Developing and Implementing an Accessible, Touch-based Web App for Inclusive Learning

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Abstract

With the prevalence of mobile devices and platforms used throughout the world and the increasing number of organizations with mobile versions of their web sites, it is essential that those applications and sites are accessible, usable and flexible. This project involved the inclusive development and iterative evaluation of a platform-independent, web-based learning app. Usability testing with students, faculty, and individuals with disabilities were combined with manual accessibility evaluations to ensure that a wide range of users and devices would be able to benefit from the structure of such an application. The results of this project detail the process of creating a flexible, platform-independent mobile learning app as well as some of the broader benefits that can result from accessibility and usability improvements to a mobile application. The resulting prototype has been implemented in a "live" environment at a non-profit organization that serves individuals with disabilities.

Keywords

Mobile web site accessibility, mobile web site usability, UX testing, inclusive learning.

Introduction

Many individuals use their mobile, touch screen devices (such as smart phones and tablets) in most aspects of their lives, including education. This has resulted in a variety of proprietary "apps" which have been developed as learning tools for both students and educators (Barnes and Herring 2013). Most of these apps are designed to work on a specific platform (e.g., Android, iOS), are designed for synchronous use (e.g., socrative.com), or are not based on an inclusive approach to interface design. The primary goal of this project was to leverage inclusive design in the creation of an open-source learning game app that would be platform independent, web-based, highly usable, and accessible to individuals with disabilities. It was a secondary goal for the interface to allow for the generic use of this app to many types of subject matter.

It is estimated that approximately 15% of the world population (over one billion people) have some form of a significant disability that could impact their ability to fully use technology (WHO 2013). The possible opportunities that mobile devices can provide for individuals with disabilities are significant and widely-discussed (FernáNdez-LóPez, et al. 2013; Kane, et al. 2009; McNaughton and Light 2013; Wong and Tan,

2012). Since the emergence of mobile, touch-screen devices, research has also highlighted a number of accessibility challenges as well as solutions and opportunities to make mobile devices more accessible and usable for people with disabilities (Bigham, et al. 2008; Billi, et al. 2010; Chiti and Leporini 2012; Kane 2009; Kane, et al. 2008; Plos and Buisine 2006; Trewin 2006). "Accessible" software can be accessed by individuals with disabilities, and "usable" software can be used successfully by the greatest number of people in diverse situations and on multiple devices/platforms.

Screen readers (software that reads the visual content of a software interface or web page audibly to a user) are a type of assistive technology that are commonly employed by users who are blind or have low vision. Analyzing the usability of an interface with a screen reader (such as JAWS, VoiceOver, NVDA, or WindowEyes) can often provide insight into the broader accessibility of an interface. According to a recent survey, 82% of screen reader users use a screen reader on a mobile device, with iOS devices being significantly more popular than any other platform and Android being the second most popular (WebAIM 2014). The iPhone has a screen reader called VoiceOver that is included as part of the operating system, and the Android 4.3 and newer platform has a screen reader called Talkback that is included as part of its operating system. Most BlackBerry devices do not have a screen reader available, and as such, they are not popular with blind users. The Windows Phone platform does have the Microsoft Narrator screen reader installed, however this platform has been declining in use by blind users (WebAIM 2014). Web apps for mobile devices are beginning to gain attention as an alternative to propriety apps that rely on a particular platform such as iOS or Android and often need to be updated with major updates to the mobile platform. Mobile apps that are accessible typically use HTML5 and some form of WAI-ARIA (ARIA stands for Accessible Rich Internet Applications, and it is a new way to make dynamic webs sites more accessible). This does not guarantee their accessibility, but it does permit developers to leverage new accessibility features. HTML5 is the newest W3C (World Wide Web Consortium) standard for Web markup language and is supported on web-based, touch screen devices as well as all modern web browsers. It avoids the need for plug-ins and proprietary applications to access multimedia content.

ITERATIVE METHODS AND RESULTS

A Prototype for an Inclusive Learning App

This project began as a discussion with a university chemistry department in fall 2012 because the department could not find a customizable mobile app that would work as a study tool for chemistry students. It was decided to create an app that could be used for any type of learning or discipline, and rather than create a number of different proprietary apps that would constantly need to be updated, the researchers would create a web-based, platform-independent app that would be accessible and usable for the broadest range of users. Unlike similar resources, this research focused on a flexible, inclusive design of the prototype. The design for the app was first created with a paper prototype, which was modified to meet the user needs, and then a web-based prototype was created to gain additional feedback regarding the design. The design process involved regular meetings between the researchers and the end users. From October 2012 through February 2013, the researchers used an iterative and systematic process to develop the app interfaces per the requirements that had been gathered. It was ultimately determined that a combination of HTML5, WAI-ARIA, PHP (scripting language), MySQL (database), and JQuery (scripting language) would be used for the development and implementation of the interface with accessibility conformity to WCAG 2.0. WCAG are the web content accessibility guidelines published by the W3C (W3C, 2008). HTML5 and WAI-ARIA that follows the guidance of WCAG 2.0 has been noted as a good framework for developing accessible mobile web sites (Abou-Zahra, et al. 2013). The researchers also decided to develop a web-based management console for instructors to manage user accounts as well as create, modify, and delete questions. During the various iterations of the early prototype and throughout the rest of the app development process, the app was tested with different versions of commonly-used Web browsers (e.g., Internet Explorer, Firefox, Google Chrome, and Safari).

The app design provides users with an initial screen which allows a user to sign in with an existing account or create a new user account. The user is then provided with main menu of choices, which include playing the game, changing the game level or "learning mode," viewing score information, getting help or instructions, and logging out of the game. The purpose of the "learning mode" option is to allow users to test themselves with questions without competing or receiving a score. After a user selects a game level,

the user can then play the game. Depending on whether the instructor/administrator creates text-based or graphics-based questions, the format of the questions will change. The user is able to answer questions and is provided with feedback as to whether the answer is correct or incorrect. If the answer is incorrect, the user can "try again" or go on to the next question. When the user is in learning mode, the correct answer will always be provided.

Initial Usability Testing

During spring of 2013, the app was tested for usability with faculty and students in undergraduate courses. Although automated usability testing tools for mobile interfaces have also been proposed (Au, et al. 2008; Coursaris and Kim 2011), physically interacting and eliciting feedback from users can provide valuable insight to developers. Six undergraduate chemistry students participated in the usability testing of the learning app, and six faculty members from disciplines across the university tested the app management site. Students were asked to interact with the app by doing task such as the following:

- creating accounts,
- logging in to the app
- answering questions
- interacting with correct and incorrect question feedback
- locating instructions and help information
- changing game levels and learning mode
- viewing personal and peer scores

The researchers also collected qualitative feedback at the end of each testing session. IPads (first and second generation), a Samsung Galaxy, and a Windows RT Tablet were all used by various students testing the app. The students rated the game either a "1" or "2" (evenly split) on a scale of 1-5, with 1 being very easy to use. Students commented that the app was primarily easy to use and understand. One student commented that the buttons on the interface were too close together, other minor suggestions for improvement included more interaction, some layout and button changes, as well as the need for the current learning level to be shown on the main menu and during gameplay. Five out of the six students noted that this type of a learning app would be helpful for learning academic concepts.

Faculty were asked to interact with the app's web-based management site on their personal computers. They attempted to complete tasks such as adding new questions to the learning app, deleting questions, and modifying user accounts. They were also asked to provide feedback relating to ease of use, functionality and potential improvements, and qualitative survey data were collected after each testing session. They rated the ease of use on the management interface as being either a "1" or "2" (four 1s) on a scale of 1-4, with 1 being very easy to use. Faculty members commented that the interface was well laid-out and fairly intuitive and simple with a clean interface. Faculty noted that the search function could be improved, some of the instructions were unclear, and some of the HTML labels were confusing. The faculty volunteers noted a mean of 3.5 (on a scale of 1-5, with 5 being extremely likely) as to whether they would use such an app for a course that they were teaching.

Accessibility Evaluations and Initial Modifications

There are many automated tools freely and commercially available for evaluating web accessibility (such as Deque WorldSpace, Odellus ComplyFirst, or SSB Technologies InFocus), and they are commonly used when expert evaluations are not possible. Similar to the tools designed for full web site accessibility evaluations, tools have being designed to provide automated evaluations of mobile web sites (Arrue, et al. 2006). However, manual accessibility inspections, by multiple individuals with experience in accessibility are a more accurate way to gauge the true compliance of an interface (Mankoff, et al. 2005; Vigo, et al. 2013; Yesilada, et al. 2009). Automated tools can only determine the presence of certain components and HTML markup, while human evaluation can determine the context of the markup. The project team began to analyze the application for broader usability and accessibility, including testing the "app" with screen readers on both Android and iOS devices. The focus of the evaluations was conformance to WCAG 2.0 guidelines as well as perceived accessibility problems that users might encounter. For example, it has been previously noted that ambiguous design and the lack of good feedback can create additional

challenges for users with disabilities (Babu and Singh 2009). It is relevant to also note that the evaluations were in conformance to the recently published recommendations of the W3C relating to accessibility evaluations (W3C 2014).

During these evaluations it became clear that the app needed to be tested for use by users with disabilities using their mobile device environment. The goal of the multiple accessibility iterations evolved into discovering any aspects of the app that were not accessible and modifying those aspects prior to any additional usability testing. One example of items that were discovered during evaluations with the mobile screen readers was "alt" tags that were not being generated for image-only questions. "Alt" tags provide equivalent text for instances where graphics are used to display information. Another issue addressed was the format of dynamically generated feedback, such as "Welcome User 01" or "Current Score: 14 points" which where formatted in a way that made the flow of the information difficult to understand when accessing it with a screen reader. Based on the feedback received from the spring 2013 testing of the interface and the initial accessibility evaluations of the app, the research team began to modify the app. The app modifications focused on issues mentioned by users or observed during the usability testing process, and many of those and the following issues were addressed prior to the usability testing with blind users, such as the following:

- the mobile screen readers were not reading the current difficulty level
- only the text part of the main navigation buttons was "clickable"
- the location of the login and account creation buttons was not intuitive
- an issue with the "alt" tags not reading on image-only questions was present
- the buttons to change the learning mode were confusing
- the size of the main page image needed to be scalable for a wider variety of mobile devices
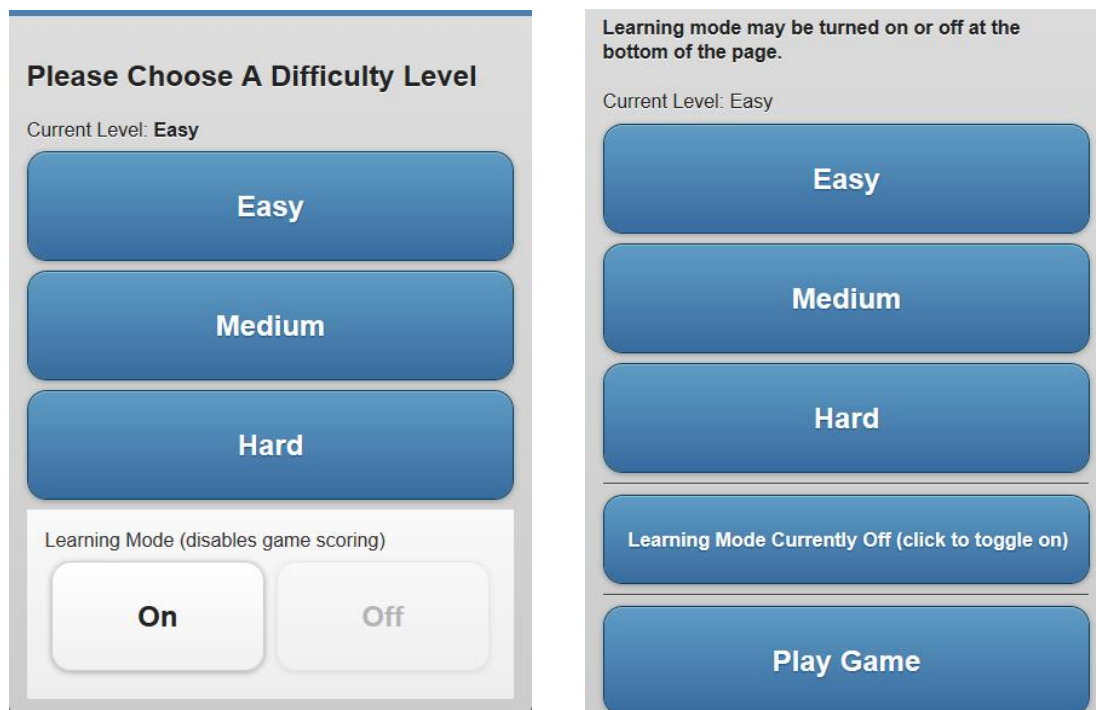
Figure 1: Comparison of the initial and revised method for changing the "learning mode"

Usability Testing with Blind Users

Usability testing with blind users and screen readers is helpful for discovering both usability barriers and overlooked accessibility problems with an interface (Vigo, et al. 2013). While this seems to focus on a subset of perceptual impairments, in reality, in order for an interface to work well with a screen reader, it

has to comply with most aspects of accessibility guidelines (e.g., WCAG). The second round of usability testing for this project involved usability testing with six blind users recruited through contact with advocacy groups such as the American Council of the Blind. Based on survey questions, there was a mean of two years of mobile, touch-screen experience prior to evaluating the app. Most users tested the web app with the Safari mobile web browser on some version of the iPhone. P6 tested the web app using the Firefox mobile web browser on the Samsung S3 (Android platform).

After using the app, the users rated the ease of use of the app at a mean of "2" on scale of 1-5 (with 1 being very easy). The first user (P1) noted that the instructions for creating an account were not clear, and it was annoying to hear the screen reader reiterate the instructions for answering a question on each new question. It was suggested that perhaps the instructions could be read once, then not appear again. This was a request that the researchers did not receive from any of the subsequent participants. The instructions for answering a question were corrected prior to testing with P3. P1 also noted that there was no link or button to return to the learning game on the screen that allowed users to select a learning level or learning mode. It was also observed that a confirmation when logging out of the app would be helpful to users, and there was a clearly identified usability problem with the structure of the learning game score screen (which was confirmed by subsequent users). The score screen was later modified to provide an easier-to-read and understand format for personal and competitive learning game scores (Figure 2 shows a "before" and "after" screenshot, illustrating the more usable format that was adopted).
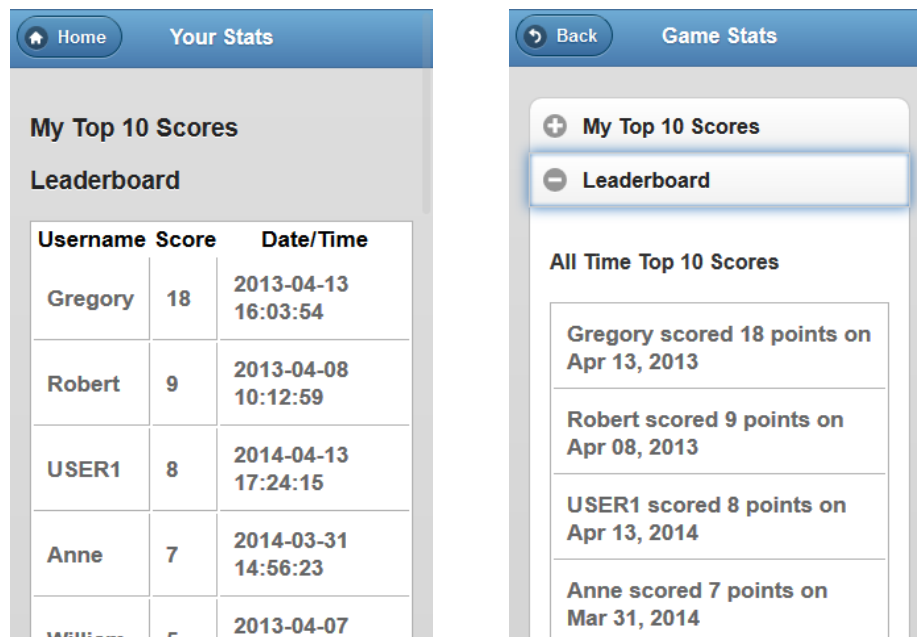
**Figure 2: The initial and re-designed app score screen**

P2 noted that the format of the app was very user friendly, however, there were some new problems that were identified on the app, and some of the items noted by P1 were also reiterated (unusable score screen and lack of logout confirmation). It was observed by P2 that there was some ambiguous terminology used on the app, such as the terms "home" and "main" used interchangeably. The instructions for turning on/off the "learning" mode of the app were also creating some confusion for the user. The structure of the headings and content of the Help interface caused some additional frustration for the user.

True to iterative development, some improvements were made to the app prior to the usability session with P3. Many of the above suggestions from P1 and P2 were implemented on the interface, including account creation usability, learning mode instructions, and a log out confirmation. Figure 3 illustrates the modifications that were made to make the account login more intuitive to users accessing the app for the first time.

Figure 3: The re-designed entry screen for app users

P3 noted that masked password fields (such as what is used on the learning app and is common on many Web interfaces) are often frustrating to blind users. It was observed that the Help button was not easy to locate on the app interface. P3 also suggested that the "level of difficulty" buttons could be changed from "links" to something such as a checkbox or similar in HTML, because the "link" buttons require users to tap directly in the center of the text, rather than simply selecting the button. P4 noted the same frustration with "masked" password fields as well as a question relating to the placement of the "forgot password" link prior to the login area. It was suggested that the "forgot password" link be moved below the login button. Figure 4 shows a side-by-side comparison of the original "forgot password" design next to the improved one.
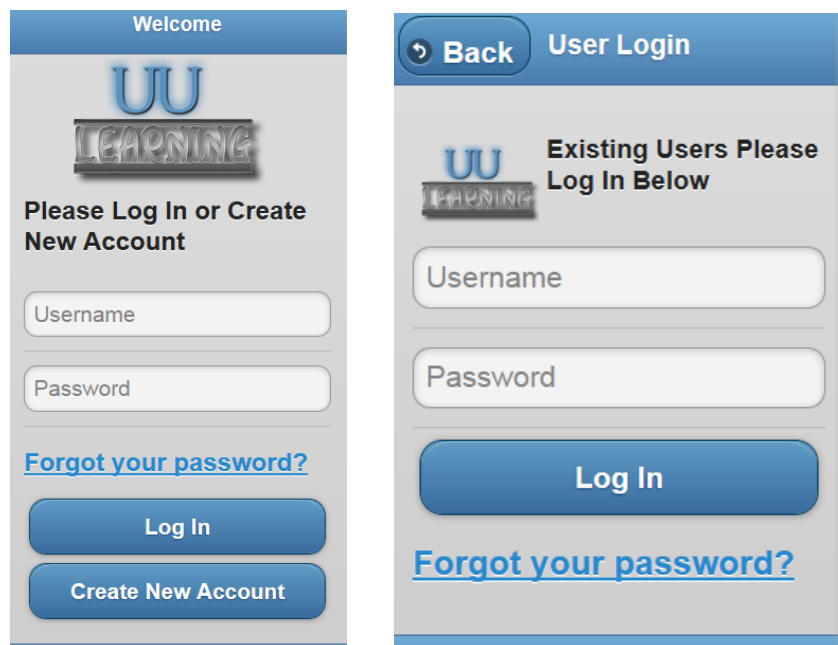
Figure 4: The modified "forgot your password" link on the existing user login screen

P5 also noted that the "help" link was difficult to locate on the screen and commented on the frustration of having a "masked" password field for the login. Similar to the observation of P3, P5 noted that some of the

app buttons that are currently HTML "links" could be changed to some other element in order make it easier to select the buttons on a touch screen. P5 further noted that when in learning mode and exiting the screen that tells a user they've made an incorrect answer selection, it is confusing that heading for the exit screen said "Correct Answer." The rationale for this was that all incorrectly-answered questions in learning mode are followed by the correct answer. However, it is confusing to blind users for the heading on that screen to say "Correct Answer," when the user has just been informed that the answer given was incorrect. P5 did note that the app was easier to use than most apps used previously, and the user liked the fact that all graphics-based questions and answers had "alt" text.

Similar to most of the other blind participants, P6 noted that masked password fields are frustrating. It was also noted that heading levels should be used consistently throughout the app, and the text associated with learning mode "button" should read "touch" or "tap" rather than "click." On the help interface, the user suggested that HTML "links" would be more usable than expandable "div" elements. P6 did note that everything on the app was easy to find, simple, and "not cluttered." On a scale of 1-5 (with 5 being extremely likely), users rated the likelihood that they would use an app like this for training as a "4.8." Users felt that it would be a good way to learn new concepts or take an exam.

Items such as the location of the "forgot password" link and "help" link were corrected to make them more usable. The heading of the learning mode correct answer feedback and the inconsistency of the "back" button on the instructions screen were also, and the heading levels were analyzed for consistency across the app. It was determined that the expandable "div" elements on the "Help" screen would be converted to HTML "links" to improve their usability.

Implementation at a Non-profit Organization

The final stage of this project involved the practical implementation of the resulting prototype of the app at a non-profit organization for use with their technical training of blind individuals. The director of training at the organization is blind, so the management console for the prototype had to undergo additional testing and evaluation prior to the actual implementation. This was going to be addressed during future work on this project, but this partnership opportunity necessitated that the management interface receive immediate attention. The revised management console can be accessed by any device and provides the ability to embed alternate text with any graphics that are uploaded as part of a question or answer. The organization is using the app as a tool to teach technology concepts to individuals in their training program, so the flexibility of the app and its content was beneficial. This practical implementation of the developed prototype illustrates the effectiveness of the inclusive design process during this project in that the app is accessible and usable for many users with disabilities beyond merely the small sample of blind users tested during the development. It is also important to note that the inclusive design process was the catalyst for both the non-profit organization and the researchers to apply the results of this project to a "live" implementation of the prototype. As the app is used in this environment, it is anticipated that more suggestions for improvement will be received.

Conclusion

To stress the importance of combining accessibility evaluations with usability testing, it should be noted that an interface can be technically accessible but not usable for a particular user population (Power, et al. 2012; Powlik and Karshmer 2002). One example of an item that was technically "accessible" but was not usable for blind users, was the score interface. The app was developed using accessibility standards for tables, however the design of the table content ended up being modified to make it more understandable and usable. Visually, this change did not negatively affect the look or feel of the app, yet it made the interface usable for blind users. The log out confirmation that was added to the app was very helpful for blind users, and all users are likely to benefit from that addition. Most accessibility improvements on interfaces do not impact the look and feel of the interface and often provide other indirect benefits to the interface or other users (W3C 2009). A further example is the request by blind users to change the HTML "link" buttons to a format that allows for less precise touch (wider area in which the button can be activated). This is a usability change that will also have benefits to other users, particular those working under less than ideal environmental conditions or in situations in which users do not have the ability to make a precise touch on the screen. While there has been some discussion of the pros and cons of "unmasking" password fields on web sites (Schneider 2009), future work related to this project will likely

include additional investigation into the benefits versus frustrations of masked password fields on low security mobile apps.

It can be noted that users reported satisfaction with the learning app prior to the accessibility and usability improvements, however, it is likely that longer-term accessibility, satisfaction, and ease-of-use will be accomplished through those improvements. With the ubiquity of mobile, touch-based interfaces, increasing attention must be given to the accessibility and usability of proprietary and web-based apps designed for those interfaces. The need to constantly update proprietary apps and offer them for a variety of platforms might reduce the likelihood of accessibility for all versions of an app on each platform. In addition, with recent changes announced by Google to its ranking system for mobile searches (Google, 2015), it is likely that more organizations will be creating mobile web sites, and it is imperative that those sites be accessible. Developers of mobile interfaces should consistently follow standards such as WCAG, and verification of accessibility and usability prior to publication of those interfaces should ideally employ a combination of accessibility evaluations and user testing (with a diverse range of users). Regular testing with end users will not only ensure usability for individuals with disabilities, but it will also increase the likelihood of broader satisfaction and usability of mobile web sites and interfaces.

Acknowledgements

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