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Pedagogical Evaluation of Cognitive Accessibility Learning Lab in the Classroom

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Pedagogical Evaluation of Cognitive Accessibility Learning Lab in the Classroom

by

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Abstract

In a study conducted by Webaim, 98.1% of sites had a detectable accessibility issue. This poses a profound challenge to the 1 billion users across the world who have a disability. This indicates that developers either are not aware of how to make the sites accessible or aware of how critical it is to make the sites usable by all users. This problem is further compounded by the lack of available resources that can educate students and future developers in making their software accessible. To address current limitations/challenges, we have developed an all-in-one immersive learning experience known as the *Accessibility Learning Labs* (ALL). These modules are carefully crafted to provide students a better understanding of various accessibility topics and increase awareness. They incorporate the best of all learning methods, from case-studies to hands-on activities and quizzes.

In this paper, we focus specifically on the cognitive module developed under the Accessibility Learning Labs. This module strives to educate students on the importance of building accessible software for users with cognitive disabilities. We discuss the pedagogical approach used to craft the components of the cognitive module and the design rationale behind the experiential activity. We investigate how the order of the reading and experiential activity affect the students' understanding of the material. To do this, we perform a study involving 28 students in 2 computer science related courses. Our findings include: (I) The accessibility improvements made in the lab have a positive impact on the students' performance when compared to the inaccessible version (II) When the reading material is presented after the experiential activity, students have a better understanding of the cognitive accessibility principles.

Chapter 1

Introduction

According to the US Census, over 16 million people are living with cognitive a impairment [11]. These individuals face difficulties in perception, memory, language, attention, problem-solving, and comprehension [12]. Thus, they have an especially difficult time using the software. For instance, a user with Dyslexia experiences visual stress when dealing with large amounts of text and therefore needs well defined headings to better navigate the content. Unfortunately, much of the software developed today is not built in an accessible manner [24, 21]. This is attributed, in part, to the lack of accessibility-related material to educate engineers on how to build accessible software [19]. Moreover, based on existing pedagogic literature there is a deficiency in support for this field to grow in teaching and learning [13].

To combat this, we developed a set of immersive learning modules known as *Accessibility Learning Labs* (ALL). These labs provide students an all-in-one learning experience to educate them on the various accessibility principles. Each of the labs has the following components: (I) Background material on the topic (II) A hands-on activity that teaches the accessibility principles (III) Empathy creating material (IV) A quiz to test the students' understanding. The labs are available via browser, making them easily adoptable and incorporated into an already packed curriculum. One of the primary goals of these labs is to demonstrate the need to create accessible software, as future improvements to the accessibility landscape is driven through these young engineers.

The focus of this paper is to introduce the cognitive accessibility lab, which utilizes best practices from Web Content Accessibility Guidelines (WCAG), published by W3C

[4]. Cognitive disabilities are widespread and diverse, ranging from Alzheimer's to developmental disabilities such as Down Syndrome. The severity of this issue in combination with the lack of supporting material makes cognitive accessibility a crucial topic to cover. Moreover, the technologies of cognitive accessibility improvements, such as text simplification and single sign-on systems, can have great value for many other users [12].

To verify the effectiveness and educational impact on the students, we evaluated this module in several computing courses. More specifically, we evaluated them in a software engineering Research Methods course as well as in a Human Computer Interactions course, totalling 28 students. The material was incorporated through both in-person and online course offerings. Through this, we found that (I) The labs effectively communicated the accessibility principles (II) The accessibility repairs had a significant improvement on the students' user experience (III) Students had a better understanding of the principles when the reading material followed the experiential activity.

To summarize, this work makes the following contributions:

- **Systematic evaluation:** In this paper we break down the components of the Accessibility learning lab. More specifically, we describe the approach to developing the intervention activity. Every sub-activity aims to reinforce the WCAG guidelines and best practices for cognitive accessibility. Our analysis demonstrates that these sub-activities meets the learning objectives set forth in the paper.
- **Impact of reading and intervention material arrangement:** We analyze the impact of the order of intervention activity and reading material on student learning. Through our conducted research, we conclude that students gain a deeper understanding of the material when the reading material follows the experiential activity. This is supported by the significant increase in quiz scores.
- **Impact of proposed accessibility improvements:** To further examine the suggested improvements and validity of the accessibility repairs presented in the lab, we evaluate multiple data thresholds. Specifically, we evaluate the time spent to complete the given activities and the correctness of the comprehension questions

following the activity. We evaluate these metrics before and after the accessibility repair and observe statistical improvement. Based on our results, we confirm that the improvements increased the accessibility of the page.

The rest of the paper contains the following chapters: Chapter 2 presents the related works and motivation for this paper, Chapter 3 takes a holistic view of the Accessibility Lab, Chapter 4 describes the specific construction of the intervention activity, Chapter 5 discusses the research questions and analysis, Chapter 6 presents the discovered results, Chapter 6 discusses limitations, and Chapter 7 provides a conclusion.

Chapter 2

Related Works

There is currently a lack of accessibility standards and practices utilized in software engineering. Much of the web continues to cater to the “everyday” user instead of to a broader audience, leading to a lack of inclusiveness for those with disabilities. Scientifically, if developers incorporate accessibility into their software it will benefit everyone since various environments can impact the usability of the software. For instance, a person with sleep deprivation will face similar struggles using the software as one with permanent cognitive impairments [1]. Thus, software made accessible to users with cognitive disabilities using features like simplified text, can also be beneficial to users using the software in limited cognitive settings [2].

How do we improve the current climate of accessibility on the world wide web? We start by introducing accessibility in early education so that developers are aware of these issues and can make conscious decisions with accessibility in mind [18, 8, 23]. According to Leventhal *et al.* [18] and Shaun Kane [8], inclusion of accessibility in a curriculum is crucial as it shapes the students’ attitudes towards issues in computing. Leventhal *et al.* experimented with 63 Computer Science students at Bowling Green State University who were asked to complete a term project with significant accessibility requirements, such as accommodating users with motor abilities by coming up with unique alternatives to traditional up/down arrow keys. These students completed a pre/post survey and researchers found that students significantly increased their ratings on the importance of accessibility. This work supports the idea that experiential learning labs increase student engagement in accessibility and raise awareness of the issue [18].

However, this approach and that proposed by Rachel Menzies *et al.* [15] requires major revamping of the course. This time-consuming task involving approval from the department and training on the faculty end [9], presents a great source of resistance for incorporating accessibility. One of the leaders in computing accessibility, Access Computing [10], which is funded by the National Science Foundation, still struggles to find a nationwide plan for incorporating this into the curriculum. Our solution avoids this pitfall, by providing a lab that includes all the material for the instructors. Students simply navigate to the Accessibility Learning site and follow the activity instructions. As an added bonus, there is no overhead. The publicly hosted site requires no maintenance or cost from the schools. It is handled by our team who work diligently to roll out new and relevant material so students can continue to expand their accessibility knowledge.

We believe that students learn best when they can engage with the material from multiple perspectives [24]. This is why our lab utilizes active pedagogies through learning by doing, immersion, and simulation. Students start by experiencing the accessibility problem from the perspective of the cognitive impaired user. Next, they learn how to refactor the code and perform the repair themselves. Lastly, they observe the impacts of the changes to appreciate the improvements made to the usability of the software. This type of hands-on learning is endorsed by researchers like Shaun Kane [8] who understand that simply showing resources like WCAG guidelines does little to teach students on how to incorporate accessibility. Instead, learning modules should challenge students to actively recognize weaknesses in software and correct them with the appropriate repairs.

Our lab doesn't stop at just the interactive module. We incorporate one more essential component: empathy-building material. Empathy, according to Cynthia Putnam *et al.* [19], significantly increases student appreciation and connection to the learning material. Researchers like Rachel Menzies *et al.* [15] advocate small group meetings with users of various disabilities to empathize and better understand how to come up with solutions to meet their needs. Similarly, we incorporate this in our lab as a set of videos in which impaired students at higher level education talk about their experiences with using inaccessible software. In particular, they mention the hurdles they face in performing basic tasks, demonstrating the need for creating accessible software.

Similar work has been performed by Weishi Shi et al. [24]. Like our proposed solution, they used multiple components to incorporate accessibility into the existing curriculum. Each lab contains a case study, module, and quiz to assess student understanding. However, their work does not evaluate the effectiveness of the accessibility improvements through quantitative data. In addition their work focuses on the impact of empathy material on the students, whereas this paper aims to evaluate the impact of the order of lab components (reading and intervention activity) on student learning.

The dynamic relationship between intervention activity and reading was explored by Lonnie Yancsurak, who studied the impact of a web based prescriptive English reading and writing program on the reading comprehension of middle school students [25]. His work supports that students who utilized the interactive module were able to increase their reading comprehension. Thus, his work coincides with our investigation of how an immersive engaging activity may impact the absorption of reading material provided in conjunction with the intervention. However, our work differs in that we are focused on a different demographic and subject area.

Chapter 3

Accessibility Learning Labs Overview

The following sections will define the components of the cognitive lab, an introduction on cognitive accessibility, and the learning objectives.

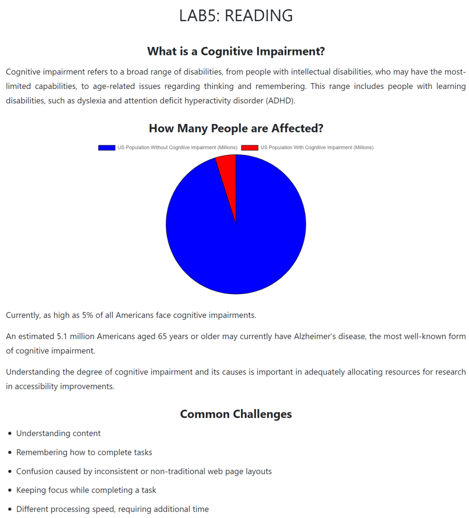
3.1 Lab Components

Within accessibility, there is no formally agreed upon curriculum. This is reflected through the lack of literature coverage targeted at supporting instructors to incorporate accessibility in the classroom [7]. However, existing research supports that accessibility requires a unique combination of theoretical understanding, procedural knowledge and technical skills competence [13]. It is multidisciplinary, borrowing from human-computer interactions and aspects of ergonomics and psychology, especially factors that influence discrimination against those with disabilities. In the following sections, we describe the specific components of our lab and how they are designed to target the factors listed above.

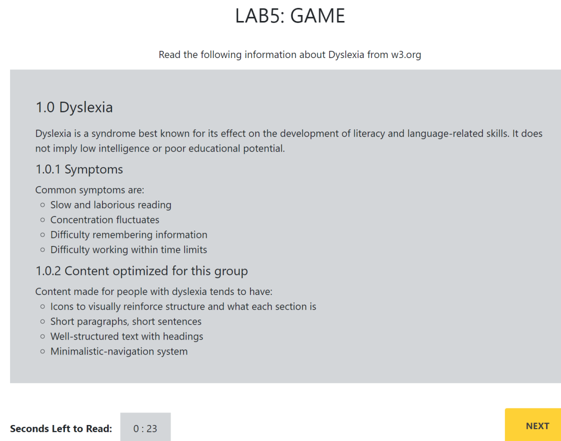
3.1.1 Background Reading Material

We provide students reading material to develop a theoretical understanding of the topic. This material not only provides an overview of the topic and the learning objectives, but allows students to gain a deeper understanding of the topic. The material is composed of the following:

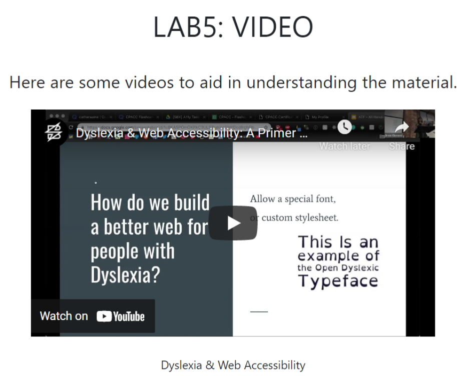
1. **An overview of the topic:** This defines the topic of the accessibility issue and the users who are impacted. Particularly, students understand what it means to have a



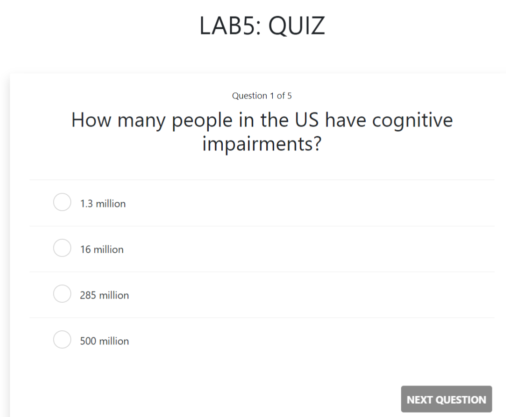
(a) Background Reading Component



(b) Experiential Activity



(c) Empathy Creating Videos



(d) Quiz Component

Figure 3.1: Accessibility Lab Component Overview

cognitive disability.

2. **Quantifying the problem:** This section provides a global perspective on the problem and conveys the magnitude of the accessibility issue. This also presents statistical information on the demographic affected. This motivates students as they understand the impact of their work.

3. **Common challenges faced by cognitively impaired users:** In support of the first learning objective, we present students with a list of common challenges that users with cognitive disabilities face. These challenges, based on WCAG Guidelines, draws upon socio-cultural aspects from a wide variety of cognitive disabilities.

4. **Solutions to address cognitive issues:** In support of learning objective 2, we present students with a series of accessibility patterns that when implemented, improve the user experience and accessibility of the software. These patterns include making the software predictable though consistent design, readable through appropriate font styling, and adaptable by having compatibility with assistive technology.

5. **Case Study:** In order to convert theoretical knowledge into a concrete real-world application, we present students with a case study. As supported by David Cook [6], learning should closely relate to understanding and solving real life problems, such as case-based learning. Specifically, students explore the benefits of using simplified authentication flows and grouping content in an online-shopping experience.

3.1.2 Experiential Activity

While it is important to grasp the core guidelines and the best practices, studies show that guidelines and their associated learning materials need to part of a wider learning ecology [13]. This can be achieved through just-in-time learning, in which students face a real-world problem and must immediately apply a solution [5]. This active style pedagogy and learning-by-doing instills confidence in the students' ability improve the accessibility of the software. We exercise this through the following activity structure:

1. **Interaction with the software:** Students will interact with the software without any emulation feature. In other words, they experience the software as a user without any cognitive disability. Upon interaction, they will be asked to complete a task. For example, in the page-layout activity, students must answer comprehension questions after reading the content.

2. **Interaction with inaccessible lens:** This component presents a new perspective to the students. It is meant to closely emulate the experience of a user with a cognitive impairment. For example, in the notification activity, Figure 3.2a, students must read the notification that appears for a very limited time. This is meant to emulate the struggle of users encountering time restricted content.

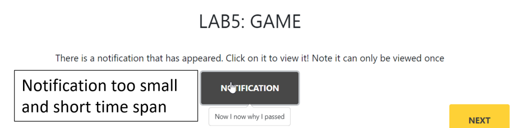
3. **Problem and solution discussion:** After interacting with the inaccessible version, students are presented with best practices and principles that help address the issues encountered. For example, in the notification activity, students are instructed to provide enough time for users to read content.

4. **Implementing the repair:** Just as students would perform software repairs in the real-world, they are provided a code editor to implement the suggested improvements. For example, in the form activity, students add appropriate styling to the form to indicate errors and successful form submission. An example of the code editor is shown in Figure 3.2b.

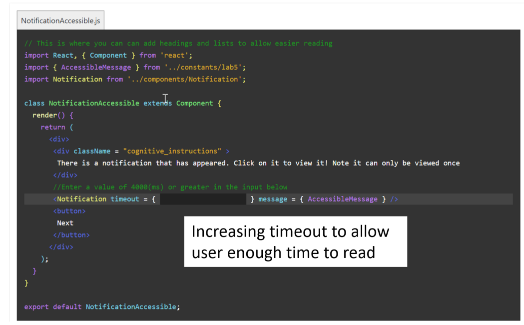
5. **Interaction with inaccessible lens + repair:** This last phase allows students to view the impact of their repairs on the software, Figure 3.2c. They perform similar tasks as the first step; however, with the accessibility fix in place, they will observe the ease of use. After seeing the improvement in user experience, students realize the importance of using inclusive design.

3.1.3 Empathy Material

Equally as important as providing students the technical knowledge to repair software is conveying the *need* for building inclusive and accessible software [19, 20, 14]. This is accomplished through empathy creating material. We use empathy to drive our students to think about accessibility first. It is not just about repairing broken sites, but being able to design from the ground up with accessibility in mind. This comprehensive inclusive design strategy that keeps pace with innovation can be obtained once students develop a



(a) Inaccessible software since user cannot see the notification (timeout too soon and font too small)



(b) Code editor used through browser

(c) Software made more accessible by student increasing timeout and font size.

Figure 3.2: Example of student repairing accessibility problem using simulated code editor

deeper motivation for accessibility through these empathy creating materials [17]. One way we create empathy is through our short (5-10 minute) videos interviewing students with disabilities in the classroom. Listening to first-hand challenges these students face develops an authentic perspective bringing to light the realness of the issue. The testimonials are also provided by undergraduate students (age 18-24). This allows students to better connect with and empathize with users of their own age group.

3.1.4 Quiz

Once the activity is completed, students are able to test their understanding with a rapid feedback quiz. Using the reading material, activity, and empathy material, students answer ten questions aimed to target the learning objectives of the lab and stimulate the students to think critically about the application of the accessibility topic. As described by David Cook, self-assessment and reflection is a critical aspect in stimulating learning by reinforcing current knowledge or by highlighting differences between current understanding and new information [6]. This also allows instructors to gauge how the students performed and provide us researchers the ability to improve our content to cover deficiencies. To ensure the validity of the quiz, subject matter experts evaluate and provide feedback. Further explanation of the quiz follows in the sections below.

At the conclusion of the quiz, we provide students with a certificate of completion. This acts as a source of motivation and acknowledgement of the students' progress. As described by David Cook [6], promoting a positive affective or emotional experience is key to a successful learning program.

3.2 Introduction to Cognitive Lab

Cognitive accessibility spans a wide range of disabilities, from people with age-related issues with thinking and remembering, to people with learning disabilities like dyslexia and attention deficit hyperactivity disorder. Despite this diversity, users with cognitive impairments all share certain common challenges. These include problems understanding the content, remembering how to complete tasks, and confusion from inconsistent web page layouts. These challenges can be addressed through common best practices that help reduce the overall cognitive load on the users.

The Web Content Accessibility Guidelines published by the World Wide Web Consortium (W3C) outlines 17 guidelines that can help improve accessibility. Six of the guidelines are especially relevant for providing cognitive accessibility. These guidelines not only improve the experience for users with cognitive impairments but provide benefits to all users. For example, providing additional time on an application that requires 2 factor authentication can assist users who have poor wireless connection, face motor issues or are less technologically literate.

The cognitive lab developed in this paper aims to synthesize the six accessibility guidelines to create an immersive experience for students. Using a combination of reading materials, intervention activity, videos, and quiz, we aim to enable students to recognize difficulties that users with cognitive impairments face, evaluate solutions to address the problems, and finally take action to implement the changes to make the site accessible. These objectives are explained in further detail below.

3.3 Learning Objectives

The cognitive accessibility lab is focused on the defined learning objectives based on Bloom's Taxonomy [3]. The accuracy and appropriateness of each lab was verified by accessibility experts from external institutions. The objectives are as follows:

1. **Recognize challenges that users with cognitive disabilities face (Comprehension):** Students will be able to understand the specific accessibility issues these users face. For example, given a poorly organized site, students will be able to identify that anti-patterns, such as small font-size and lack of headings, hinder readability.

2. **Evaluate various accessibility solutions to the problems (Analysis):** Once the accessibility problem is detected, students will be able to assess solutions to improve the accessibility of the software. For example, in understanding that content is poorly organized, students perceive that sectioning content through proper headings and bullet points can improve the structure and readability of the content.

3. **Implement the accessibility fix to improve cognitive experience (Synthesis):** After selecting an accessibility solution, students will be able to implement and construct a more accessible version of the software. For example, to improve the structure of a site, students will add heading tags and bullet content where appropriate.

Chapter 4

Cognitive Lab

In order to better understand the rationale behind the lab activities and the design choices, it is important to understand the various cognitive groups and their challenges. While cognitive disabilities are diverse, we aim to define three of the common disability groups for sake of brevity. Following these definitions, we discuss the 6 WCAG Guidelines that drive the activity creation.

Users with Dementia

Dementia is defined as a significant loss of cognitive abilities that disrupt daily life.

- **Motive:** By 2050, it is projected that there will be 115 million people with dementia worldwide [22]. It is imperative that we as a society design inclusively to be prepared for the future.
- **Demographic:** While dementia is commonly found in older age groups, it is not a normal part of growing old. It is caused by diseases to the brain, such as Alzheimer's, which decline memory, thinking, and reasoning.
- **Challenges:** Users with dementia have a difficult time remembering information, organizing thoughts, and working within time limits. They also face difficulty when completing tasks, especially ones with multiple steps like sending an email.
- **Optimizing Content:** To improve experience for users with dementia, it is important to provide step-by-step instructions, rapid and direct feedback, and a simple, clear writing style.

Users with Dyslexia

Dyslexia is a specific learning disability of neurological origin.

- **Motive:** A staggering 5 to 15 percent of Americans have dyslexia [22]. There is a false notion that dyslexia is associated with low intelligence or poor educational potential [22]. Raising awareness to this is important in providing effective solutions for dealing with dyslexia.
- **Demographic:** Dyslexia is independent of race, gender, and social background.
- **Challenges:** Users with dyslexia encounter problems with short term memory, processing information, sequencing strings and letters, and working within time limits. Particularly in literacy, these users have difficulty with reading quickly, extracting meaning, and remembering information.
- **Optimizing Content:** To assist users with dyslexia, it is important to use short paragraphs, well structured headings, and simplified text avoiding jargon.

Users with Down Syndrome

Down Syndrome is a genetic disorder caused by the presence of all or part of a third copy of chromosome 21, affecting the development of literacy and language-related skills.

- **Motive:** At least half of all children and adults with Down syndrome face a major mental health concern during their life span [16]. Assisting users with accessible technology can mitigate anxiety when interacting with interfaces.
- **Demographic:** According to the CDC, 1 in 700 newborns are diagnosed with Down Syndrome.
- **Challenges:** Users with Down Syndrome have difficulty remembering information, working within time limits, and processing information.
- **Optimizing Content:** To improve experience for users with down syndrome, it is important to use concise writing, plain font, and bullets when possible.

WCAG Guidelines

Though diversity exists among the groups listed above, they share similar challenges and optimizations. The WCAG guidelines synthesizes these commonalities into 6 specific guidelines:

1. **Adaptability:** Guideline 1.3 [4] states that all information should be available in a form that can be perceived by all users. For example, the information could be spoken aloud via a narration tool. Thus, ensure the content can be understood by assistive technology such as screen readers.

2. **Time:** It is important to allow users sufficient time to complete tasks. Guideline 2.2 [4] states ”provide users enough time to read and use content.” People with cognitive disabilities may require more time to read content, or to perform functions such as filling out forms.

3. **Navigation:** Guideline 2.4 [4] states to include clear and descriptive headings so users can easily find information and understand relationships between different content sections.

4. **Readability:** Guideline 3.1 [4] states ”make text content readable and understandable.” Keep the writing style simple and easy to understand.

5. **Predictability:** Guideline 3.2 [4] states to ”make web pages appear and operate in predictable ways.” Use consistency with the page layout.

6. **Input Assistance:** Guideline 3.3 [4] states to ”help users avoid and correct mistakes.” If they do make a mistake, ensure the message allows them to easily fix the error.

4.1 Page Layout Activity

4.1.1 Overview

The page layout activity is the first interactive experience for the students. Students are asked to read content regarding one of the cognitive disabilities. The reading material is time boxed to 25 seconds. After completing the reading, students answer reading comprehension questions related to the content. Students perform these steps in three stages of the experiential activity: (I) Accessible Content, (II) Inaccessible Content, (III) Repaired Content.

4.1.2 Purpose

This activity allows students to have a first-hand experience of poor content organization and the impact it has on cognitive load. As the students complete the accessible reading, they will notice how easy it is to read the content and most likely correctly answer the reading comprehension question. However, as they complete the inaccessible version, they will discern the difficulty in reading the content, especially within the given time limit. This will likely be followed by difficulty answering the comprehension question. This will demonstrate the importance of using proper page structure and headings to mitigate the cognitive load.

4.1.3 Design Rationale: Content

Users with cognitive disabilities such as Dyslexia, have a difficult time processing information, reading quickly and traversing through large text blocks.

In order to reduce the cognitive load from reading, developers should have clear organization of content [4]. This means utilizing clear descriptive headings that indicate the purpose of the content allowing for easier comprehension. Next, developers should use a plain, evenly-spaced, sans-serif font, such as Arial. In addition, bullet points should be used instead of a continuous prose. Lastly, text in all block capitals should be avoided as it makes it more difficult to read.

Based off Guideline 3.1 (Readability), we created the accessible reading page shown in Figure 4.1. Closer observation of the figure shows the distinct header and sub-header

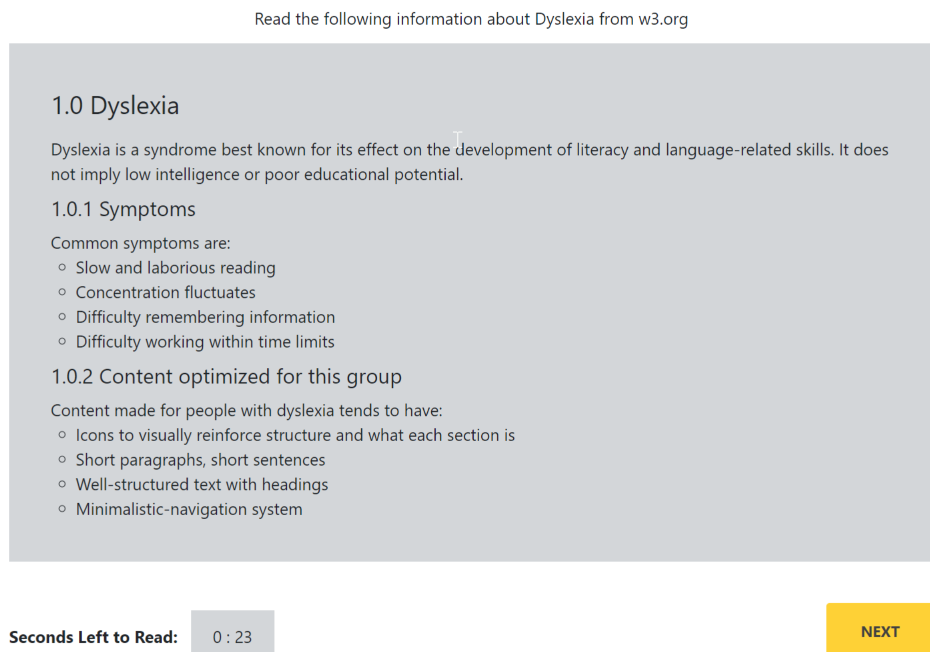


Figure 4.1: Accessible page layout demonstrating the use of proper headings, font size, and separation of content to increase readability.

separation, allowing easy navigation through the content. The font size is appropriately sized, with headers distinctly larger to denote the division of sections. The font-family is Arial, which allows users with cognitive disabilities to easily read the text. Bullet points are used in place of a comma separated sentence. This gives a cleaner look as well as providing sufficient white space around the text. Sentences are short and concise, allowing users to easily scan and discern the information. This is the format to adhere to when building an accessible web content page.

As depicted in Figure 4.1, there is a time limit placed on the reading activity. Once students reach the end of the limit, they are asked to proceed to the next question. The limit is placed as an emulation feature. As described above, users with cognitive disabilities, face difficulty when completing tasks in a given time frame. This allows students to face similar cognitive load and pressure as those users.

Once students complete the accessible stage of the experiential learning, they progress to the inaccessible version, denoted by Figure 4.2. From a first glance we notice a marked

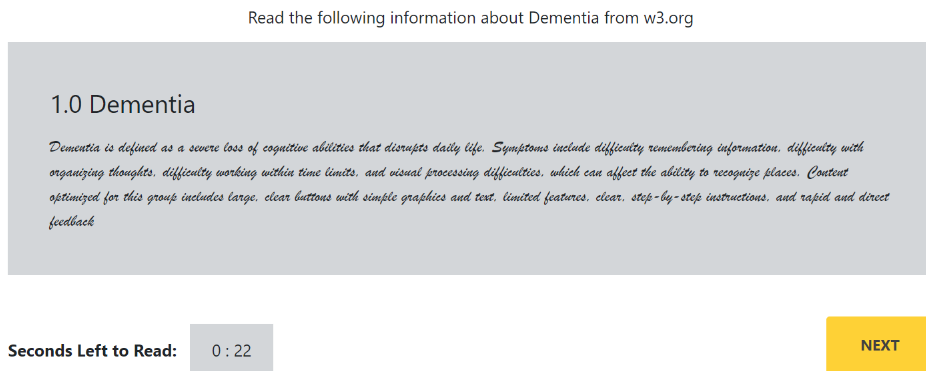


Figure 4.2: Inaccessible page layout depicting poor content structure caused by lack of headings, non san-serif font and blocky text.

difference in the formatting of the page structure. There is no separation of content through headings. Content is clustered together creating extra strain on the eyes and preventing quick scanning of the text. The font family is non san-serif which makes it more difficult to read the words. Lastly, the lack of bullets makes it more difficult to understand and retain the information listed. This structure follows all the anti-patterns of poor content and page structuring. After completing this stage, students will be able to realize just how important it is to design with accessibility in mind.

To improve this design, students are guided to apply the following corrections in the IDE Figure 3.2b:

- **Heading:** Students add h tags to denote section headers
- **Font Family:** Font family is updated to roboto or arial
- **Font Size:** Font size is increased to 16px to make content more readable
- **Lists:** List is inserted where block text existed. This creates shorter sentences

After applying the fix, students will see the content reflect the new refined page structure, making it much easier to read and comprehend the information.

4.2 Notification Activity

4.2.1 Overview

After completing the page-layout activity, students explore a new cognitive pain-point. This notification activity introduces the importance of providing enough time for users with cognitive disabilities to read and understand the content. As experienced in the prior activity, students were time boxed to a certain time limit. We look more into the aspect of time boxing content and how it can affect cognitive load on a user. Specifically, students are challenged to view a notification pop-up, which expires after x seconds, and attempt to recognize any sentence flaws by answering a follow up after viewing the notification. Students complete three sections of this activity: (I) Accessible Version, (II) Inaccessible Version, and (III) Accessible Version with repairs applied.

4.2.2 Purpose

This activity stresses the importance of providing sufficient time for users with cognitive disabilities, such as Dyslexia and Dementia, who have difficulty reading. As students view the first version of the notification, they will notice it is easy to understand and read, as there are no sentence errors. However, as they progress to the inaccessible version, the sentence is a little more complicated and will face difficulty in interpreting what grammatical errors appear in the sentence. This is meant to emulate the experience of a user with Dyslexia. Finally, as they apply the repairs to the notification by enlarging the text and providing a longer timeout, they will understand how much easier it is to comprehend and recognize sentence flaws.

4.2.3 Design Rationale

Users with Dyslexia have a hard time processing information quickly and working within time limits. They require extra time to complete tasks that require reading as they are prone to incorrect sequencing of letters and numbers. More specifically they face the following challenges when reading:

1. Distinguishing among homophones such as ”their” and ”there”
2. Reading complex words or jargon
3. Phoneme Processing - recognizing sound in words
4. Missing parts of a word or sentence

Thus, Guideline 2.2 [4] recommends giving users enough time to read content, so they are less prone to making mistakes.

As a real world example, consider an airline website that gives users a 2 minute limit to select the seat they want. While this may be sufficient for someone without a cognitive disability, it poses a real challenge for users with a disability like Dyslexia to properly comprehend and execute the task in time. Thus, W3 encourages developers to avoid timeouts when possible or extend them if they are to use them.

Inspired by this real world scenario, we created a similar activity that brings to light the challenges of Dyslexic users in a time constrained environment. Students first view the notification as a user without any cognitive disability. As captured by Figure 4.3, the sentence: ’Meeting at 12pm!”, appears for about 2 seconds before disappearing. Two points of poor cognitive design appear in this notification: small font and quick time out. However, since it is a simple sentence, students will likely not experience any issues answering the question shown in Figure 4.4.

However, this poor design becomes amplified as students examine a new notification, this time, with an incorrectly spelled word (Figure 4.5). This emulates the experience of a dyslexic user who may commonly skip over letters and not notice. The sentence, ’Now I now why I passed’, uses now instead of ’know’. However, due to quick time out, students will be less likely to perceive the error in the sentence much like a dyslexic user and will likely incorrectly answer the question in Figure 4.6 .

To improve this design, we instruct the students to increase the font size for increased visibility and extension of the timeout to beyond 4 seconds. This will enable the students

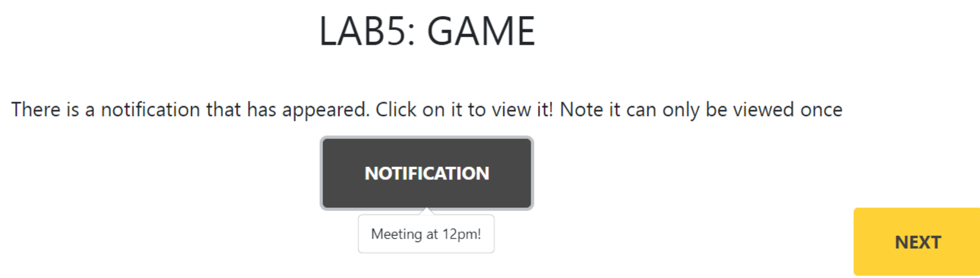


Figure 4.3: Notification for users without cognitive disability

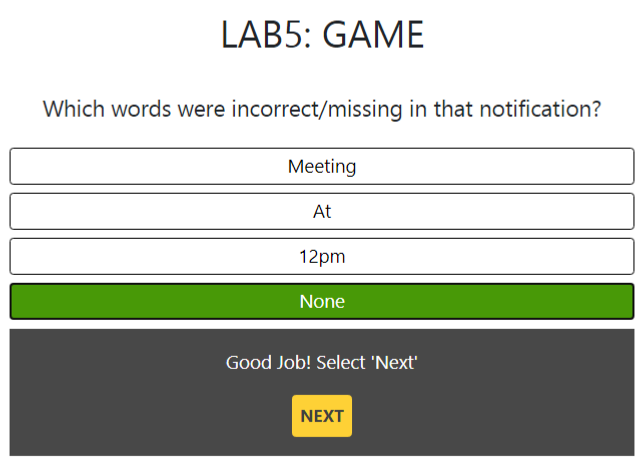


Figure 4.4: Comprehension question following non-emulated notification

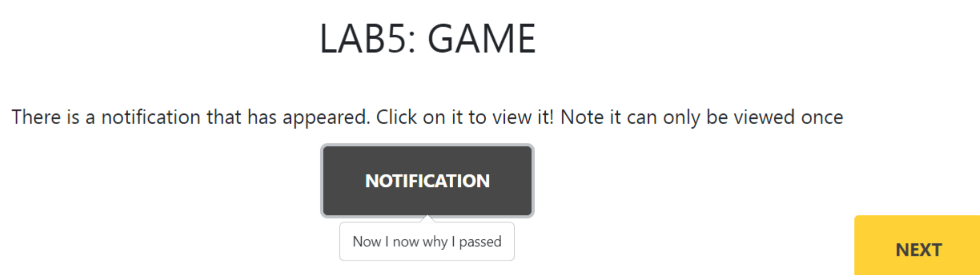


Figure 4.5: Notification emulating the experience of a user with Dyslexia

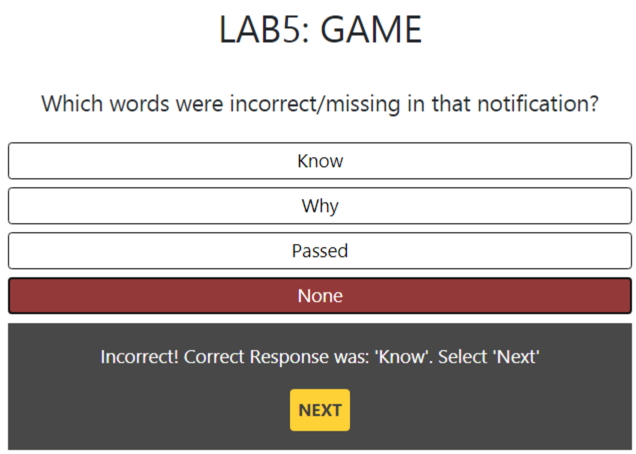


Figure 4.6: Comprehension question following the emulated notification

to easily detect any issues in the sentence presented in the notification (Figure 4.7). We revisit the improved version of the notification, allowing students to first hand experience the improvement in reading experience (Figure 4.8) and thus the importance of providing users enough time to process content.

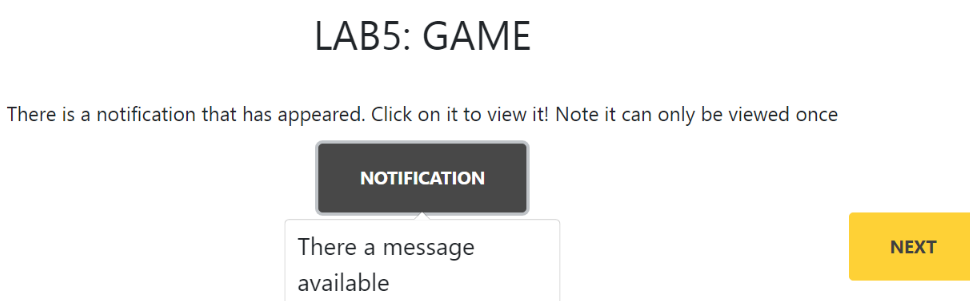


Figure 4.7: Notification with emulation feature and repairs applied

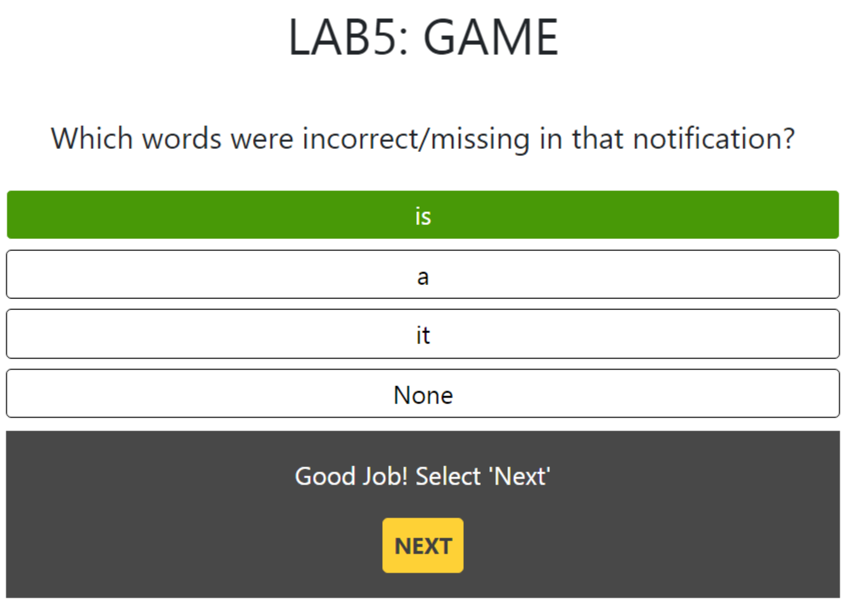


Figure 4.8: Comprehension question following repaired notification

4.3 Form Activity

4.3.1 Overview

The final section of the experiential activity entails a form-based interaction. This activity introduces the importance of providing users with cognitive disabilities appropriate feedback when using the application as well as preventing them from making errors. Students are challenged to complete a form without any input assistance and, upon making errors, directed to improve the experience through helpful hints and descriptive feedback.

4.3.2 Purpose

Forms are widely used across applications and often lack the accessibility standards to make them usable by those with cognitive disabilities. These users are more prone to making errors and therefore often abandon their tasks as they do not believe they can complete them. This problem is compounded by the lack of form feedback and often confusing error messages causing cognitive fatigue. The form activity addresses this pain point and allows students to experience first-hand the annoyance of poorly designed forms. After improving the design by implementing guidelines, students understand the importance of ensuring accessibility in forms.

4.3.3 Design Rationale

Completing forms and similar tasks can be overwhelming for users with cognitive and learning disabilities like Dyslexia. These users have difficulty remembering numbers such as their zip code, credit card and address. Thus, they are more likely to make mistakes when copying or recalling numbers/letters and their order. To mitigate this, developers should adhere to Guideline 3.3, which recommends designing forms that help users avoid making mistakes and assist in correcting them if they occur. Aspect of good form design include:

1. Entering as little information as possible
2. Clearly indicating required fields
3. Detect input errors as early as possible
4. Provide users with any known suggestions and corrections

As a real world example consider a banking website that uses a form to gain feedback from their customers. Allison, an aging user with cognitive impairments, has a hard time concentrating and correctly spelling words. As Allison uses this banking website, she notices that she is unable to submit the form after filling in her feedback. The submit button is disabled, implying that there is missing information. However, due to the lack of feedback, Allison is unable to detect the missing fields and successfully submit. Thus, in frustration, she leaves the site and her valuable feedback is lost.

Inspired by this use case, we developed the form activity where students must fill out basic information. Captured by Figure 4.9, we notice that users are asked to enter the date. However, upon entering the date, a vague error message is presented. This inaccessible version, presents a challenge to users as they are unable to detect what is actually wrong with the form submission. Students will encounter frustration as they attempt to resubmit the form in attempt to correct their mistakes. This is meant to emulate the experience faced by Allison in the case study. Without proper guidance, students are unable to successfully complete the form and must use the give up button to proceed on.

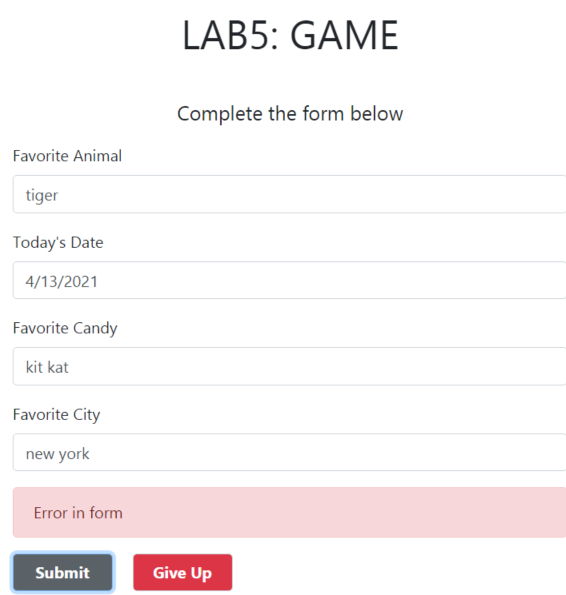


Figure 4.9: Inaccessible form demonstrated through poor error feedback.

Following the inaccessible version, we describe the following improvements to incorporate accessibility:

1. Adding descriptive input feedback
2. Providing a suggested format to enter the input
3. Indicating successful form submission
4. Incorporating styling to the form for easy error recognition

As shown in Figure 4.10, students completing the form are able to receive immediate input feedback. The input box changes colors to indicate the source of error, allowing users to fix the input before moving on while the information is fresh in their mind. This eliminates the confusion that is caused by ambiguous errors and having to wait for form submission before realizing a mistake was made. In addition, the input feedback is clear and written in simple English, allowing the user to quickly interpret the error. Finally, the feedback provides a suggested format so that the user can understand how they may correct the inputted data.

Figure 4.10: Accessible form demonstrated through appropriate feedback and suggestions to correct mistakes.

Figure 4.11, shows the final step of the form completion. Indicating a successful form submission is just as important as notifying errors. Through the repairs applied, we notice that users are now able to recognize that the form was correctly filled out and submitted. After completing the accessible version, students should notice how imperative it is to provide feedback in forms and how they impact the cognitive experience for a user.

Evaluating Learning Objectives

To determine if students met the learning objectives proposed, we created a quiz that targets the 3 objectives. We describe the specific questions that align with these goals.

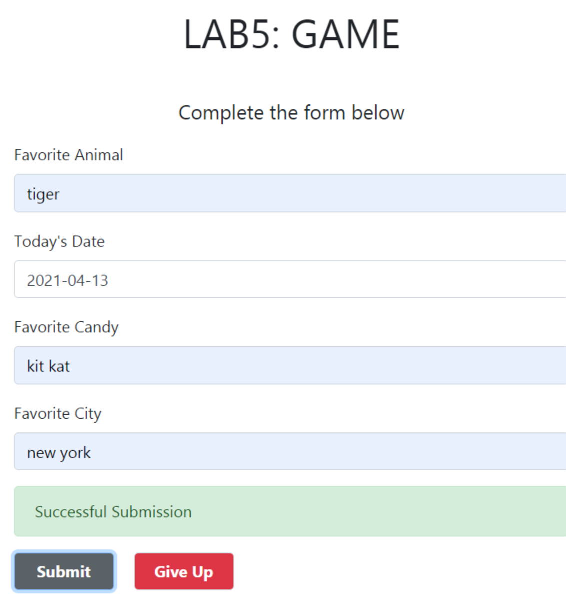


Figure 4.11: Successful Form Submission

Recognize challenges that users with cognitive disabilities face (Comprehension)

1. **What is a common challenge for cognitively impaired users?:** This question focuses on the challenges discussed throughout the activity. Particularly, students should recognize that time constraints place increased cognitive load on these users.

2. **What is a common challenge of dyslexic users? Select all that apply:** Focusing specifically on dyslexia, this question challenges students to identify the accessibility issues for dyslexic users. Students should recognize that these individuals face difficulty in matching letters with the sound of those letters and in spelling.

Evaluate various accessibility solutions to the problems (Analysis)

1. **How can you improve accessibility for cognitively impaired users? Select all that apply:** Equally important as identifying challenges is evaluating solutions for these issues. Students should understand that using proper headings,

providing assistance in form completion, and ensuring enough time is available to read content all lower cognitive load.

2. **How do you make forms more accessible to users with cognitive disabilities?:** Users with cognitive disabilities often face difficulty when completing forms and are more prone to making errors. Thus, students should perceive that in order to prevent errors and allow for quick correction of the error, it is critical to provide clear error messages, suggestions to correct the error, provide simple choices, and indicate successful form submission.

Implement the accessibility fix to improve cognitive experience (Synthesis)

1. **What is a practical application of cognitive accessibility? Select all that apply:** Synthesis of the aforementioned learning objectives is demonstrated through recognition of real world scenarios where applications are designed with cognitive accessibility in mind. Students should perceive that a simplified user authentication flow allows those with cognitive impairments to easily authenticate themselves.

2. **Which of the patterns below are accessible to users with cognitive disabilities? Select all that apply:** Part of the synthesis involves recognizing principles that improve cognitive accessibility. Students should distinguish that accompanying words with symbols and applying path markers in sites assist in the cognitive affordance of the site.

Chapter 5

Research

The following sections describe the experimental design and the analysis of the results.

5.1 Evaluation

Our work addresses the following research questions:

RQ1. *How does the order of the reading and intervention activity impact the performance of the students?* Through an experiment using our material, a statistical analysis demonstrates the positive impact of placing the reading material after the interactive material.

RQ2. *How effective are the labs in informing students about foundational accessibility principles?* A statistical analysis demonstrates that our individual lab components provided significant improvements to the accessibility of the lab, indicating the effectiveness of the repairs presented.

5.2 Experimental Design

To evaluate the impact of the component placement and the effectiveness of the repairs, we placed our lab in two Computer Science-focused courses. These were held in a virtual Zoom setting with a total of 28 students participating. The two courses were a Research Methods class offered to primarily graduate students in the Software Engineering MS curriculum and a Human Computer Interfaces (HCIN) course offered to graduate students in the Human-Computer Interaction MS curriculum. For the majority of the students in the

Research Methods course, this was the first time they were interacting with an accessibility learning activity. Conversely, students in the HCIN course indicated that they had prior knowledge about accessibility as the curriculum introduces formal accessibility education.

For the study, we created a pre-lab survey, post-lab survey, and quiz to evaluate the impact of our material. The survey and quiz questions were created and reviewed by subject matter experts before being implemented in the study. To perform the study, we separated students into two groups: A or B. All Hard-of-Hearing and Deaf students were placed in Group A along with their interpreters. Remaining students were then randomly assigned to fill up Group A, ensuring half the class was left for Group B. Students were placed into breakout rooms and provided a link to activity instructions. This strategy was used for both courses.

- **Group A: Reading prior to activity (control):** This control group was instructed to complete the reading material prior to the activity. This is the order originally presented in the paper, serving as a baseline.

- **Group B: Reading after activity:** This group completed the interactive learning activity before moving on to the reading. This will allow us to determine if the order of the materials has any impact on students with respect to quiz scores.

To collect the appropriate data, each of the groups completed the following steps:

1. **Pre-lab-survey:** The pre-lab survey serves two primary purposes: providing relevant background on the students' year-level, major and prior experience with accessibility. Students answer a series of questions that additionally gauge how important they believe accessibility is when developing software.

2. **Background Material/Reading:** This component gives students a literature-based understanding of the material with a mixture of guidelines and practical application of the cognitive accessibility suggestions. The reading is designed to take around 5-10 minutes. Students in Group B perform this step after the activity.

3. **Activity:** The activity is the interactive learning module composed of the three sub activities described in Section 4: I) Page Layout II) Notification III) Form

4. **Quiz:** Students then completed a quiz comprised of 10 questions targeting the comprehension, analysis and synthesis of the material presented. Both groups received the identical quiz. This served as a mechanism to understand how the order of the reading and activity impacted student learning.

5. **Post-lab-survey:** Finally, a post-lab survey is completed to see how the interest of the students changed after completing the activity.

As part of the activity, students were required to use their Google account. This provided us the ability to group artifacts and results. However, they were given anonymous IDs and no personally identifiable information was stored in our database.

5.3 Overview of Collected Data

Table 5.1 provides a breakdown of the students in each group and their majors. The results are limited to the students who completed all portions of the study: Pre-lab-survey, Reading, Activity, Quiz, and Post-lab-survey. Table 5.2 defines the distribution of the students across the years: Year 1, Year 5, and Graduate. Finally, Table 5.3 illustrates the breakdown of students from each course.

Table 5.1: Students by major for each group

Group	SE	CE	Other	Total
A	8	0	6	14
B	7	1	6	14
Total	15	1	12	28

Table 5.2: The year type distribution of the students

Group	Year 1	Year 5	Graduate
A	1	1	12
B	1	1	12
Total	2	2	24

Table 5.3: Distribution of students across the two courses

Group	Research Methods	HCIN
A	8	6
B	7	7
Total	15	13

5.4 Analysis Results

RQ1. *How does the order of the reading and intervention activity impact the performance of the students?*

To answer this first research question, we compared Group A (reading before activity) against Group B (reading after activity). We wanted to determine the impact of the ordering of the materials on the students' learning. This impact was evaluated by the quiz scores in each group.

According to the pre-survey result, 62% of students in the HCIN course had prior exposure to accessibility. Thus, the two courses were evaluated separately. We began by performing an independent t-test on the quiz scores (out of 10 possible points) from Group A and Group B. This method was chosen over dependent t-test since the participants in the two groups were different.

In the following expression, the null hypothesis, $\mathcal{H}_0$, states that there is no change in the quiz results between the two groups. Let $\overline{\mathbf{X1}}$ and $\overline{\mathbf{X2}}$ represent the means of Group A quiz score and Group B quiz score respectively. **S1** and **S1** denote the standard error of each group and **N1** and **N2** are the number of observations of the groups. The t-scores were then calculated using the following expression:

$$t = \frac{\overline{\mathbf{X1}} - \overline{\mathbf{X2}}}{\sqrt{\frac{\mathbf{S1}^2}{\mathbf{N1}} + \frac{\mathbf{S2}^2}{\mathbf{N2}}}} \tag{5.1}$$

After calculating the t-value, we computed the p-value by using the degrees of freedom (N- 1) against the values in a critical value chart.

Table 5.4: T-test result indicating Group B performed significantly better on the quiz - Research Methods Course

Group A $\overline{\mathbf{X1}}$	**Group B $\overline{\mathbf{X2}}$**	**T-value**	**P-value**
7.38	8.71	2.78	0.016

The t-test performed on the Research Methods course indicated that there was an increase in the mean of the quiz scores from Group A to Group B. Furthermore, the p-value supports that the increase was statistically significant at the 95% confidence interval. Thus, for this course, we can conclude that placing reading material after the activity does increase the students' learning potential. We believe this impact is beneficial under the assumption that students increase interest in a topic after interacting with an experiential activity [24].

These findings also suggest that the experiential activity piqued student interest in the reading material as the quiz had questions specifically targeted at content from the reading component. Group B performing better on the quiz could indicate that students paid closer attention to the reading material. To further investigate this proposition, we evaluated the 4 out of 10 quiz questions directly probing knowledge from the reading component. Using the same approach with the overall quiz score, we gathered the results illustrated in Table 5.5, Our findings demonstrate that Group B scored significantly higher on the quiz questions directly related to the reading component. This supports the idea that the experiential activity increased student interest in the reading material.

Table 5.5: T-test result isolating reading related questions indicating increased student interest in reading material

Group A $\overline{X1}$	Group B $\overline{X2}$	T-value	P-value
2.63	3.57	2.39	0.03

Next, upon analyzing the overall quiz results results for the HCIN group (Table 5.6, we noticed that the mean also increased from Group A to B, consistent with the Research Methods course. However, the p-value does not indicate statistical significance. Note that this result excludes one outlier from Group B with a score of 5 which caused the overall mean to drop to 8.14. This may be due to the student not putting reasonable effort into either understanding the material or properly completing the quiz. We surmise that this is due in

Table 5.6: T-test result indicating drop in quiz scores for Group B- HCIN Course

Group A $\overline{X1}$	Group B $\overline{X2}$	T-value	P-value
8.33	8.67	0.34	0.74

part to the fact that 62% of students in the HCIN course reported in the pre-survey that they frequently consider accessibility. This is in contrast to the 13% of students in the Research Methods course that frequently think of accessibility when designing software. The high pre-exposure to accessibility in the HCIN course may cause students to be less affected by the arrangement of the material as they are most likely already interested in accessibility. Another reason for this low significance is the small sample size of 6-7 students in each group. Having a large sample size would allow us to gather a more accurate mean and possibly increase statistical significance.

To summarize, the findings of this research question include:

- Results from the overall quiz scores in the Research Methods course demonstrated that presenting reading material after the activity improved quiz scores indicating better understanding of the foundational principles presented in the lab.

- Results from isolating the performance on the reading related questions indicates that the experiential activity piques student interest in the reading material.
- Group B in both the Research Methods course and the HCIN course showed improvements in the quiz scores based on the mean. However, only the Research Methods course showed significant improvement.

RQ2. *How effective are the labs in informing students about foundational accessibility principles?*

To examine the effectiveness of the accessibility lab in informing students about accessibility principles, we evaluated the student performance on individual activities. Particularly, we compared how students performed pre and post repair using the following metrics:

- **Time to complete task:** We examined the time in seconds spent on the task both pre and post repair. Observing a significant decrease in the time spent on a given activity page would demonstrate that the repair was effective in improving the accessibility as students required less time to complete the task.

- **Performance on comprehension questions:** After each activity, students were asked to answer a comprehension question to test their understanding of the content. If the repair was effective, we should notice a significant improvement in the correctness of the responses.

To validate the effectiveness of the repair on student comprehension, we utilized a dependent t-test. This method was used because the participants in both observations were the same. In Figure 5.1, let **pr** and **po** denote the n-dimension pre-repair and post-repair vectors of comprehension scores (percentage) respectively. In addition, $\overline{\mathbf{pr}}$ and $\overline{\mathbf{po}}$ are vector means of **pr** and **po** respectively. The constant μ_0 is set to zero because we state the null-hypothesis $\mathcal{H}_0$ as the expected comprehension level does not change significantly from pre-repair to post-repair. Generally speaking, a repair that significantly impacted student comprehension will result in small P-values. Table 5.7 summarizes the p-values from the t-tests.

$$t = \frac{\overline{\Delta \mathbf{p}} - \mu_0}{\mathbf{s}_{\Delta p} \cdot n^{-\frac{1}{2}}} = \frac{\overline{\mathbf{pr}} - \overline{\mathbf{po}}}{||(\mathbf{pr} - \mathbf{po}) - (\overline{\mathbf{pr}} - \overline{\mathbf{po}})||_2 \cdot n^{-\frac{1}{2}}} \tag{5.2}$$

Table 5.7: T-test results indicating increased reading comprehension post-repair.

Activity	$\overline{\mathbf{pr}}$ (Pre-Repair)	$\overline{\mathbf{po}}$ (Post-Repair)	$\overline{\Delta \mathbf{p}}$	P-value
Page-Layout	0.58	0.88	0.3	0.01
Notification	0.63	0.85	0.22	0.03

The results demonstrate that the students performed significantly better from a comprehension perspective when they applied the repair. Not only did the percentage of correct answers improve from **pr** to **po**, but the overall p-value indicates that at a 95% confidence interval, we can reject the null hypothesis that there is no change in the comprehension level between the two observations.

Let us explore the results for each of the activities:

- **Page Layout Activity:** The page layout activity, as discussed earlier, is meant to introduce the idea of proper headings and page structure to increase readability and decrease the cognitive stress on users with cognitive disabilities. Students were instructed to apply improvements ranging from increased font size to improved sentence structure and organization of content through headings. The statistical significance from above, demonstrates that: (I) The WCAG guidelines for readability improve reading comprehension and (II) The accessibility learning lab correctly implements the guidelines to illustrate the impact of good content design.

- **Notification Activity:** In this activity, students were tasked with uncovering mistakes within a given notification. However, as students experienced, the lack of time given to read the notification along with the smaller font size, makes it difficult to comprehend and interpret the mistake. Thus, once they implement the improvement, according to Guideline 2.2, the added time should allow people to adequately understand the message. Based on our results, we can confirm that improved comprehension scores are consistent with the guideline suggestions and that the activity effectively guides students in making the improvements.

Note: The form activity was not a reading related task, thus we did not examine the students' comprehension through a formal post-repair question. However, as discussed later, we employ a different mechanism to verify the effectiveness of the repair.

Next, we explored the effectiveness of the repair on time to complete a task through a dependent t-test. Once again, since we were working with paired samples, we used this mechanism over the independent t-test. In Figure 5.1, let **pr** and **po** denote the n-dimension pre-repair and post-repair vectors of time (seconds) spent on task respectively. In addition, $\overline{\mathbf{pr}}$ and $\overline{\mathbf{po}}$ are vector means of **pr** and **po** respectively. The constant μ_0 is set to zero because we state the null-hypothesis $\mathcal{H}_0$ as the expected time to complete task does not change significantly from pre-repair to post-repair. A repair that significantly impacts completion time will result in small P-values. Table 5.8 summarizes the p-values from the t-tests.

Table 5.8: T-test results indicating reduction in time to complete task post-repair.

Activity	$\overline{\mathbf{pr}}$ **(Pre-Repair)**	$\overline{\mathbf{po}}$ **(Post-Repair)**	$\overline{\Delta\mathbf{p}}$	**P-value**
Page-Layout	19.89	19.22	-0.67	0.67
Form	67.35	26.88	-40.47	0.0001

From a high level view, we noticed that in both of the activities, the time to complete a task reduced from the pre to the post repair stage. This demonstrates that there is visible improvement in the usability of the software after the repair when strictly using the mean. However, a deeper analysis showed that the page-layout activity only improved by .67 seconds on average and thus does not indicate a statistical significance. This is surprising as we assumed that a more readable layout would allow students to quickly read the content. However, upon looking closely at the data, we found that there were two students who only spent 1 second on the pre-repair stage. This indicates that they did not take this activity seriously. After removing those two data-point outliers, we see that the group achieves an improvement in the reduction of time spent on the page. The new mean and statistical significance are shown in Table 5.9. Though still not significant at the 95% confidence interval, we surmise that with a greater sample size we could obtain statistical significance.

Table 5.9: T-test result indicating greater reduction in time for page-layout activity after removing outlier.

Activity	$\overline{\text{pr}}$ (Pre-Refactor)	$\overline{\text{po}}$ (Post-Refactor)	$\overline{\Delta \text{p}}$	P-value
Page-Layout	21.40	19.28	-2.12	0.08

In regards to the form activity, we observed a drastic improvement in the time spent on the task from pre to post-repair. The activity, meant to demonstrate the importance of using proper form feedback, was built upon Guideline 3.4 surrounding input assistance. As students complete the inaccessible version, they face challenges in identifying the errors they produced on the form. However, as they apply repairs designed to improve form interaction through descriptive error feedback and error prevention, they should notice the ease in completing the form. The results from the activity indicate that the redesigned form adds significant improvement, allowing students to quickly finish the form (60% faster). We surmise that this is attributed to the instant feedback that students gain when completing the redesigned form, allowing them to quickly identify any errors and how to resolve them.

Note: The notification activity was not examined in this section, as the structure of the activity did not match what was studied here. There is no time relevant task to monitor. Users simply view a notification that expires after x seconds elapse. Observing the time elapsed with the notification would not provide valuable insight into the impact of the repair. Instead, we used the reading comprehension question as a mechanism to evaluate the effectiveness.

To summarize, the findings of this research question include:

- The repairs suggested in the page layout activity have a statistically significant improvement in the reading comprehension of the material, confirming their effectiveness in improving cognitive understanding. This is consistent with the observations made in the time to complete the reading. Specifically, there was a 10% decrease in the overall time spent on reading the content. While not a statistically significant observation, it does help suggest that the repairs allow students to more efficiently read the text.
- Within the form activity, we observed a significant improvement in the time spent on completing the form. The average time decreased by 40 seconds. This indicates the strength of the accessibility improvements and the delivery of them through the activity.
- Finally, when examining the notification activity, we noticed a 22% increase in the reading comprehension, denoting a statistically significant observation. This improvement suggests that increasing the time to read content, along with the font size, allows users to better comprehend text. Moreover, these results confirm that the activity effectively conveyed the principles of strong cognitive design in an interactive medium.

Chapter 6

Discussion

6.1 Primary Findings

Our findings demonstrate that Group B (reading after the material) performed better on the quiz material and hence had greater understanding of the material when compared to Group C. This was especially true for the research methods course. Evaluating the HCIN course alone, we notice that while there is an improvement in the mean, the results are not statistically significant. We surmise that with a larger sample size we can achieve significance in this group as well.

Nonetheless, these results indicate that experiential learning piques student interest and therefore students are able to better understand the reading material as demonstrated through the higher quiz scores. Instructors should use these findings to incorporate more experiential based learning into the classroom in order to motivate the students and increase their learning potential.

After conducting the dependent T-test on the lab activities, we found that the labs are effective in conveying the accessibility guidelines. This was observed through an increase in the students comprehension following the page layout and notification activity, along with significant decreases in time spent to complete the task for the page layout and form activity.

6.2 Benefits to Cognitive Users

The statistically significant improvements in performance post repairing the application demonstrate that if developers and students implement the accessibility suggestions, they can make a profound impact on the cognitive accessibility landscape. Once developers and students adopt the accessibility first mindset and take steps to consciously think of how design decisions will impact those with cognitive disabilities, then those users will see drastic improvements in their experience with software. In particular, developers will ease the cognitive strain to complete tasks such as filling out forms and reading content.

6.3 Benefits to Adopters

The cognitive lab discussed in this paper offers several benefits to adopting instructors. As described earlier, the self contained nature of the lab allows it to be easily incorporated into an already packed curriculum. Everything from reading material to experiential activity and quiz are included in the lab. Since this lab and other labs created under Accessibility Learning Labs are verified through accessibility experts, instructors need not have any prior knowledge in accessibility themselves. The findings in this paper support the quality and validity of the suggested improvements. Thus, instructors can be assured that students will be learning valuable material that will enable them to incorporate accessibility into their own day to day software development. Lastly, instructors can be assured that students will enjoy the activity as found through feedback in the post-lab surveys.

Chapter 7

Limitations and Future Work

Preliminary evaluation of the results indicate that students in the research methods course performed better on the quiz when the reading material was presented after the activity as opposed to before. However, we notice that these results are not as consistent with the HCIN course. We surmise this is due to prior exposure to accessibility. Future work should be performed to understand how this influence may impact student understanding and interest in the topic.

Larger sample sizes provide more accurate mean values, help identify outliers that could skew the data in a smaller sample, and provide a smaller margin of error. While this is the aim, it is often difficult to procure a large sample size, as was the case in this study. We were unable to target a large group of participants amidst the pandemic as instructors were already packed with course material by the time the activity was available. We surmise that having a larger sample size would allow us to overcome the outliers pointed earlier in the dataset and develop more robust results as in the HCIN course. Future work should be performed to conduct this study in additional computer science courses to achieve more conclusive results.

Analysing the datasets we noticed a handful of outliers as well as students who did not complete every component of the study. This may indicate that some students were not taking the activity seriously, skewing the results. We believe that motivating students before presenting the activity may counter this. As described by Wlodkowski [6], teachers should encourage a positive attitude toward learning at the start of the activity. Future work should be performed to implement this strategy and observe the impact.

Our lab was created upon foundational accessibility principles from WCAG. The statistical analysis from RQ2 corroborates the effectiveness of the principles introduced. However, feedback from actual users with cognitive disabilities would reinforce the validity of the lab and provide additional sources for improvement. Specifically, the emulation features presented in the lab should be verified against these users. Furthermore, there are multiple other cognitive disabilities, such as Aphasia and Autism, which were not specifically targeted in this lab. Future work should be performed to build upon this lab to include awareness of these other cognitive disabilities.

After further work with a larger sample size is performed, and more robust results are gathered, the labs should be updated to match the outcome of the findings. For example, if results confirm that reading material placed after the activity does improve learning and understanding of the material, then the lab structure should adjusted to match that order.

Chapter 8

Conclusion

This work examines the pedagogical structure of the Accessibility Learning Lab to discover how the arrangement of reading and interactive material impact student learning. Our primary findings demonstrate: (I) When the reading material is presented after the hands-on activity, students with no prior background in accessibility have a greater understanding of the foundational accessibility principles (II) The lab effectively communicates and delivers the accessibility principles as shown through the improvements in accessibility post-repair.

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