E-book Accessibility Evaluations

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Abstract. This paper illustrates how the level of accessibility of e-textbooks can be evaluated using a process developed by Human Factors researchers. We report the results from accessibility evaluations of 140 publically available e-textbooks from the California Open Online Library for Education (COOL4ed). Each textbook was evaluated for adherence to 15 SkillsCommons accessibility checkpoints developed by the MERLOT (Multimedia Educational Resource for Learning and Online Teaching) project using accessibility manuals and a scoring system developed for e-textbooks. Some books were made available in more than one format (e.g., EPUB, HTML, or PDF), and each e-textbook was evaluated in the formats that it was made available. Moreover, each book was evaluated for accessibility using assistive technologies (AT) and using non-assistive technologies (NAT). A total of 166 evaluation reports using non-assistive technologies and 163 evaluation reports using assistive technologies were produced. We found that e-textbooks in HTML and EPUB formats were more accessible than PDF. We also examined how the technical content of the textbook differed in terms of accessibility. There was no difference in accessibility scores between books with STEM versus no STEM content; however, when examining the "passing rate" of the books, there were differences depending upon whether the evaluation was performed using NAT or AT. Overall, this project provides evidence that methodology for evaluating e-textbooks can be applied to a broad library of books. Providing accessibility scores rather than simply whether the e-textbook is compliant with the American Disability Act (ADA) can be useful to a variety of stakeholders.

Keywords: Accessibility · Accessibility evaluations · E-textbook accessibility · E-textbook usability · Electronic book accessibility

1 Introduction

A majority of universities in the United States are adopting online components in their education curriculum. Some of these components are designed to supplement the traditional material that students receive in the classroom, and other components are designed to replace them. E-learning has been a growing area since the 1990s [1]. Many studies have shown that online courses could produce equivalent learning

T. Andre (ed.), *Advances in Human Factors in Training, Education, and Learning Sciences*, Advances in Intelligent Systems and Computing 596,
DOI 10.1007/978-3-319-60018-5_32

outcomes compared to traditional, face-to-face courses [2]. A major benefit from online learning is that it provides greater access than traditional classrooms [3]. With the proliferation of computers and laptops, and the introduction of e-readers and tablets, many printed books are being replaced by e-books. The growing use of digital learning materials such as e-textbooks and their integration into the educational system have created a need for evaluating the accessibility and usability of such resources.

When textbooks are converted into an electronic format, the e-textbook can simply be a digital copy of the printed material (e.g., a pdf file of the book) or it can be converted into a more interactive form (e.g., web-based book with hyperlinks and multimedia). Regardless of the format, the content should be accessible. Federal regulations provide minimum accessibility guidelines that need to be followed [e.g., compliance with the American Disability Act (ADA); compliance with Web Content Accessibility Guidelines (WCAG)] but as human factors practitioners, we should advocate going beyond meeting minimum accessibility requirements because increasing the accessibility of e-textbooks can also increase their usability [4].

Making e-textbooks more accessible can help benefit people with disabilities by allowing them to better perceive, understand, and navigate/interact with the materials. It has been shown that improving web accessibility not only benefits people with disabilities, but it can also benefit other groups of people, including older users and users accessing information under restrictive conditions or even on mobile devices [5]. e-textbooks that are rated higher in accessibility can be more beneficial to a variety of different users compared to e-textbooks that are rated lower in accessibility. Thus, there is a need to evaluate the level of accessibility of an e-textbook rather than just a check to ensure that the e-textbook is ADA compliant.

E-textbooks are particularly beneficial for students because, in comparison to printed textbooks, e-textbooks cost less and can be accessed from different locations and from various web-enabled devices (e.g., desktop computer, laptop, tablet, or mobile device). The prospect of affordable and accessible education has led to a collaboration of several California school systems (e.g., California State University, University of California, and California Community College) in the promotion of the use of free or low-cost e-textbooks, with the goal of "making higher education in California more affordable by providing faculty and students access to free and lower-cost instructional materials" [6]. We use the e-textbooks in the COOL4ed collection to determine the level of accessibility of current e-textbooks.

2 Practice Innovation

The purpose of this paper is to illustrate that e-textbooks vary in the level of accessibility provided to students. By providing students, faculty, and publishers with an accessibility score for different e-textbooks, faculty and students can use this information to select textbook for adoption/use, and publishers can direct development efforts to make the individual e-textbook more accessible. We used the e-textbooks from California Open Online Library for Education (COOL4ed) collection because it is a large and freely available resource. We employed the methodology and scoring

system developed by Sun et al. [7] and Chan et al. [8] to perform the accessibility evaluations of e-textbooks in different formats (i.e., EPUB, HTML, PDF, and WORD).

Each e-textbook evaluation consisted of a score on 15 SkillsCommons [9] accessibility checkpoints that were tailored from Section 508 standards to address the content found in college-level textbooks. The SkillsCommons accessibility checkpoints were developed by the MERLOT (Multimedia Educational Resource for Learning and Online Teaching) project and Web Content Accessibility Guidelines (WCAG) 2.0 of the Web Accessibility Initiative (WAI) [10], which have been used for evaluating the accessibility of electronic learning materials and web content [7].

Assistive technology (AT) and non-assistive technology (NAT) manuals [7] for each of the four e-textbook formats were used in the evaluation. Assistive technologies refer to specialized software designed for use by people with disabilities (e.g., Kurzweil, Zoomtext, etc.). Non-assistive technologies refer to tools that can be used to assess the accessibility checkpoints that are not designed specifically for people with disabilities. Assistive technologies often incur more costs to the users to employ compared to non-assistive technologies. Thus, evaluations performed with both types of tools can provide evidence regarding whether it is necessary to use assistive technologies in the evaluation of e-textbook accessibility. The manuals provide step-by-step procedures for each checkpoint. For each checkpoint, there is a description of the checkpoint, instructions to obtain specific tools to be used, procedures for using the tools, and instructions on how to evaluate and score each checkpoint. Scores for each of the 15 checkpoints ranged from 1 to 10; a final score was obtained by using a weighted-average formula [8]. E-textbooks were considered to "pass" with a score 7 or higher, but the individual scores are made available for each book. Six trained raters evaluated all 140 available e-textbooks in the COOL4Ed library. A total of 329 evaluation reports (166 reports using non-assistive technologies, 163 reports using assistive technologies) were produced, and each report included an accessibility score based on the evaluation.

3 Findings

As noted earlier, accessibility scores could range between 1 and 10, with 10 being the highest score. Scores for each book and the evaluation reports are posted on the COOL4ed website: http://cool4ed.org/courseshowcase.html (see Figs. 1 and 2 for example screenshots).

We submitted the accessibility scores to a 3 Book Format (HTML, EPUB, or PDF) $\times$ 2 Evaluation Type (NAT or AT) between factors ANOVA. We found significant differences between the accessibility scores for the different book formats, $F(2, 328) = 23.98$, $p < .001$, where HTML and EPUB e-textbooks scored higher in accessibility compared to PDF e-textbooks. There were no significant differences between NAT and AT evaluation type, and evaluation type did not interact with the book format. For HTML e-textbooks, the mean score was 7.33 and 7.20 when using NAT and AT to perform the evaluations, respectively. EPUB e-textbooks yielded a mean score of 7.04 when using NAT evaluations and 7.18 when using AT evaluations. PDF e-textbooks yielded the lowest scores of 6.19 and 6.22 for NAT and AT

Fig. 1. Screenshot of two books from the COOL4ed collection [6]: http://www.cool4ed.org/courseshowcase.html. The accessibility evaluations are highlighted by the arrows.

evaluations, respectively. There were only a few books available in WORD format; therefore, the results from WORD format are not analyzed. The correlation between the NAT and AT scores was $r = .312$, $p < .01$.

Chan et al. [8] indicated that e-textbooks with a score of 7 or higher are considered to "pass" the accessibility test. That is, these books are likely to offer an adequate level of accessibility to students (see Fig. 3). Based on this criterion, the passing rate was 64% and 55% for HTML e-textbooks when evaluated with NAT and AT tools, respectively. EPUB e-textbooks had a 50% and 59% passing rate using NAT and AT evaluations. For PDF e-textbooks, the passing rate was only 26% when using either NAT or AT evaluations.

One possible reason for the lower passing rate is that EPUB is still fairly new compared to HTML. The International Digital Publishing Forum (IDPF) [11] standardized EPUB as the official e-book format in 2007, and it is only in its third iteration. HTML has been around for a much longer time period, and the higher passing rate for HTML is likely due to the versatile nature of HTML, which allows Internet users to modify and customize websites coding and their content to fit the users' individual needs. PDF format tends to be inflexible, yielding the lowest accessibility scores and percentage of "passed" books.

SUMMARY OF ACCESSIBILITY EVALUATION:

Textbook: **How to Think Like a Computer Scientist**
Format of Textbook: **HTML**

Assistive Technology (AT) Evaluation Score: Overall	**6.2 (Maximum score = 10)**
Assistive Technologies (AT) Evaluations applies specialized tools and software in the accessibility evaluation process. These specialized assistive technologies, see list below, are typically not used or available by the general public into the accessibility evaluation process. • Accessibility features of desktop operating systems (e.g. high-contrast display themes, settings from the Keyboard and Mouse control panels) • Accessibility-related software included with desktop operating systems (e.g. VoiceOver, Microsoft Narrator) • Third-party accessibility software and hardware: • Screen readers (e.g. JAWS, Window Eyes) • Magnification software (e.g. ZoomText Magnifier/Reader, MAGIC Pro with Speech) • Reading software for users with learning disabilities (e.g. Read and Write Gold, Kurzweil 3000) • Refreshable Braille displays	
Non- Assistive Technology (NAT) Evaluation Score: Overall	**7.0 (Maximum score =10)**
Non-Assistive Technologies (NAT) Evaluations applies only native or basic tools and software such as the keyboard and Narrator in the accessibility evaluation process. These non-assistive technologies are readily available and used by the general public.	

Fig. 2. Screenshot of part of an evaluation for 1 e-textbook from the COOL4ed collection [6]: http://www.cool4ed.org/courseshowcase.html, illustrating the overall accessibility score for the AT and NAT evaluation.

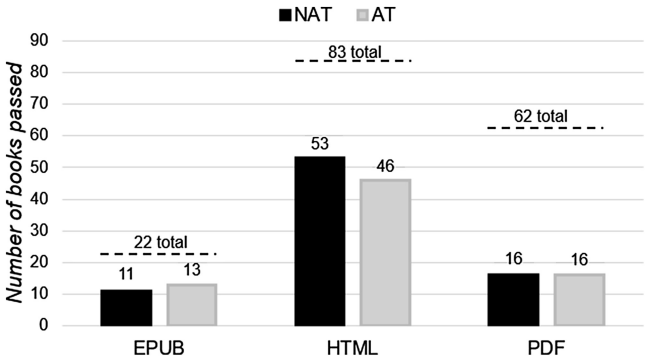

Fig. 3. E-book passing rates by format.

We also examined how the passing rates changed with each e-textbook with the use of AT versus NAT evaluations. For EPUB, we found no difference: half of EPUB e-textbooks received a higher score in AT evaluations compared to NAT evaluations

and the other half higher scores with NAT evaluations compared to AT evaluations. When comparing passing rates for HTML format, we also found little difference: 53% of the time, HTML e-textbooks received a higher score in AT evaluations compared to NAT evaluations. When comparing the scores in PDF format, we again found little difference: 52% of the time, PDF e-textbooks received a higher score in AT evaluations compared to NAT evaluations. Thus, passing rates did not differ much when using assistive technologies to perform the evaluations compared to when using non-assistive technology.

To determine whether e-textbooks with more technical content are more or less accessible compared to e-textbook with less technical content, we looked at the accessibility scores of e-textbooks with more technical content (STEM- science, technology, engineering and mathematics) or less technical content (non-STEM). We found no significant differences between accessibility scores for non-STEM (M = 6.96) and STEM (M = 6.60) books, $F(1,332) = 2.45$, $p > .11$. Furthermore, there were no significant differences in scores for e-textbooks with STEM or non-STEM content when evaluated using NAT or AT tools, $F < 1.0$.

When comparing the passing rates for STEM and non-STEM e-books (see Figs. 4 and 5, respectively), we found different patterns of results. For STEM books, NAT evaluations led to higher passing rates for EPUB (56%) and PDF (33%) formats compared to the AT evaluations (passing rates of 22% and 18%, respectively). The opposite pattern was found for e-textbook with non-STEM content, as NAT evaluations produced lower passing rates for EPUB (47%) and PDF (21%) formats compared to AT evaluations (85% and 38%, respectively). For HTML format, the passing rate differed depending on book content (STEM and non-STEM). For STEM related books,

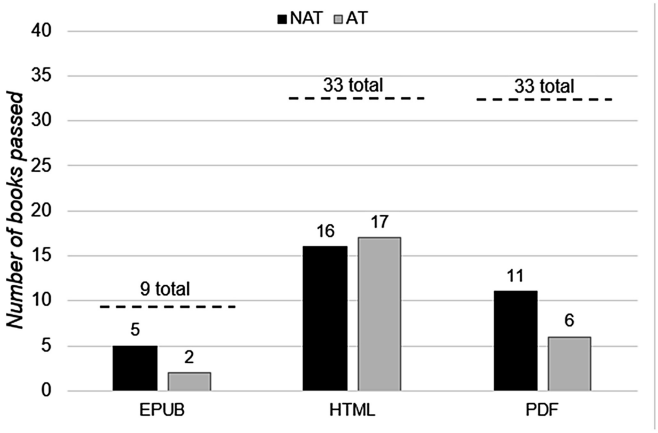

Fig. 4. Passing rates of STEM e-books by format.

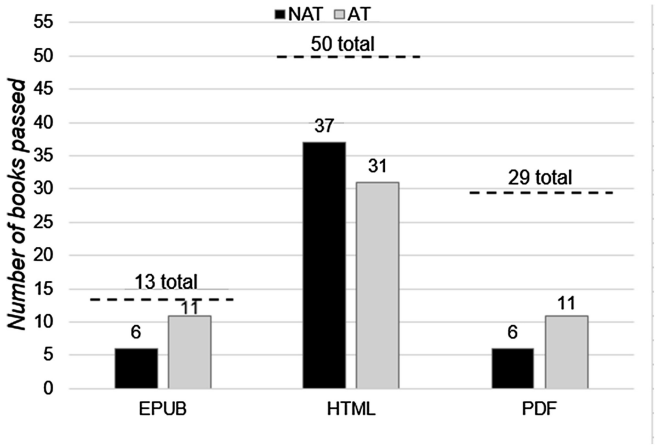

Fig. 5. Passing rates of non-STEM e-books by format.

HTML books yield a similar passing rate when using AT (52%) and NAT (48%). For non-STEM-related books, though, HTML books evaluated with NAT had a higher passing rate (74%) compared to books evaluated with AT (62%).

4 Discussion

We have demonstrated how accessibility evaluations for e-textbooks can be used and implemented in a large digital library. We found that HTML and EPUB e-textbooks scored higher in accessibility compared to e-books in PDF format. Evaluations performed using NAT or AT did not yield significantly different accessibility scores, but resulted in differences in passing rates.

The accessibility scores and detailed evaluation can be beneficial to a variety of stakeholders. By evaluating the accessibility level of the e-textbooks, faculty will be able to use this information to select e-textbooks for course adoption. Students will be able to gauge how much accommodation will be provided by the e-textbook, and publishers can help prioritize where to direct their resources for making e-textbooks more accessible. For example, examining the detailed evaluation captured in Fig. 6, publishers may decide that color and contrast problems may be easily fixed and doing so would increase the accessibility scores of the e-textbook.

Sun et al. [4] conducted a validation study to examine if the scores we assigned to a small sample of books in the COOL4ed collection resulted in differences in user performance and user experience with the e-textbook. Sun et al. found little differences in reading comprehension performance between e-textbooks that scored higher or lower in accessibility, but the e-textbooks that were given higher scores resulted in better user experience across a number of metrics. Thus, the accessibility scores provided by this project are useful in practice.

8. Hyperlinks

A. In-book links take you to a location within the textbook. For example, the table of contents would be considered in-book links and embedded links take you to the correct location in the book.	**N/A**
Additional Information:	**All HTML links are live.**
B. Live hyperlinks take you to any website or webpages external to the book.	**Pass**
Additional Information:	**Most links work and most have sufficient descriptive text.**
C. Live links take you to the correct webpage that is functioning properly.	**Pass**
Additional Information:	**46/50 links work, home page: 35/35, preface: 3/4, contributor list: 0/2, ch. 1: 2/3, ch. 2: 1/1, ch. 3: 1/1, ch. 4: checked first 4, 4/4.**
D. Live links are descriptive enough for the users to know where it should take them.	**Pass**
Additional Information:	**43/50 links have sufficient descriptive text, home page: 35/35, preface: 1/4, contributor list: 0/2, ch. 1: 3/3, ch. 2: 0/1, ch. 3: 1/1, ch. 4: 3/4.**

9. Color and Contrast

A. All information within the material that is conveyed using color is also available in a manner that is compatible with those that do not perceive color, and information conveyed by color is also conveyed in other ways.	**Pass**
Additional Information:	**Checked home page, ch. 5-10: everything has color redundancy, but "how to think like a computer scientist", "index", and "next" are questionable. Their location might indicate that they are links.**
B. Information is conveyed from the sub-categories for contrast.	**Fail**
Additional Information:	**Checked home page, ch. 11-14.**
C. Contrast for headers passed WCAG AA standards for large texts (contrast ratio 3:1).	**Pass**
Additional Information:	**Checked home page, ch. 11-14, all headers pass.**
D. Contrast for text passed WCAG AA standards for normal texts (contrast ratio of 4.5:1).	**Fail**
Additional Information:	**Checked home page, ch. 11-14: orange (links and in python code), light blue (in python code), red (in python code), gray copyright text at the bottom of each page all fail.**
E. Contrast for simple images (for example, images of atoms) passed WCAG AA standards (contrast ratio of 4.5:1).	**Fail**
Additional Information:	**Checked home page, ch. 11-14: all gray boxes of python code fail against white bg, ch. 12: 2/2 fail, ch. 13: 1/1 fail.**

Fig. 6. Screenshot of the detailed evaluation from the COOL4ed project [6], http://www.cool4ed.org/courseshowcase.html, where readers can examine the scores for each checkpoint and reasons for why the e-textbook passed or failed each criterion.

Acknowledgements. Special thanks to the Center for Usability in Design and Accessibility for supporting this project. Partial funding for this project was provided by the State of California, the William and Flora Hewlett Foundation, and the Bill and Melinda Gates Foundation for the California Open Online Library for Education.

References

1. Rosenberg, M.J.: E-learning: Strategies for Delivering Knowledge in the Digital Age, vol. 9. McGraw-Hill, New York (2001)
2. Hansen, D.: Knowledge transfer in online learning environments. J. Market. Educ. **30**(2), 93–105 (2008)
3. Mayadas, A., Bourne, J., Bacsich, P.: Online education today. Science **323**(5910), 85–89 (2009)
4. Sun, Y., Vu, K., Strybel, T.: A validation test of an accessibility evaluation method. In: Ahram, T., Falcão, C. (eds.) Advances in Usability and User Experience, Advances in Intelligent Systems and Computing, vol. 607. (2017). doi:10.1007/978-3-319-60492-3_59
5. Caldwell, B.B., Vanderheiden, G.C.: Access to web content by those with disabilities and others operating under constrained conditions. In: Handbook Human Factors Web Design, vol. 2 (2011)
6. Cool4Ed, about this project. http://www.cool4ed.org/about.html
7. Sun, Y., Manabat, A.K.M., Chan, M., Chong, I., Vu, K.: Accessibility evaluation: manual development and tool selection for evaluating accessibility of e-textbooks. http://link.springer.com/chapter/10.1007/978-3-319-41691-5_28 (2016)
8. Chan, M., Sun, Y., Tesoro, A., Vu, K.: Development of a scoring system for evaluating the accessibility of etextbooks. https://www.researchgate.net/publication/304995934_Development_of_a_Scoring_System_for_Evaluating_the_Accessibility_of_eTextbooks (2016)
9. SkillsCommons, Accessibility and SkillsCommons. http://support.taaccct.org/accessibility/
10. Web Accessibility Initiative (WAI): Introduction to web accessibility. https://www.w3.org/WAI/intro/accessibility.php
11. International Digital Publishing Forum: About Us. http://idpf.org/about-us