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# Accessibility Lab #1: Audio Cues

Jan-Michael Guillermo  
jg7934@rit.edu

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# **Accessibility Lab #1: Audio Cues**

by

**Jan-Michael Guillermo**

A Thesis Submitted  
in  
Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Software Engineering

Supervised by

Dr. Daniel Krutz

Department of Software Engineering

B. Thomas Golisano College of Computing and Information Sciences  
Rochester Institute of Technology  
Rochester, New York

July 2019

The thesis “Accessibility Lab #1: Audio Cues” by Jan-Michael Guillermo has been examined and approved by the following Examination Committee:

---

Dr. Daniel Krutz  
Assistant Professor, Department of Software  
Engineering  
Thesis Committee Chair

---

Dr. Michael Stinson  
Professor, Department of  
MSSE

---

Dr. J. Scott Hawker  
Associate Professor, Department of Software  
Engineering

# Dedication

To my family and friends who have supported me, and my teachers who made learning  
fun.

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# Abstract

## Accessibility Lab #1: Audio Cues

**Jan-Michael Guillermo**

**Supervising Professor: Dr. Daniel Krutz**

An increasingly large number of people with disabilities are using software nowadays. However, much of the software created today is inaccessible to people with disabilities. The World Wide Web Consortium (W3C) and many other well-known companies have provided the best practices of creating accessible software. Unfortunately, developers either struggle to sympathize with accessibility issues, do not know the best practices of accessibility design, or both. Hence, there is a need to teach developers about accessibility and how to create accessible software. Unfortunately, accessibility is not widely taught in education.

The *Accessibility Learning Labs* (ALL) were created to address the limitation of readily available, high-quality accessibility educational material. The aim of the labs is to help students understand accessibility issues, increase awareness of the need to create accessible software, and empathize with problems that people with disabilities go through. This research focuses on the first accessibility learning lab utilizing audio cues and teaching students about people with hearing impairments.

# Chapter 1

## Introduction

As the number of people with disabilities grows larger [34, 35], the need for accessibility in software has greatly increased, becoming one of the most important factors to be considered during software development [9]. *Accessibility* means the ability of everyone regardless of their condition to have access to something [38]. More specifically, accessibility means people with disabilities can perceive, understand, and interact with something. Hence, it is the primary goal of universal design. *Universal design* is the design and composition of an environment so that it can be accessed, understood, and used to the greatest extent possible by all people regardless of their age, size, ability or disability [12]. Universal design aims to eliminate barriers and improve access for all. Tim Berners-Lee, the director and inventor of the World Wide Web Consortium (W3C), once stated, “*The power of the Web is in its universality. Access by everyone regardless of disability is an essential aspect.*” [4].

To ensure that software is made accessible to everyone, the Americans with Disabilities Act (ADA) [1] and Section 508 of the Rehabilitation Act [3] were created. Unfortunately, much of the software created today remains inaccessible to many people with disabilities [29, 21, 22, 19, 8] which cause more problems than solutions in their daily lives. In 2012, National Association of the Deaf (NAD) sued Netflix for their inaccessible streaming video platform [27]. Previously, Netflix delivered captioned DVDs to their Deaf and Hard of Hearing (DHH) customers until they changed their services to include online video streaming. However, their online video streaming did not have closed captioning, which was not accessible to DHH customers. With that accessibility issue, NAD took Netflix to courts, and Netflix argued that the ADA applied only to physical places and therefore,



could not apply to website-only businesses. The judge denied the motion and stated that the ADA also applies to the Internet, then ruled that Netflix has to provide closed captioning for their customers. This lawsuit shows that providing inaccessible software could have serious ethical and legal ramifications.

W3C created the Web Content Accessibility Guidelines (WCAG) with the aim of universal web accessibility [39]. Along with that, many well-known companies such as Google [18], Apple [11], Adobe [6], IBM [20], Firefox [14], and Microsoft [26] provide methods in how best to make content more accessible to the general public. Despite the helpful resources, software developers either struggle to comprehend the accessibility issues, do not know the best practices of accessibility design, or both [24]. Hence, there is a need to teach current and future software developers about the importance of accessibility and how to create accessible software. Unfortunately, despite the fact that accessibility is an essential computing topic, it is generally excluded from education [17, 33, 23].

To educate current and future software developers further about accessibility, *a comprehensive collection of accessibility laboratory activities* is necessary to improve the current state of computing accessibility education and expand the workforce to create more chances in developing accessible software. These labs are referred to as the *Accessibility Learning Labs* (ALL), a project funded by National Science Foundation (NSF) [15]. The primary goal of the educational accessibility labs is to increase awareness of the need to create accessible software by demonstrating fundamental accessibility concepts and providing activities to help the students sympathize with the problems that people with disabilities face everyday. There are five initial “ALL” labs being created. However, this paper will focus on the first accessibility learning lab.

The first lab will make use of audio cues to teach students about the *Perceivable* accessibility principle, which we will explore more about later in this paper. Not only that, the first lab also will teach students about people with hearing impairments. The phrase “people with hearing impairments” refers to people with any degree of hearing loss, from mild to profound, including those who are deaf and those who are hard of hearing [37]. “Deaf”

refers to a severe hearing loss, while "hard of hearing" refers to a hearing loss where there may be enough remaining hearing for an auditory device such as hearing aids or cochlear implants to assist with process speech. There is also a matter of self-identification relating to people with hearing impairments. The "small d" deaf people typically do not associate themselves with other members of the deaf community, while the "big D" Deaf people typically have a strong deaf identity and identify themselves as culturally deaf. Some deaf people may favor to identify themselves as hearing or hard of hearing. For that reason, we will be using the phrase "people with hearing impairments" for the rest of the paper.

The rest of the paper is organized as follows: Chapter 2 discusses related work that has motivated this study. Chapter 3 gives an overview of the accessibility learning labs, and Chapter 4 goes into detail on the first proposed lab. Chapter 5 examines the research questions our work addresses and discusses how experiments were set up. This work is then concluded with limitations/future work that arises from the experiment.

# Chapter 2

## Related Work

This chapter will formally define accessibility and then discuss papers related to accessibility in software and education.

### 2.1 Accessibility Definition

W3C [39] defines accessibility as the ability to perceive, understand, navigate, and interact with websites, tools, and technologies regardless of disabilities. First, we must best understand the meaning of disabilities. There are several models of disability that have been defined in previous years. The two most-often used models are the medical and social models of disability [36]. The medical model of disability explains that people are disabled by the impairments they have, while the social model of disability focuses on the idea that society disables people with disabilities and that everything is designed to meet the needs of people without disabilities. Developers typically utilize the medical model as it only focuses on the physical and functional limitations a person may demonstrate and create software that is accessible to them based on their disability while the social model do not benefit the developers as it expects people with disabilities to fix it themselves.

Various studies [25, 7] have shown that accessibility tool kits have been used to explore interaction. An example tool kit is shown below:

- **Visual impairments:** relates to blindness, visual loss, and color vision deficiency.
- **Cognitive impairments:** relates to memory issues and fluid intelligence.

- **Physical impairments:** relates to limited motor skills.
- **Communication impairments:** relates to the ability to speak, hear, express, or read.
- **Socioeconomic impairments:** relates to cultural inclusion and economic considerations.

This shows that there are many accessibility factors to consider during software development and it can be rough for developers to design software to match everyone's needs, but it is not entirely impossible to do so.

## 2.2 Accessibility in Software

Various validators, such as W3C and AChecker [5], can be used to analyze webpages and check if they meet the criteria defined in WCAG [39] to ensure that it is accessible for everyone regardless of disabilities.

Gilbertson et al. [16] conducted an accessibility evaluation on 100 web development company homepages using the web validators and discovered that 46 of the websites failed to provide text alternatives for any non-text content, 36 of the websites failed to show content that can be presented in different ways without losing information or structure, and 71 of the websites failed to make text content readable and understandable.

Calvo et al. [29] conducted a study where seven accessibility experts investigate mobile and desktop websites/applications and create accessibility evaluation reviews using the criteria from WCAG. Using the information from reviews, the researchers discovered that a total of 1,214 issues, such as incorrectly hidden information, unused common design patterns, small button/text size, bad color contrast ratio, and many others, were found along various sport, government, bank, airline, and other websites.

To improve video game accessibility, International Game Developers Association (IGDA) compiled a list of their top ten accessibility design guidelines [2]. Porter et al. [28] conducted two studies - one involving an online survey of 55 gamers with disabilities based on

their play habits, experiences, and accessibility issues, and another consisting of interviews with individuals from game industries to better understand their accessibility design process. First, the researchers analyzed the top ten grossing PC games of 2011 and discovered that the majority of the games completely met at least four out of ten IGDA's accessibility guidelines. The first study showed that many people with motor and cognitive impairments had accessibility issues with video games regarding the lack of screen reader accessibility, compatibility with modified assistive controllers, and game speed control. The second study showed that video game developers have a lack of awareness or education regarding accessibility and are unable to conceptually grasp the implications of inaccessible video games.

Giraud et al. [32] conducted a study with six blind participants performing various tasks (buy a CD, post a message, send a message, and others) on Fnac and Facebook. The average execution time of tasks on Facebook for sighted users is about 6 seconds, while blind users took 25 seconds to execute a task. The researchers learned that websites had inappropriate content for an easy and fast comprehension and the information exhaustiveness of webpages. Screen readers would read “handheld recorder (5)” as “handheld recorder opened bracket 5 closed bracket” instead of “5 handheld recorders”. This mentally exhausted blind users as they needed to do more work to figure out the correct order for the information.

Those studies have shown that accessibility has become one of the important factors in software development and there is a need to teach developers more about accessibility and the ability to make software accessible for everyone.

## **2.3 Accessibility in Education**

Shinohara et al. [23] conducted a survey with 14,176 computing and information science faculty in the United States and received 1,857 responses. The survey showed that about 175 institutions had at least one instructor teaching accessibility. Most responses agreed that accessibility should be taught in computer-related courses, but the lack of expertise

and sub-area specific materials act as key barriers for accessibility education. Most faculty also expressed that they were open to learning accessibility.

Kawas et al. [30] conducted 18 semi-structured interviews with U.S. computer science faculty regarding a web-based professional development tool that linked accessibility topics to CS topics. The tool allowed users to map CS learning objectives to accessibility learning objectives and in turn, the tool provided relevant materials that taught specific accessibility topics. The faculty expressed enthusiasm in the tool. Unfortunately, most of the faculty were restrained by narrow choices due to curricular frameworks, fear of change due to departmental values, and a lack of time due to busy schedules.

Ludi et al. [31] conducted a study where students took a human-computer interaction (HCI) course and received a week of lectures about accessibility. The study had two groups where one had first-hand interaction with someone with a disability and the other did not. Based on the survey results, the group that interacted with people with disabilities had more sympathy and accessibility awareness compared to the other group.

Freire et al. [10] proposed an approach for web accessibility education taking advantage of short introductory courses. The researchers conducted an experiment using the approach with 18 participants. The experiment had the participants use screen readers either with blindfolds on or display off, then had them evaluate a small website containing accessibility issues that was developed by the researchers using WCAG. Testimonials by students expressed that the experiment helped them understand the difficulties and barriers faced by blind users.

Studies have shown that accessibility is an essential computing topic that needs to be widely taught all over the United States. To improve the current state of accessibility education, we need to invest more resources in creating accessibility learning materials, having more accessibility experts teach computing classes, helping future developers understand the barriers faced by people with disabilities, and creating more accessible software.

# Chapter 3

## Accessibility Learning Labs

This chapter will discuss accessibility learning labs further by stating their objectives. The initial labs and their components will be presented. Finally, an explanation of how the student will walk through each lab activity will be provided.

### 3.1 Objectives

The goals of the labs are to motivate students to create accessible software and to inform students how to create accessible software. These labs can be easily integrated into existing introductory computing courses and will provide instructors with teaching materials including videos, lecture slides, and activities. Each lab activity will be written entirely in HTML, CSS, and JavaScript so that it will be able to run on any computer that has a modern web browser and Internet connectivity.

### 3.2 Initial Labs

ALL will be comprised of five initial labs:

- **Lab 1: Use of Audio Cues [Hearing Impairment]:** This lab aims to introduce the *Perceivable* accessibility principle. This principle explains that information and user interface components must be presentable to users in ways that they can perceive [39].

- **Lab 2: Use of Colors [Visual Impairment]:** This lab aims to introduce the *Distinguishable Content* accessibility guideline. This guideline explains that the content must be distinguishable to make it easier for users to see and hear content including separating foreground from background [39].
- **Lab 3: Where to Click? [Visual Impairment]:** This lab aims to introduce the *Understandable* accessibility principle. This principle explains that information and the operation of user interface must be understandable [39] and contains different guidelines such as that the text content must be readable and understandable, web pages must be made able to appear and operate in predictable ways, and there should be input assistance to help users avoid and correct mistakes.
- **Lab 4: Autoplay Video [Visual and Hearing Impairment]:** This lab aims to introduce the *Audio Control* accessibility guideline. This guideline explains that if there is any audio on a Web page that plays automatically for more than 3 seconds, there must exist either a mechanism to pause or stop the audio or a mechanism to control audio volume independently from the overall system volume level [39].
- **Lab 5: Captions [Hearing Impairment]:** This lab aims to the introduce the *Time-based Media* accessibility guideline. This guideline explains that if non-text content is time-based media, then text alternatives must provide descriptive identification of the non-text content [39].

Each lab will address at least one accessibility issue and contain: relevant background information on the examined accessibility issue, an example activity that contains an accessibility issue, a process to emulate this accessibility process, details on repairing the accessibility issue from a technical perspective, and information from actual people about how this accessibility issue has impacted their life. These labs will be able to cover a diverse set of accessibility topics and be easily understood in courses.



### 3.3 Lab Components

Each lab will contain several components. These components are further described in Table 3.1.

Table 3.1: Lab Components

<b>Component</b>	<b>Description</b>
Accessibility information	Background information regarding the accessibility issue in the lab activity. This will include information about how people with specific disabilities are affected.
Lab instructions	Information on performing the lab.
Lecture slides	Slides that an instructor may use to present the material.
Video presentation of lecture slides	ADA-compliant video of the lecture being presented. This will support students performing the labs on their own or in the flipped classroom environment.
'Empathy' material	Written material and ADA-compliant video from actual people with disabilities, along with industry professionals explaining why it's important to address the specific accessibility issue in software.
Video of conducted lab	ADA-compliant video of the conducted lab
Lab activity	A lab activity to be conducted
Emulation component	Feature to emulate accessibility challenges for people with disabilities.

*Continued on next page*

Table 3.1 – *Continued from previous page*

Component	Description
Quiz	Quiz that will be provided to instructors if they'd like students to be evaluated at the end of the activity.

### 3.4 Steps for Lab Completion

Each lab has three main steps:

1. **Discover the accessibility issue:** Each lab will address at least one accessibility issue. Students will use an inaccessible version of the software to directly experience the effects of inaccessible software on people with disabilities. This demonstration will help students understand accessibility issues, increase awareness of accessible software, and empathize with problems that people with disabilities go through.
2. **Explain the accessibility issue:** Each lab will explain the accessibility issue that was demonstrated in the activity. The lab will address the accessibility guideline that can fix the accessibility issue. Best practices of accessibility design and implementation [18, 11, 6, 20, 14, 26, 39] will be utilized to properly teach students how to properly design and implement accessible software.
3. **Fix the accessibility issue:** After experiencing the effects of how people with disabilities use inaccessible software, the lab will walk students through the necessary steps to fix the accessibility issue by applying the accessibility guideline addressed in the activity. By doing this, students will understand how accessible software will positively impact the experience for people with disabilities.

# Chapter 4

## Lab 1: Hearing

This chapter provides the objective and full details of the components of the first accessibility learning lab. Not only that, the surveys, supplementary materials, and lab quiz will be also briefly explained.

### 4.1 Objective

The primary goal of the first accessibility learning lab is to teach students the *Perceivable* accessibility principle. The *Perceivable* accessibility principle explains that information should be presented in multiple forms (visual, auditory, or tactile) without a loss of information [39]. In this lab, we will demonstrate that applying this accessibility principle will enhance the accessibility for Deaf and Hard of Hearing users by presenting audio information visually.

### 4.2 Pre-Survey

The pre-survey's goal is to assess the initial knowledge students have regarding accessible software and people with hearing impairments. The questions are listed below. Each question can be answered with a linear scale from one to four: 'one' ranks strongly disagree, while 'four' ranks strongly agree.

1. How strongly do you agree with the statement: 'It is difficult to create accessible software'?

2. How strongly do you agree with the statement: ‘I find planning for accessible software difficult’?
3. How strongly do you agree with the statement: ‘I frequently think about accessibility when designing software’?
4. How strongly do you agree with the statement: ‘I look for accessibility features when I get a new app’?
5. How strongly do you agree with the statement: ‘I consider accessibility as a top priority when designing software’?

After completing the lab activity, students will be tested again with their new knowledge in the post-survey using the same questions from the pre-survey.

### 4.3 Supplementary Materials

The supplementary materials for the first accessibility learning lab consist of lecture slides, a testimony video, and a case study, which are further shown in Table 4.1. These materials are to provide students with the information on people with hearing impairment, how inaccessible software can impact those people, and how to create accessible software for DHH people.

Table 4.1: Supplementary Materials

<b>Material</b>	<b>Description</b>
Lecture slides	Provide information on hearing impairment and how to create accessible software.
Testimony video	A video from a DHH individual explaining how their hearing loss has impacted their life and how inaccessible software has affected them.

*Continued on next page*

Table 4.1 – *Continued from previous page*

Material	Description
Case study	A case study explaining the ethical and legal importance of developing accessible software.

## 4.4 Lab Activity

To demonstrate the problem to users without hearing impairments, a simple game will be developed to help hearing users face what DHH users may encounter when using inaccessible software. This game, referred to as **Treasure Hunter**, consists of a hint box and four boxes, shown in Figure 4.1.

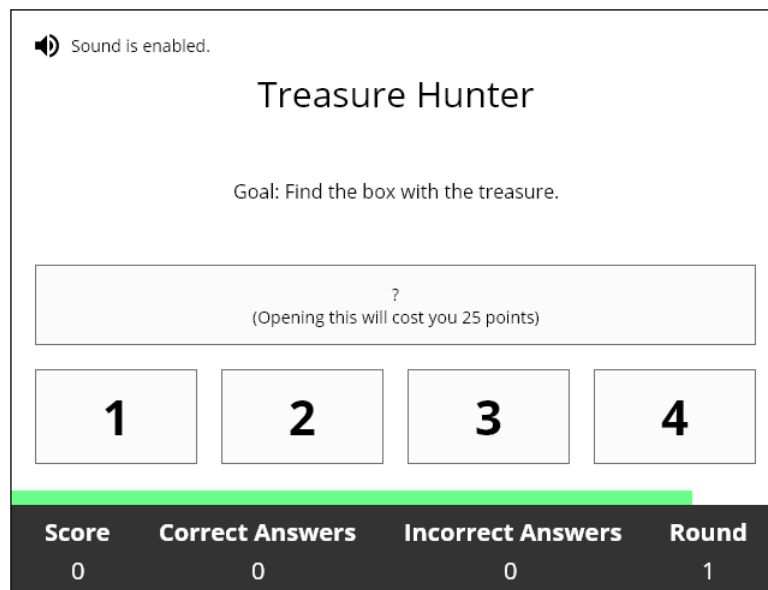


Figure 4.1: Concept Design

The objective of the game is to find the box that contains the treasure and get the highest score. The hint box can be used to get a hint on the location of the treasure with a cost of a set amount of points. After the player uses the hint box, figure 4.2(a) shows the location of the treasure by adding a glow outside the specific box and hovers an arrow underneath.

However, the hint box is not always guaranteed to contain a hint inside, shown in Figure 4.2(b). If the player selects a box that contains no treasure, they will have points taken away from their score. Otherwise, their score will be increased by a number of points, and the game proceeds to the next round. To inform the user that the hint box contains a hint inside, an audio cue will play in the beginning of each round with a fifty percent chance of occurring.

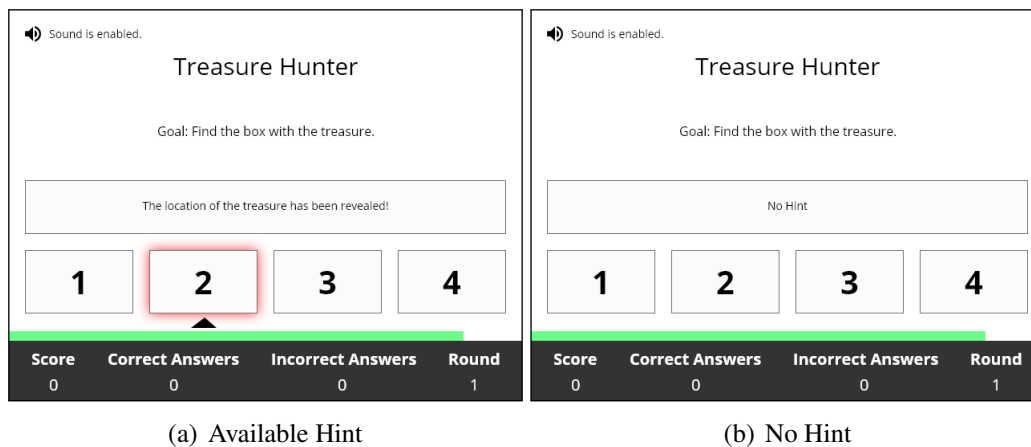


Figure 4.2: Results after opening the Hint Box

To avoid the player taking advantage of the hint box without delay, the hint box will “wait” for a set amount of time before giving out the answer, shown in Figure 4.3. This feature gives players more incentive to carefully pay attention to the audio cue every round in order to have as high a score as they can in a limited time.

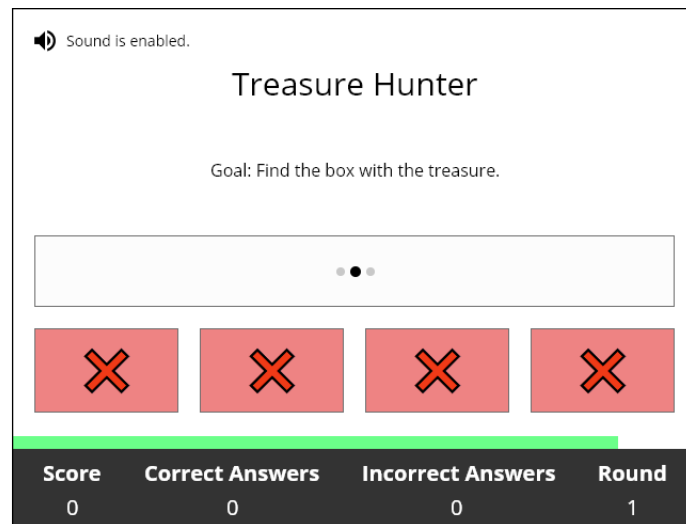


Figure 4.3: "Thinking" Hint Box

### 4.4.1 Playthroughs

To provide a complete learning experience of the lab activity, each student will play a total of at least three playthroughs:

- **First Playthrough:** This playthrough will have hearing users play the game with sound enabled.
- **Second Playthrough:** After completing the first playthrough, the hearing users will play the game again, but with sound disabled. This is to provide students a simulation of what users with hearing impairments experience every day using inaccessible software.
- **Third Playthrough:** After completing the second playthrough, the hearing users will have an opportunity to repair the lab activity. This is to teach students the proper approaches to repair inaccessible software that utilizes audio cues as well as to create accessible software.

This approach is set up that way so that the student should have a lower score in the second playthrough compared to other playthroughs. This is to demonstrate if software is

not accessible, they will feel helpless and unsure on what to do, reasoning that it is critical to design accessible software for everyone. Finally, a graph of the scores from all the playthroughs, shown in Figure 4.4, will be shown at the end of the lab activity to help the student realize the impact of inaccessible software on people with hearing impairment.

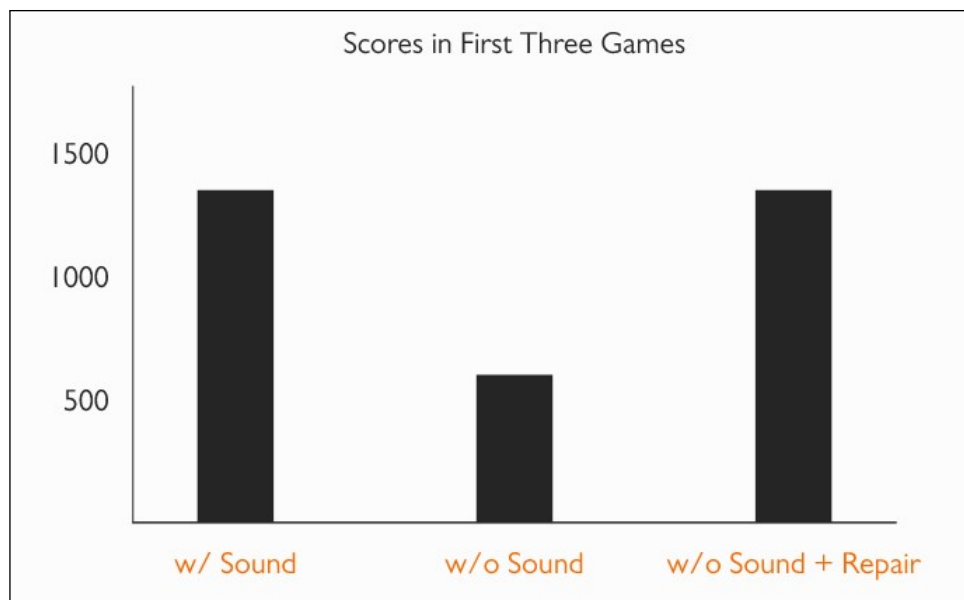


Figure 4.4: Results after playing three games

#### 4.4.2 Repair Process

To fix the accessibility issue, a repair editor will be provided in the beginning of the third playthrough. The repair editor provides a code simulation and allows the user to tweak the hint box's messages and background color to convey key information, as shown in Figures 4.5 and 4.6. The purpose of the repair process is to teach the students how to make software more accessible for people with hearing impairments.





The image shows a code editor window with two tabs: 'HintBox.js' and 'HintBox.css'. The 'HintBox.js' tab is active, displaying the following JavaScript code:

```
// This is where you can change the hint box's default messages.
import React, { Component } from 'react';

class HintBox extends Component {
  render() {
    let { hint, isExtended } = this.props;
    let content = "?";

    // Check if hint is empty
    if (hint !== "") {
      // Update the variable 'content' to "Available Hint here!"
      content = '?';
    } else {
      // Otherwise, update the variable 'content' to "No Available Hint yet..."
      content = '?';
    }

    return (
      <div>
        { isExtended ? (hint ? hint : "No hint") : content }
      </div>
    );
  }
}

export default HintBox;
```

A red rectangular overlay is positioned over the code, containing the text 'Update' in white, centered within the box.

Figure 4.5: Repair Editor: Changing Messages

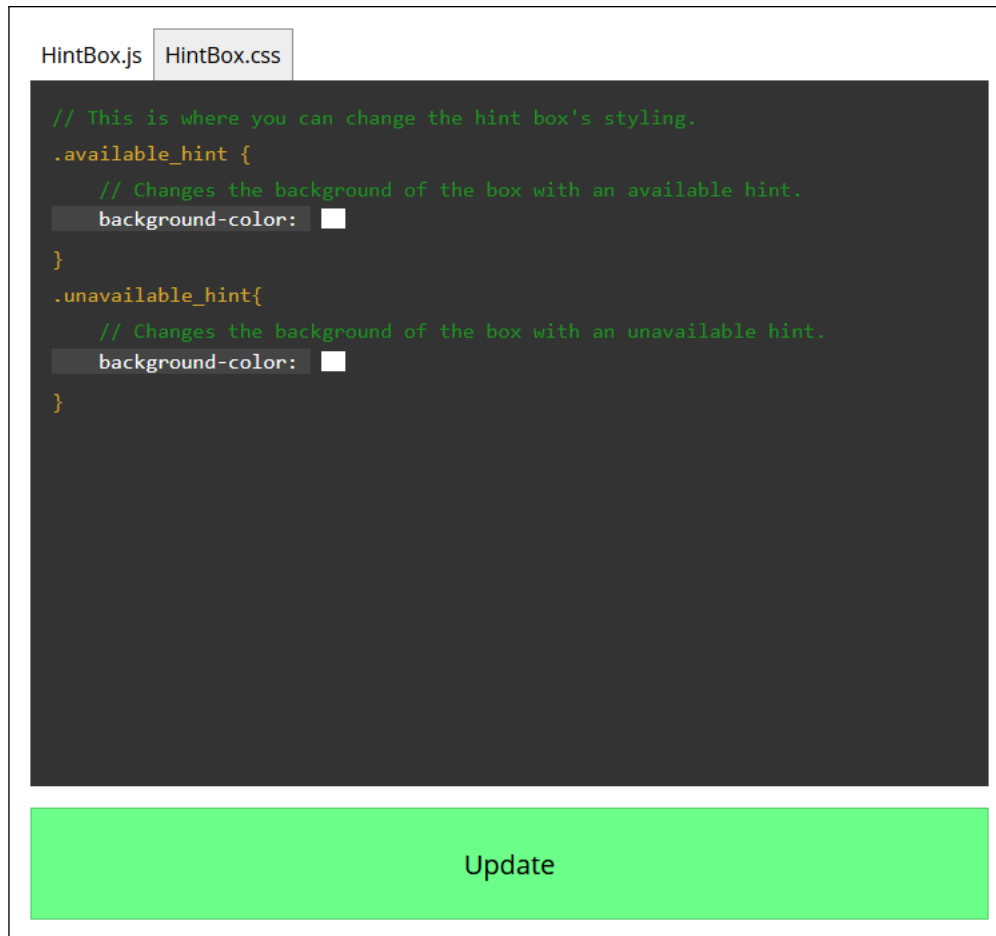


Figure 4.6: Repair Editor: Changing Background Color

### 4.4.3 Data

The lab activity will collect all of the players' data in the various playthroughs, further explained in Tables 4.2, 4.3, 4.4, and 4.5:

Table 4.2: 'AudioCue\_Game' Table

Data	Description
GameID	A unique identifier for the game
LoginID	A unique identifier for the player
Score	The score the player received in the game
Playthrough	The playthrough number the player is currently on
TimePlayed	Timestamp indicating when the game was played

Table 4.3: 'AudioCue\_Round' Table

<b>Data</b>	<b>Description</b>
RoundID	A unique identifier for the round
GameID	A unique identifier for the game
HintUsed	A boolean value indicating whether hint has been used or not
SoundOption	A boolean value indicating whether sound is on or not

Table 4.4: 'AudioCue\_Choice' Table

<b>Data</b>	<b>Description</b>
ChoiceID	A unique identifier for the choice
RoundID	A unique identifier for the round
BoxNumber	The box number the player selected
Correct	A boolean value whether the player is correct or not

Table 4.5: 'AudioCue\_Repair' Table

<b>Data</b>	<b>Description</b>
RepairID	A unique identifier for the repair
LoginID	A unique identifier for the player
AvailableMessage	The message that shows when there is a hint
UnavailableMessage	The message that shows when there is no hint
AvailableBackgroundColor	The background color that is used when there is a hint
UnavailableBackgroundColor	The background color that is used when there is no hint

Chapters 5 will utilize the 'Score' data from the 'AudioCue\_Game' table, more explained later on. The remaining data is not used for the evaluation. However, it may serve helpful information for future purposes.

## 4.5 Quiz

After performing the lab activity, the students will go through a quiz to test their knowledge on people with hearing impairments, audio cues, and the best approaches to fix the

accessibility issue regarding audio cues. The quiz questions are listed below along with answers:

1. **What is an audio cue?** *A playing sound that conveys key information.*
2. **How many people (aged 18 and over) with hearing loss are there in the United States?** *30-40 million people.*
3. **What's a sign of hearing loss?** *Have trouble hearing over the telephone, think that others seem to mumble, and need to turn up the TV volume so loud that others complain.*
4. **How is hearing loss caused?** *Noise, age, disease, and heredity.*
5. **Do users with hearing loss have a disadvantage when they use applications that utilize audio cues?** *Yes.*
6. **How do you make an application that utilizes audio cues more accessible to Deaf and Hard of Hearing users?** *Add additional messages and add visual cues.*
7. **When should accessibility be considered in the development process?** *From the beginning.*
8. **Who is responsible for creating accessible software?** *Software developers, user interface designers, and accessibility experts on the development team.*
9. **What does the 'Perceivable' accessibility principle mean?** *Information and user interface components must be presentable to users in ways they can perceive.*
10. **Which of the item(s) below are accessible to Deaf and Hard of Hearing people?** *Vibrating alarm clocks and strobing doorbells.*

## **4.6 Post-Survey**

The post-survey contains the same questions as the pre-survey. After going through the supplementary materials and lab activity, this survey will test the students' newfound knowledge.

# Chapter 5

## Evaluation

This chapter will first present the research questions for this study. Then a full explanation of how the first accessibility learning lab is evaluated will be provided.

### 5.1 Research Questions

To investigate whether the first accessibility learning lab is effective in improving the current state of accessibility in an educational context, we present the following research questions:

**RQ1. How effective is the lab in motivating students to create accessible software?**

**RQ2. How effective is the lab in educating students to create accessible software?**

For RQ1 and RQ2, using the statistical tool R, the answers to the pre-survey and post-survey questions listed in Chapter 4 by students are compared. The results between students who learn through existing accessibility activities (Group A) and students who learn through the lab along with the supplementary materials (Group C) are compared to determine whether if the proposed lab along with the supplementary materials are more effective than available provided materials such as through W3C.

**RQ3. How effective are the supplementary materials?**

To investigate whether including supplementary materials along with the lab activity are effective in improving student response to the lab, the results between people who

learn through the lab without the supplementary materials (Group B) and Group C are compared.

**RQ4. Does the absence of sound impact the user’s response rate?**

Using the data collected from the lab activity, we compare the scores from both the first and second playthroughs, factoring in that the sound is enabled in the first playthrough, and off in the second.

## 5.2 Experiment Setup

This section outlines how the first lab is set up in each course.

### 5.2.1 Course

The first accessibility lab got permission to be tested in a single online introductory computing course (N = 8), split into three groups as shown in Table 5.1. More information on each group will be further detailed in the section below.

Table 5.1: Evaluation Groups

Group	# of students
A	2
B	3
C	3

The online class uses MyCourses, a tool that allows instructors and students to interact and with access to course materials online. MyCourses will split the students into three groups and show material based on the assessment group.

### 5.2.2 Groups

Students in each course will be split into three assessment groups:

- **Group A:** The students will learn the material through existing accessibility activities such as Firefox [13], W3C [40], and others. These students will be considered our control group.
- **Group B:** The students will learn the material through the first accessibility learning lab. However, the supplementary materials will not be taught to these students. This is the first study group to determine if the lab approach is effective in teaching accessibility concepts and making students understand the need of accessible software.
- **Group C:** The students will learn the material through the first accessibility learning lab, including the supplementary materials. This is the second study group to determine if the lab approach along with the supplementary materials is effective in teaching accessibility concepts and making students understand the need of accessible software.

Each assessment group will have their own specific instructions to complete the lab activity.



## Chapter 6

# Limitations and Future Work

This chapter identifies factors that limited this study regarding the first accessibility learning lab, and in turn, a suggestion will be provided for future work to combat each limitation shown below.

Due to the time constraints, the most notable limitation is that the first accessibility learning lab was only tested in a single computing course ( $N = 8$ ). Not only that, the course that conducted the first lab was online. There is no evidence that the first lab would deliver the same results both in-person and online courses. The lab was also not successfully completed in the time for this paper. In the future, the first lab should be tested in more courses to confirm that the accessibility labs in fact help improve the current state of accessibility education and increase awareness of the need to create accessible software.

Existing accessibility activities relating to audio cues and people with hearing impairments were to be utilized for Group A (explained in Chapter 5), but they were quite limited, as either, they do not contain sufficient information or provide enough activities. However, this is the reason why the accessibility learning labs are proposed to address this problem. The labs are needed for two reasons: to teach developers how to create accessible software, and to conduct research on how to best teach developers about accessibility issues.

Another notable limitation is that the testimony video was not able to be created in the time for the experiment, so the supplementary materials only consisted of lecture slides and a case study for students to learn the material. However, the video will be created for future lab activities.

# Chapter 7

## Conclusion

This paper presents the accessibility learning labs as a solution to the lack of high-quality accessibility educational materials and discusses the first accessibility learning lab. This work shows that the first lab teaches students to understand accessibility issues, increase awareness of the need to create accessible software, and empathize with problems that people with hearing impairments go through every day. While the experimental results from a single course during the evaluation of the first lab are not enough to ultimately conclude the validation of the research questions, this is truly the first step in improving the current state of accessibility education and teaching current and future software developers the proper approaches to create accessible software.

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