Accessibility Evaluation: Manual Development and Tool Selection for Evaluating Accessibility of E-Textbooks

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Abstract The growing availability of digital learning materials and their integration in many facets of the education system have created a need for evaluating the accessibility and usability of e-learning materials. In some cases, these digital resources are simple conversions of the original, printed materials into electronic formats. In other cases, the digital versions of the materials take advantage of the interactive abilities of the online and electronic media to enhance students' learning experiences. Regardless of format, however, the content needs to be accessible. Although accessibility guidelines and accessibility evaluations tools are available to users, there is no comprehensive accessibility evaluation technique to help guide users in selecting the most accessible learning materials. In this study, we surveyed existing accessibility tools, selected a recommended tool set, and created a manual for post-secondary educators, students, and other stakeholders to use for evaluating the accessibility of e-textbooks.

Keywords Accessibility evaluation · Web accessibility · Disability · Assistive technology · E-textbook

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1 Introduction

Most universities in the United States are adopting online components in their education curriculum. Many studies have shown that online courses could produce equivalent learning outcomes compared to traditional, face-to-face courses [1]. However, a major benefit from online learning is that it provides greater access than traditional classrooms [2]. For example, if students are able to access their textbooks online and retrieve class information online, they will have convenient access to their learning materials. In addition, students could save money due to the reduced costs associated with producing electronic materials. However, the online course materials must be accessible for the students to be able to maximize their potential use.

Originally, web accessibility was thought to be primarily important for people with disabilities because it allows this group of users to perceive, understand, navigate, and interact with online materials. It has been demonstrated, however, 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 [3]. Although federal regulations are available for providing minimum accessibility requirements [4], when considering e-learning for post-secondary education, broader accessibility issues need to be considered. First, it is important to determine how accessible a learning material is for individuals who use assistive technologies versus those who do not. Beyond this comparison, measuring the degree of accessibility provided by different e-learning materials is also key. A final issue to consider is whether the optimal accessibility tools identified for one type of format (e.g., HTML) are ideal for use with other formats (e.g., EPUB or PDF). In this study, we take the first step at examining these issues by evaluating the accessibility tools that are available for checking different accessibility components of e-textbooks in different formats.

E-textbooks are usually 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). For example, the California school system (California State University, University of California, and California Community College) has enacted legislation to promote the use of 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" [5]. This legislation supports students' access to free e-textbooks and will likely to increase the number of users who regularly access e-textbooks for their classes. Although EPUB, HTML and PDF are common e-textbooks formats, at the time of this writing, no accessibility tools or guidelines for evaluating the accessibility of e-textbooks across all of these formats have been released.

Current guidelines are available for web-based content, but these guidelines may not be directly applicable to specific e-textbook formats. Several accessibility evaluation tools are available on the market for people to use for conducting

Table 1 Comparisons of candidate non-assistive color and contrast tools based on price and compatibility (yes or no) with different e-textbook formats

Tools/software	Price	EPUB	HTML	PDF
Color contrast analyzer (CCA, stand alone tool)	Free	Yes	Yes	Yes
WebAIM color contrast checker	Free	Yes	Yes	Yes
Google chrome extensions—color contrast analyzer	Free	No	Yes	No
Check my colors	Free	No	Yes	No

accessibility evaluations, but there has been little research illustrating the effectiveness of each of these tools [4]. Moreover, many of these accessibility tools cannot be used in an automatic fashion (i.e., press a button and receive results). Rather, the tools need to be used by human accessibility evaluators and these evaluators have to perform manual checks and make judgements of accessibility based on the outcomes. Most importantly, we are not aware of standard accessibility techniques that available for evaluating e-books in different formats. To fill this gap in the literature, the goal of this project was to develop a methodology for evaluators to determine the level of accessibility of e-textbooks in different formats.

We will present two phases of the present project: (1) accessibility tool review and (2) instruction manual creation. In the first phase, we compiled an inventory of existing tools that were available to evaluate different aspects of e-books, using a SkillsCommons checklist. The SkillsCommons checklist includes a list of 15 checkpoints that evaluators should assess when determining the overall accessibility of a product (refer to Tables 1, 3 and 4, for details about each checkpoint). The SkillsCommons accessibility checkpoints were developed by the MERLOT (Multimedia Educational Resource for Learning and Online Teaching) project, and WCAG 2.0 guidelines. The checklist has been used for evaluating the accessibility of electronic text and media on the web [6]. In the second phase, we describe the methods used to develop accessibility manuals for e-textbook evaluation.

2 Phase One: Accessibility Tool Review

2.1 Method

A total of 10 human factors students were involved in the checkpoint tool/method review and evaluation phase. The students worked in 4 groups of 2–3 students each. Their task was to find existing tools that can be used to evaluate a subset (3–4) of the SkillsCommons accessibility checkpoints (see Fig. 1 for flow model). Some of the checkpoints could be assessed using non-assistive technologies, and others using assistive technologies. We will describe the methods used for each of these technologies separately below. Each group presented their findings to the entire group and two subject matter experts (SMEs). In consultation with the two SMEs, a subset of tools were selected to be used in the evaluation process based on the
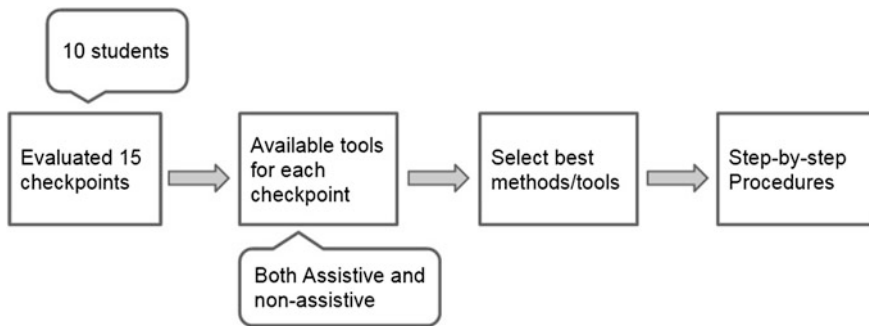
Fig. 1 First stage of manual creation and tool evaluation process

Table 2 Comparisons of four popular assistive technologies' based on format compatibility (yes or no) with different e-textbook formats

Software	Price	EPUB	HTML	PDF
JAWS	$895	Yes (JAW12+)	Yes	Yes (tagged files)
ZOOMTEXT	$595	No	Yes	Yes
Kurzweil 3000	$1495 (Pro, color)	Yes (ver. 13.09+)	Yes	Yes (pro/V5)
NVDA	Free	No (w/adobe digital editions)	Yes	Yes

availability of the software, functionality, pricing, popularity among users, and our subjective assessment of the reliability of the tools.

Non-assistive Technologies. For non-assistive tools, the group found 20 tools. For each checkpoint, we compared the proposed tools based on their functionality and price. Due to the page limitations of this paper, only one example is provided here for the color and contrast checkpoint (see Table 1 for a listing of tools and review criteria). After demonstrating each tool, the group discussed the advantages and disadvantages associated with each tool with the SMEs, and the most suitable tool was selected for each checkpoint. It should be noted that many of the checkpoints needed to be manually checked by the human evaluators.

Assistive Technologies. For checkpoints that required use of assistive technologies, four recommended software tools were compared (see Table 2): JAWS, ZoomText, Kurzweil 3000 and NVDA. These tools were candidates for comparison because they have been identified as the most popular tools that are used by students with disabilities.

JAWS (Job Access With Speech) is a screen reader software that converts text and components of the operating system into synthesized speech. JAWS can read text out loud from the computer screen, and can be used to browse the internet, read electronic books, and other materials. JAWS can also be used in telecommunicating and word processing [7].

ZoomText is mainly a screen magnification tool, but it has several other accessibility features. ZoomText allow you to zoom content from $1\times$ to $36\times$ magnification with eight zoom window types. It also includes features such as color, brightness, and contrast controls, visible pointers and cursors, dual monitor support and application-specific settings. Options for human-sound reading voices and automatic document reading are also available [8].

Kurzweil 3000 allows users to read electronic and printed materials. Kurzweil 3000 is an optical character recognition system that displays printed or electronic text on the computer screen. Text can be read by a speech synthesizer or by the user on the computer screen. Kurzweil 3000 has many options such as a dictionary and spell checker. It can also be used in web browsing with an installation of extension [9].

NVDA (Nonvisual Desktop Access) is an open-source, Windows screen reader that uses eSpeak speech synthesizer, SAPI 4 and SAPI 5 synthesizers. NVDA can be used for browsing the internet, telecommunications, word processing and reading electronic books and other materials [7].

2.2 Results

Non-assistive Technologies. The tools selected for non-assistive technologies are shown in Table 3. All of these tools/software are freely available to the general public. We focused primarily on these tools because free tools/software are more likely to be used by organizations such as educational institutions.

For each software, we analyzed the usability of the tool. For example, both CCA (Color Contrast Analyzer) and WebAIM contrast checker tools can be used across all e-textbook formats; however, CCA was selected as the best tool because it was easy to use. CCA uses an eyedropper tool that an evaluator can use to select a color from the electronic file and the tool will analyze the extracted color. In contrast, WebAIM requires that the evaluator enter the hex color code for specific color (for example, color white is represented as #ffffff). There were other free contrast checker tools that are available on the market, but most of them were not selected as potential candidates because they required special knowledge of color coding similar to WebAIM.

Assistive Technologies. The tools selected for assistive technologies are shown in Table 4.

Kurzweil 3000 was determined to be the most popular assistive software among all students due to its functionality and ease of use. Kurzweil, however, is not available to users for free. After comparing JAWS, ZoomText, Kurzweil and NVDA on their functions, we have decided that Kurzweil and NVDA were the best candidates to evaluate the e-textbooks.

Both Kurzweil and NVDA were tested for specific checkpoints with the different e-textbook formats. Kurzweil was found to be most appropriate for evaluating EPUB formats, and NVDA for HTML and PDF formats. Kurzweil was chosen for

Table 3 Selected non-assistive technology tools/methods to be used is accessibility evaluations for e-textbooks

Checkpoint	Suggested tools and methods		
	EPUB	HTML	PDF
Accessibility documentation	Manual check	Manual check	Manual check
Text access	Adobe digital editions with narrator (windows build in)	Google Chrome—select and speak[a]	Adobe Acrobat XI Pro
Text adjustment	Adobe digital editions	Google Chrome—care your eyes[b]	Adobe Acrobat XI Pro
Reading layout	Adobe digital editions with narrator (windows build in)	Google Chrome	Adobe Acrobat XI Pro
Reading order	N/A (not using assistive tech)	N/A (not using assistive tech)	Adobe Acrobat XI Pro and manual check
Table markup	N/A (not using assistive tech)	N/A (not using assistive tech)	Adobe Acrobat XI Pro and manual check
Structural markup	N/A (source code not available)	N/A (not using assistive tech)	Adobe Acrobat XI Pro
Hyperlinks	Adobe digital editions and manual check	Google Chrome and manual check	Adobe Acrobat XI Pro and manual check
Color and contrast	CCA[c] and manual check	CCA[c] and manual check	CCA[c] and manual check
Language	N/A	Google Chrome. manual check	Adobe Acrobat XI Pro
Images	Pagina EPUB checker and manual check	Google Chrome, W3C and manual check	Adobe Acrobat XI Pro and manual check
Multimedia	Manual check	Manual check	Manual check
Flickering	Adobe digital editions and manual check	Manual check	Adobe Acrobat XI Pro
STEM	Manual check	Manual check	Manual check
Interactive elements	Manual check	Manual check	Manual check

[a]Select and speak—text-to-speech extension for Google Chrome
[b]Care your eyes—webpage color modifier extension for Google Chrome
[c]Color contrast analyzer (CCA)—free accessibility tool to help determine color contrast ratio in all formats against WCAG 2.0 color contrast success criteria

EPUB evaluations due to its popularity among users and the fact that the other tools have issues with the EPUB reader that was employed for evaluation. The free EPUB reader that was used for non-assistive technology evaluations was Adobe Digital Editions and NVDA did not work well with it. Therefore, we decided to use Kurzweil to evaluate books in EPUB format only. NVDA was selected to evaluate HTML and PDF book formats. NVDA is a free tool that allows users to navigate

Table 4 Assistive technology tools/methods suggestions

Checkpoint	Suggested tools and methods		
	EPUB	HTML	PDF
Accessibility documentation	Manual check	Manual check	Manual check
Text access	Kurzweil 3000[a,b]	NVDA and Google Chrome	NVDA and Adobe Acrobat Pro XI
Text adjustment	Kurzweil 3000[a,b]	Google Chrome—care your eyes[b]	NVDA and Adobe Acrobat Pro XI
Reading layout	Kurzweil 3000[a,b]	NVDA and Google Chrome	NVDA and Adobe Acrobat Pro XI
Reading order	Kurzweil 3000[a,b]	NVDA and Google Chrome	NVDA and Adobe Acrobat Pro XI
Table markup	Kurzweil 3000[a,b]	NVDA and Google Chrome	NVDA and Adobe Acrobat Pro XI
Structural markup	N/A (source code not available)	NVDA and Google Chrome	NVDA and Adobe Acrobat Pro XI
Hyperlinks	Kurzweil 3000[a,b] and manual check	NVDA and Google Chrome and Manual check	NVDA and Adobe Acrobat Pro XI and manual check
Color and contrast	CCA[c] and manual check	CCA[c] and manual check	CCA[c] and manual check
Language	Kurzweil 3000[a,b]	NVDA and Google Chrome and manual check	NVDA and Adobe Acrobat Pro XI and manual check
Images	Kurzweil 3000[a,b] and manual check	NVDA and Google Chrome and manual check	NVDA and Adobe Acrobat Pro XI and manual check
Multimedia	Kurzweil 3000[a,b] and manual check	NVDA and Google Chrome and manual check	NVDA and Adobe Acrobat Pro XI and manual check
Flickering	Kurzweil 3000[a,b] and manual check	Google Chrome and manual check	Adobe Acrobat Pro XI and manual check
STEM	Kurzweil 3000[a,b] and manual check	NVDA and Google Chrome and manual check	NVDA and Adobe Acrobat Pro XI and manual check
Interactive elements	Kurzweil 3000[a,b] and manual check	NVDA and Google Chrome and manual check	NVDA and Adobe Acrobat Pro XI and manual check

[a]Select and speak—text-to-speech extension for Google Chrome
[b]Care your eyes—webpage color modifier extension for Google Chrome
[c]Color contrast analyzer (CCA)—free accessibility tool to help determine color contrast ratio in all formats against WCAG 2.0 color contrast success criteria

content with keyboard-only navigation. In addition to these tools, CCA (Color Contrast Analyzer) was selected to evaluate color and contrast across all formats, in both non-assistive technology and assistive technology evaluations, due to its ease of use.

3 Phase Two: Manual Creation

In Phase 2 of this project, we created a manual for each e-textbook format to illustrate how to use the tools selected in Phase 1, and the procedures for additional manual checks that need to be performed when conducting the accessibility evaluations.

3.1 Method

Two students (project leads) re-assessed the selected tools identified from Phase 1 and verified with the SMEs that the tools/methods to use for evaluations were indeed the ideal candidates. Subsequently, a step-by-step manual was created for each format of the e-textbooks, and pilot testing was conducted to make sure these manuals were comprehended by novice evaluators (see Fig. 2).

3.2 Results

We made minor adjustments relating to clarity to the manual for each e-textbook format based on the feedback from the novice evaluators. We also created an Excel checklist that provides a detailed breakdown of the SkillsCommons checklist and a recommended number of pages of the e-textbook to be checked based on the total number of pages for the book (Fig. 3). The final manuals consist of step-by-step guides on how to evaluate each checkpoint. Each checkpoint has its own section,
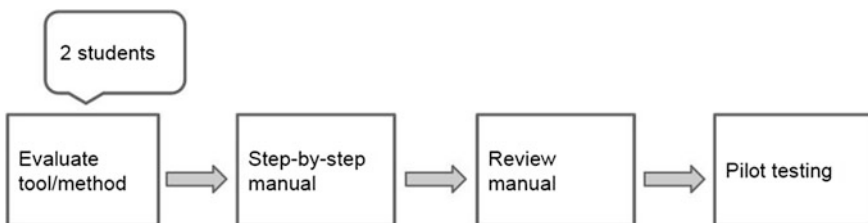

Fig. 2 Second stage of the manual creation and tool evaluation process

EPUB Accessibility Checklist

Content	Name of book	Format	OS Used	Total Number of Pa	Number of Chapters
		EPUB	Windows	300	

#	Check point	Criteria	Amount of Mate	Pass/Fail	Ranking 1-10	Additional Info	Detail
1	Acc. Documentation	A. URL to Formal Accessibility Policy					
1	Acc. Documentation	B. URL to Accessibility Statement					
1	Acc. Documentation	C. URL to Accessibility Evaluation Report					
2	Test Access	Text to Speech	30 pages				
3	Text Adjustment	A. Compatible (Size)	15 pages				
3	Text Adjustment	B. Adjust font and colors	15 pages				
4	Reading Layout	A. Reflow the text	15 pages				
4	Reading Layout	B. Page #s match printed material & reflow of	15 pages				
5	Reading Order	Digital resource layout	5 pages				
6	Structural Markup	A. Navigation text					
6	Structural Markup	B. Lists					
6	Structural Markup	C. eReader application					
7	Table Markup	Table Markup					
8	Hyperlinks	Hyperlinks (in-book)	30 links				
8	Hyperlinks	Hyperlink (live)	20 links				
		Hyperlink Functionality (Live)	20 links				
		Hyperlink Description (Live)	20 links				
9	Color and Contrast	A. Color redundancy	15 pages				
9	Color and Contrast	B. Contrast	30 pages				
		Contrast -Header					
		Contrast -Text					
		Contrast - Simple images					
10	Language	A. Markup					
10	Language	B. Passage Markup					
11	Images	A. Non-decorative	30 pages				
11	Images	B. Decorative	30 pages				
11	Images	C. Complex	30 pages				
12	Multimedia	A. Text Track					
12	Multimedia	B. Transcript					
12	Multimedia	C. Assistive Player					
13	Flickering	Flickering					
14	STEM	A. Markup (figures)	10 figures				
14	STEM	A. Markup (graphs)	10 graphs				
14	STEM	A. Markup (equation)	10 equations				
14	STEM	A. Markup (tables)	10 tables				
14	STEM	B. Notation Markup (figures)	10 figures				
14	STEM	B. Notation Markup (graphs)	10 graphs				
14	STEM	B. Notation Markup (equation)	10 equations				
14	STEM	B. Notation Markup (tables)	10 tables				
15	Interactive Elements	A. Keyboard					
15	Interactive Elements	B. Markup					
15	Interactive Elements	C. Text Prompts					

Fig. 3 Excel checklist

Fig. 4 Example of checkpoint description

10. Language

☑ The text of the digital resource includes markup that declares the language of the content in a manner that is compatible with assistive technology

☑ If the digital resource includes passages in a foreign language, these passages include markup that declares the language in a manner that is compatible with assistive technology

starting with a short description of what evaluators should be checking for (Fig. 4), and then followed by a step-by-step break down on how evaluators should evaluate the specific checkpoint (Fig. 5 for an example). Screenshots are provided for each step to help novice evaluators (see Figs. 6 and 7 for examples).

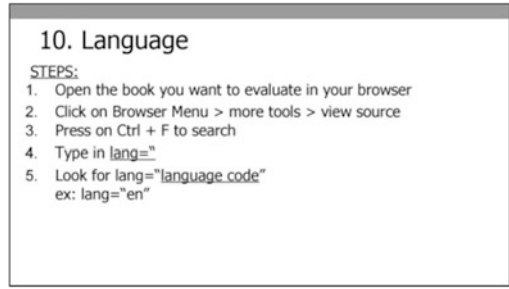**Fig. 5** Example of step-by-step breakdown for checkpoints

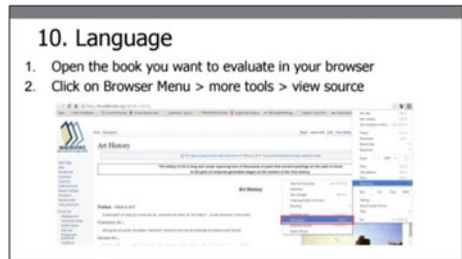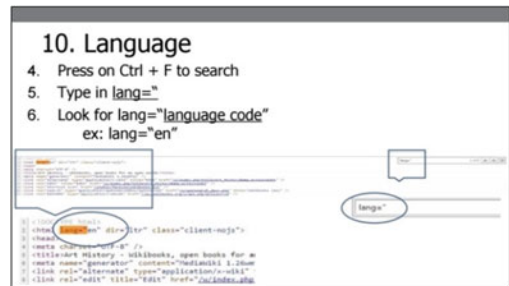**Fig. 6** Example of step-by-step breakdown with screenshots

Fig. 7 Example of step-by-step breakdown with screenshots

4 Conclusion

We have successfully developed a step-by-step manual for three e-textbook formats, EPUB, HTML, and PDF. These manuals can be used by organizations to perform accessibility evaluations. They can also be used as prototypes for creating future manuals and training systems relating to accessibility evaluations.

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