3.42 (1.24)	3.13 (1.08)	-0.30
Pursuing a job or career in accessible technology.	2.69 (1.29)	2.92 (1.21)	0.22
Pursuing research in the development of accessible technology.	2.65 (1.20)	2.88 (1.08)	0.22

Table 8

Average Pre- and Post-Survey Responses to Familiarity Question for Both Courses in Fall 2021

Statement	Pre (N=26)	Post (N=24)	Difference
How familiar are you with accessibility features built into devices?	2.65 (0.80)	3.38 (0.97)	0.72 (p-value =0.017)

Table 9

Average Responses in the Post-Survey to Evaluate the Workshop in Fall 2021

Statement	Post (N=24)
Did you find the workshop interesting?	3.17 (1.09)
Did you find the workshop applicable to your current academic career?	3.21 (1.14)
Did you find the workshop beneficial to your future studies and career?	3.21 (1.02)

ticular, the workshop significantly increased student familiarity with accessibility features built into devices

One limitation of the study is that, although offering extra credit points to students to complete the survey can reduce bias in sampling and increase response rates, it may limit the generalizability of the research findings (Padilla-Walker et al., 2005) and does not determine the reliability of the study. A second limitation of this study is that we did not work with people with disabilities or a disability service provider during the development of the lecture and assessment materials in the first two semesters of introducing accessibility in the courses. During the last semester, we collaborated with an accessibility specialist to offer a workshop about accessible design. Our recommendation to faculty developing or adopting accessibility content in their classes is to involve disability service units in the process. A third limitation is that the courses did not have content addressing user experience, which may have an effect on the results of this study.

As the demand for digital accessibility consideration and best practices in software design and development increases, so does the demand for teaching accessibility as part of the computer science curriculum. In our future work, we will seek collaboration with disability services offices during the development of content for our classes as they can serve as advisors or help faculty find students with disabilities to work on course development. A future study can explore the impact of exposure to accessibility in the curriculum on student behavior, without having accessibility as a requirement in projects and assignments. Another follow-up study could examine the effect of course context on the results by introducing similar accessibility-related content across various courses.

We hope that the present work and our findings can provide recommendations and insights to computer science instructors and institutions on how to select and implement accessibility-related activities in their courses.

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