Applying Motivational Design to Support Informal Learning of Universal Design for Web Applications

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Abstract
We introduce CAN (Composable Accessibility Infrastructure), a framework to support learning Universal Design for web applications. We present how the ARCS (Attention, Relevancy, Competence, and Satisfaction) Model of Motivational Design is implemented to support informal online learning. In particular, CAN provides different searching mechanisms that allow web developers to independently learn different aspects of Universal Design, to build knowledge on how to address web accessibility issues, and to expand their understandings by leveraging CAN’s search on relevant topics from other communities.

Keywords: Universal Design; Online learning; ARCS model; Crowdsourcing; Search


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1 Introduction
Universal Design (UD) for web applications is a topic of increasing interest and importance. It includes two main concepts, web accessibility and usability. Accessibility enables a person with a disability to access the web, and usability enables all people the ability to use web content without any specialized prior knowledge (Ellis & Kent, 2011). Despite numerous initiatives and much progress, accessibility and usability remain significant issues for millions of web users. Though visual impairments are the most commonly cited, a number of other impairments such as auditory and cognitive affect people’s access and use of web applications as well. Because there are a large variety of web implementation technologies available, if web developers are not deeply aware of web accessibility issues and methods for fixing them, it can be difficult to recognize and address the breadth of problems that can occur. Therefore, learning the concepts and practices of UD for web applications is important in preparing developers to notice and correct accessibility issues (Rosnaita, Deibel, Cohen, & Egan, 2006).

Even though the topic of UD for web applications within a formal computer science program has been noted as important, it is still challenging to teach due to a lack of consensus on teaching strategies (Wang, 2012) and a lack of tools designed specifically to help instructors teach UD for web applications (Al-Khalifa & Al-Khalifa, 2011). As such, many web developers rely on informal learning outside of the classroom. For example, they use tools such as AChecker (“IDI Web Accessibility Checker: Web Accessibility Checker,” n.d.) or Wave (“WAVE Web Accessibility Tool,” n.d.), to examine a webpage; then given the returned error messages, they look up information on what the errors mean and try to solve the problems by themselves. In fact, as we presented in our prior work (Author 1 et al., 2015), many UD issues involving dynamic web components (e.g., dropdown menus) and usability issues (e.g., quickly allocating login components) are not detectable by the current tools, which focus on checking static web components.
(e.g., HTML content). A flexible and scalable solution is needed to search, find and address UD issues on the web to support informal learning.

In order to collect rich learning materials, we designed and developed a novel framework, called Composable Accessibility Infrastructure (CAN) (Author 1 et al., 2015). CAN is a multifunctional crowdsourcing infrastructure taking a data-driven approach. It accommodates the submission of real-world web accessibility issues and their fixes from contributors, utilizes them to dynamically and seamlessly compose on-the-fly solutions for web users, and guides web developers through understanding and solving the problem. We have showed how CAN addresses a set of accessibility issues on the top 100 popular websites (Author 1 et al., 2015). We presented the results of an initial user study where web developers who had varying knowledge of web accessibility all found our system a promising and interesting platform for learning web accessibility (Author 1 et al., 2015). However, during the user studies, we also observed different searching needs when users learn in an informal environment. Findings from these studies inspired us to redesign user interactions in the CAN system so as to better support informal online learning.

In this paper, we present the evolution of CAN. We will explain how we discover learners’ needs while studying participants using the tool and our consultation with learning theories to guide our redesign of search interactions. In the remainder of this paper, we first review relevant literature from several areas of interest. We then review the crowdsourcing model of CAN at high level and present how observations of previous studies drove us to implement the ARCS (Attention, Relevance, Confidence, and Satisfaction) Model of Motivational Design to better support informal learning. We show the new user interaction and a preliminary user study. Finally, we reflect on the implications of our preliminary results.

2 Related Works

Previous work has shown that tools designed specifically to detect and assist in correcting accessibility issues also hold educational opportunities for web developers. Evaluative tools are already important for developers, as manual evaluation of WCAG has been found to be unreliable (Alonso, Fuertes, González, & Martínez, 2010). Free, simple tools such as AChecker (“IDI Web Accessibility Checker: Web Accessibility Checker,” n.d.) allow developers to upload HTML files to check for accessibility issues, identifying specific problems and offering brief repair suggestions. Feedback on accessibility issues from some tools has been found more suited to experts, leading to the development of accessibility tools such as Accessibility Evaluation Assistant, which offers explanation and guidance more suited to beginning developers, with longer written explanations of problems and how to correct them (Pearson, Bailey, & Green, 2011). Benavidez et al. (2006) explored teaching accessibility through the use of two tools: (1) a website designed to demonstrate accessibility problems, and (2) HERA, a tool that assisted students in accessibility evaluation and provided some guidance on resolution through the use of written explanation and code highlighting. Many existing accessibility evaluation tools rely on a self-contained repository of textual explanations and fixes for problems but have not incorporated the wealth of pre-existing information available online.

Among many online learning resources for web developers, GitHub and StackOverflow are often cited as two of the more predominant sites (Vasilescu, Filkov, & Serebrenik, 2013). Vasilescu et al. (2014) examined question-and-answer site StackOverflow and determined that is has increasingly taken the place of mailing lists in the programming community due to its increased visibility and the increased speed with which answers are provided. Code hosting and question-and-answer sites have been found to be among the top communication channels for software engineers (Storey, Singer, Cleary, Figueira Filho, & Zagalsky, 2014). Limited work has examined web developers’ use of online resources to learn more about accessibility topics specifically.
3 CAN (Composable Accessibility Infrastructure) – Enabling Informal Learning

We built CAN (Composable Accessibility Infrastructure) (Author 1 et al., 2015) using prior approaches (Bigham & Ladner, 2007) that used crowdsourcing as a way to improve web accessibility, but it does so in a way that can drive future data-driven approaches for fixing problems and educating developers. In particular, CAN collects a variety of web accessibility issues on real websites and their software fixes, dynamically composes fix solutions on the fly and delivers the crowdsourced content as teaching materials to improve web accessibility.

![Diagram of CAN system]

Figure 1. Crowdsourcing model of the CAN search engine

Figure 1 shows the model of the CAN system. End users who have accessibility issues make a one-time installation effort to install CAN’s End User Browser Plugin. Subsequently, whenever the end users open a new webpage link, CAN services will be executed without end users’ awareness. Running the browser plugin, end users both benefit from the system directly and contribute to the system implicitly, because the plugin checks for accessibility compliance and logs accessibility problems with the websites as potential learning objects. These problems will be used as learning objects for web developers using CAN to understand Universal Design (UD) concepts. Open-source contributors (AC Contributors) can share their code to fix accessibility issues through CAN. The solution code can be served to web developers as concrete examples for learning how to implement a particular UD concept. Web developers who may not know web accessibility and need quick solutions to fix their web page problems, or may have interests in learning how to implement the solutions by themselves can interact with CAN and have access to learning the objects and examples.

3.1 Discovering the Need to Build Relevance

To evaluate how web developers would perceive and use CAN to address an accessibility problem, we conducted a set of initial user studies focusing on how they use the web developer plugin and whether they like this learning process. The first round of study was reported in (Author 1 et al., 2015). We recruited web developers who had previous experience with JavaScript from our university’s community. The first user study focused on one specific learning outcome, i.e. how to fix an inaccessible drop-down menu. Results from the initial user study demonstrated developers enjoyed using CAN to deal with accessibility issues, but users’ comprehension of the final solution was dependent on their previous training and experience, with less experienced users needing assistance in understanding basic elements or concepts. Also, findings showed that web developers rely on searching online resources for assistance in learning.

After the first round of user study, revisions were made to the design of CAN. To support searching for further information, keywords such as “TabIndex” were also included in the solution code to provide assistance in query formation. Links to specific pages within recommended relevant online resources such as http://www.w3schools.com/ were also provided as an option to users to provide additional context and explanation.
To evaluate the effectiveness of the redesign of CAN as well as further explore web developers’ learning preferences and strategies, a second round of the study was conducted with 5 of the participants. After using CAN and reviewing the web resources, all felt confident they could now solve this problem themselves. This is a significant difference from the first user study, where not all participants felt confident in their understanding after using CAN. When asked if they had needed to do more to feel confident, four said they would post questions to a site like StackOverflow during round 1. While all five reported they would use a tool like CAN, suggestions for improvements included being able to modify the solution and being shown the problematic portions of the source code. Though the design and use of CAN for the second user study still focused on a very specific learning outcome, modifications allowed users to explore further context and content surrounding issues. This resulted in increased confidence and comprehension. Further facilitating new search options while quickly connecting users to known and trusted sources, and allowing them to discern between resources of varying structural organization emerged as important considerations in the continued development of CAN. Noticing that participants expressed a need to build relevancy, we chose to integrate the ARCS Model of Motivational Design into the next stage of CAN’s development.

3.2 ARCS Model
The ARCS Model of Motivational Design was developed by John Keller and has parallel relationships to instructional design principles (Poulsen, Lam, Cisneros, & Trust, 2008). The ARCS Model focuses on the presumption that people are motivated to learn if there is value in the knowledge presented and if there is an optimistic expectation for success (Poulsen, Lam, Cisneros, & Trust, 2008). There are four steps that are included in the ARCS Model: attention, relevance, confidence, and satisfaction. Attention and relevance are considered the backbones of the theory, whereas the other steps rely on the former. The confidence step of the ARCS Model is where the principles of constructivism reside because the learner is taking control of their learning. The participants also commented that they preferred learning through the trial and error method and being given feedback. As a result, their motivation for learning increased and the participants expressed that they valued the knowledge presented. This directly relates to the ARCS Model of Motivational Design and suggested it as a fruitful focus for our current study.
Inspired by the ARCS model, we redesigned the user interaction design. Unlike the first user interaction design that focused on delivering the solutions to enable UD for web applications, this new design tries to motivate web developers to learn technologies by exploring different search options, and each of the search results can help learners to reach a particular learning step. We implemented the new design by adding new functions to the CAN developer plugin using Chrome extension APIs.
For example, Figure 3 (a) shows that when the web developer right clicks the mouse, in addition to the classic options, e.g., Back, Reload, etc., there is a CAN option. In the first level, there are Search for problems, Highlight the detected, Stackoverflow.com, Check this fix, and Fix yourself. Then under StackOverflow.com, there are two options Find relevant topics on StackOverflow.com and Send to StackOverflow.com, as shown in Figure 3 (b).

Upon clicking Search for problems, CAN checks the WCAG 2.0 standards, and outputs to the developer console page a list of source code of the webpage that cause UD issues, as shown in Figure 4. However, as such representations may not be efficient for developers to find the problematic web components, the Highlight the detected option highlights the web components with UD issues with red boxes, as shown in Figure 5. This design aims to draw people’s attention to the related issues and quickly identify the UD concepts to review and target problems to address.

![Figure 4](image_url)  
Figure 4. Showing the list of UD problems in a webpage by selecting the menu option “Search for problems”

![Figure 5](image_url)  
Figure 5. Drawing users’ attention by highlighting the relevant web components that have UD issues

According to previous studies, web developers prefer to look up specific problems and relevant topics from certain communities such as StackOverflow. We further implemented the function of providing a related topic search from Stack Overflow, as shown in Figure 6 (a). If there is no relevant topic previously posted, learners can choose to Send to Stackoverflow.com by commenting on the problem, as shown in Figure 6 (b).
Finally, the **Check this fix** and **Fix yourself** options lead to a similar interaction to the first design in Figure 2. The only difference is that the **Check this fix** option shows the solution, and the **Fix yourself** option asks the developer to define the new function and fill in the required code that can fix the UD issues.

In summary, we include the steps of the ARCS Model to help build relevancy by first gaining learners’ attention; once learners’ attention is established, they can use the provided links and search results from relevant online communities to build relevancy. Further, they can simulate sample solutions and test by themselves, which can eventually result in the building of their confidence and satisfaction. The ARCS Model is expected to fit nicely with our study because it is directly related to the field of instructional design and design theory and helps the user to develop a unique problem-solving process.

![Relevant posts from Stack Overflow](image1.png) ![Sending questions to online community](image2.png)

**Figure 6.** Searching for information and looking for help from relevant online communities, i.e., stackoverflow.com.

### 3.3 Preliminary User Study

A preliminary user study was conducted to test this most recent design of CAN. Three participants were again given the task presented in the first two user studies, i.e., to fix an inaccessible drop-down menu. Participants were shown the accessibility problem with the menu and then introduced to the CAN developer console. They were then asked to explore each of the CAN menu options to learn more about the problem before being asked if they were able to solve the accessibility issue. Participants were then instructed to follow the links provided by CAN and to perform additional web searching as needed. Afterwards, they were asked to report their understanding of the accessibility problem and CAN’s solution.

Results of this initial user study were very positive. After using CAN and the online informational resources CAN helped them identify, participants showed an increased understanding of the accessibility problem, and all three felt comfortable facing this problem in future web development work. Participants’ use of various information resources revealed a particular interest in the format or genre of resources used by developers. For example, a participant explained that he preferred StackOverflow and similar question-and-answer sites as an initial learning resource. Additionally, two of the participants found the ability to send questions to StackOverflow to be a helpful feature. All participants reported that they would be interested in using CAN, and suggestions for improvement focused on increasing the variety of accessibility and development issues that CAN is able to address. With the addition of keywords, interactivity, and specific resources, participants reported that they felt confident in completing the activity. The participants also commented that they preferred learning through the trial and error method and being given feedback. As a result, their motivation for learning increased and the participants expressed that they valued the knowledge presented.
4 Summary and Future Work

CAN provides a collaborative mechanism for not only reporting and fixing accessibility problems, but also shows promise as an effective learning tool for web developers. Awareness and understanding of UD on the part of web developers is one crucial component for building a more accessible and usable web. The results of three rounds of user studies have shown CAN’s progressing design to be effective at supporting web developers in learning web accessibility concepts and issues through online resources. Learning support provided by CAN works towards motivating learners and connecting them to a variety of resources through effective searching. Learning web accessibility through CAN serves as an insightful case study in how particular online learning needs can be recognized, motivated, and accommodated, and how interactions with a search system can be designed to improve learning outcomes. The use of real life websites and solutions provided by other web developers increases the relevance of the topic to the user. Our future study will provide measures to further evaluate the effectiveness of the new design.

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6 References


